Standardising Materiality

Tracking Co-constructed Relationships between Quality Standards and Materiality in the English Water Industry

Ragna Zeiss

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University of York
Department of Sociology

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Παντα ρει

All things are in a state of flux.

You cannot step twice into the same river, for fresh waters are ever flowing in upon you.

Heraclitus (c. 500 B.C.)

Abstract

This dissertation argues that a singularisation in notions of (tap) water quality has taken place. Drinking water has become subject to processes of governance, globalisation, and standardisation and its quality has become increasingly defined by numerical standards. The standards are outcomes of processes of negotiation between heterogeneous actors, yet, once set, they often become synonymous with good water quality. However, the various ways in which the standards can be mobilised can, despite the broad singularisation of water quality, lead to the construction of different water qualities. These qualities do not reflect the water 'out there'; they come about through different *co*-constructions of materiality and standards, a theme that is explored throughout the thesis. Complicated systems of quality assurance, regulatory assurance, and customer assurance – that have 'enrolled' actants like detailed protocols, internal standards, alarms, blank samples, and automatic dosing installations – blur the boundaries between what is often considered 'macro' and 'micro', 'context' and 'content', and 'voluntary' and 'enforced' and determine the meaning of water quality and the notion of 'compliance'. The thesis offers the first detailed analysis of water standards and develops a new framework for analysing the mobilisation of standards within what is called 'regulated' (in contrast to 'regulatory') science.

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Preface

The thesis is there. It is a result of four years of reading, doing research, writing, and of a struggle to let go.

I want to tell you about one of the many watery encounters I had while writing my PhD; it concerns the river Ouse in York. The Ouse flooded at least six times during the years I lived in York. In fact, the river was flooded on the very day I arrived and everyone working and living on campus was asked not to use drinking water unnecessarily. The treatment plants may not have had enough capacity to store clean drinking water and not be able to clean the then muddy water in the river. ('Water, water everywhere, nor any drop to drink' – Samuel Taylor Coleridge). A few floods further, I stepped on my bike one morning and cycled to the millennium bridge which took me across the river in the direction of the university every day. However, this particular morning the river was flooded and I had to take a detour. I told myself to remember the flood for the return journey, but after a day of teaching, chatting, reading, and writing, my automatic pilot took over and I cycled the usual way home, that is, until I saw a lot of water but no cycling path. Someone had cycled in front of me. He got off his bike, took off his shoes and put them in his backpack, rolled back his trousers, got on his bike again and cycled into the water that nearly reached his hips. When he was halfway to the bridge, he turned around to me and shouted: 'it's manageable'. Yet, I turned around and tried to find a longer, but drier, way to get home.

Writing a PhD is like cycling across a sometimes flooded, or otherwise blocked, road. One follows a certain path and finds it is blocked, flooded, or does not lead anywhere. If the path is blocked or has a dead end, one has to turn back and find another path. If the path is flooded, one may decide to go back and try another road or to be brave and take the risk that the muddy water does not hide any invisible depths or under-currents which will drown you, drag you elsewhere, or make you go back after all. If one takes a different road, one might try the first road again at another moment (out of curiosity, because one has become braver or less careful, or just because one had forgotten about the flood). This time the road may be clear or still flooded and choices have to be made again, some of which will work out and others will not. I think I have turned back, been dragged away, returned to flooded paths and crossed them during the PhD, but I have not drowned.

The thesis that lies in front of you is an outcome of all these (flooded) roads, some of which I crossed the first time, some of which I never crossed, and some of which I returned to time after time (due to forgetfulness or being stubborn). Sometimes I crossed a river, but now, looking back, I can see that it might have been better if I had taken a different route. Unfortunately, one can only see afterwards whether a particular road was going in, what later seems, the only possible and correct direction.

To use the famous STS phrase, 'it could have been different'. The thesis is, after all, a construction. However, although it does not contain 'the truth' about *standardising materiality*, I would not like to say that it is 'just a story' either. Perhaps it is a constellation of contingent factors in which human and non-human actors have played a role, some of which eventually became an important part of this dissertation, even though I may have encountered them coincidentally. Yet, the contingency of the research process has been black boxed. Despite a sensitivity for the contingent factors that shaped the thesis, it has been composed as if it were a linear story and as if the chapters reflect the order of the research process. The black box will only be opened at specific moments (for example in the methods chapter) to give insights into how this thesis came to be. This is an attempt to legitimise the choices I have made and the roads I have followed. The thesis has thus been written for a certain purpose and in a certain format that, dare I say it, almost dictates when the black box can be opened and when it is better to keep it closed. The dissertations of Ashmore (1985) and, although to a lesser extent, Forero (2003), and the article by Pinch and Pinch (1988) form a welcome alternative to this format. However, there are two problems with these dissertations. First, the dissertations are original, but anyone who will copy their reflexive theses may fail their own PhD on lack of originality. Ashmore and Forero's dissertations have made it harder for others to be reflexive to the same extent. The amount of reflexivity that is considered appropriate is dependent on the wider context in which the PhD is written (whether it is in anthropology or physics) and on the reflexivity of previous works. And second, if everyone would reflect extensively on their own writing process, would we be able to gain any insights in other areas than writing? I have tried to open the black box at times that I thought it would be appropriate in the eyes of the scientific community that will decide whether this piece of work is worthy as an access ticket to that community. The thesis has thus been written in a certain context where specific norms, values, and standards determine whether it is 'just a story' or a piece of research that deserves to be called a PhD dissertation which will qualify me to continue working as an academic. In the latter case, it may be considered as a valuable construction.

The hardest thing was to get off the bike. The roads are endless, many of them are connected, and all lead to new and exciting places. I was not tired of cycling and discovered new roads time and time again. However, if one wants to continue the metaphor, the bike was starting to break down, that is, time and money were running out. I found another bike that continued on a slightly different, but also inspiring, route which has helped me to keep cycling. I tried to ride the two bikes alongside each other, and just imagine, that is not an easy task. I did need to get off one of the bikes. However, the road it followed is not forgotten. In fact, I can reconstruct it as a linear road on which I have been cycling for a long time; a continuing journey.

My first interests in standards and standardisation issues emerged when I undertook an internship in the Netherlands as an undergraduate student. Already then it was connected with water: the internship took place at a district water board. I spent three months in the archive of the water board trying to put together a historical overview of how the surface water quality had changed over time (from the 1920s until the 1970s). This overview could then be connected to the data on water quality that had been collected and saved electronically in the laboratory of the district water board. It turned out to be more complicated than I initially thought. The lists with measurements did not speak for themselves and I had to find additional material (letters, etc.) to interpret the measurements. The main problems for interpreting and comparing data were data lacking from certain periods (for example during the Second World War when the gas supply to the laboratory was stopped), changes of measurement instruments, changes in the parameters that were measured and in the places where the samples were taken, and the construction of an entirely new laboratory in 1956.

My MA dissertation then focused on the domestication of the first European drinking water directive (1980) in Norway and the Netherlands. This was my first encounter with relations between standardisation and regulation. I used the concept of 'domestication' since I wanted to explore the use of this concept as a tool to understand what is often called 'implementation' of legislation. In Norway, this already existing concept was explicitly related to technology studies (Lie and

Sørensen, 1996)[1]. Sørensen (1995) argued that Actor Network Theory, which stresses the importance of the laboratory, had serious limitations in a country like Norway, where most technology is imported and not constructed in laboratories. The concept of domestication was therefore used to explore the cultural appropriation of technologies and focuses on the user side of technologies instead of on the production side. It was exactly this focus on the implementation (but by suggesting cultural appropriation it included processes of negotiation that are lacking in the word implementation) instead of on construction that I found relevant for looking at what happens with newly constructed regulation. I identified three forms of domestication related to the 1980 drinking water directive. First, intervention-domestication in which the Dutch government actively tried to change the content of the directive. Secondly, brokerage-domestication, interpretation of the directive and translation into a specific setting, which was found at national level in Norway, municipal level in the Netherlands, and in the larger municipalities in Norway. And thirdly, non-domestication, which was only found in small municipalities in Norway. In small municipalities it was sometimes a single person who operated the treatment works, someone who ran for example a bakery at the same time. This person may not have had the knowledge to understand the language of the regulation and standards. In addition to this, different notions of 'clean water' played a role in the smaller municipalities, not enough economic resources were available to treat the water sufficiently according to the directive, and control by the national government or local food authorities that could have changed the situation lacked. However, I also identified some problems with using the concept of domestication for the implementation of legislation. Legislation *has* to be implemented, whereas the adoption of technologies (in any case the ones studied with help of the domestication concept) is often voluntary. Secondly, legislation can be regarded as a technology that is more fixed and less flexible than some other technologies (the implications of more open and closed technologies for domestication processes thus have to be studied). Another difference is that legislation is seldom entirely new (at least in the water industry) and will thus be embedded in similar existing practices. And lastly there is the question of where the boundary between domestication and non-domestication should be drawn. This is a question that is also relevant for

[1] The concept was earlier used by Silverstone, Hirch, and Morley (1992) to describe how artefacts, in particular information and communication technologies, were integrated into 'the moral economy of the household'.

mobilisation, negotiation, and translation. Are there cases when one can say that things or knowledges are not mobilised, negotiated, or translated? If there are no such cases, these concepts may lose their analytical power.

I will not go into the question of where exactly the PhD thesis will pick up on work I have done before or what it leaves out; hopefully the next few hundred pages will make that clear. I just wanted to show (and reassure myself) that the PhD thesis fits into a journey I started years ago. The bike I am riding right now follows a road that explores boundary work between science and policy and I am confident and hopeful that it will cross the road where I had to step off the bike and perhaps ride parallel to it or even on that road for a while to explore new and related standard and water issues.

Acknowledgements

Many people think that doing research is a lonely business. However, this thesis is an outcome of a process in which many people (and non-human actors) were involved. Whenever I found a flooded or blocked road, many of the people mentioned below and many others have helped me to find a way around and continue my research.

First of all, I would like to thank Andrew Webster for his outstanding supervisions and continuous encouragement. I could not have done it without him and cannot imagine anyone who would have been a better and more inspiring supervisor and colleague. He is what I believe any director, researcher, supervisor, and person should aspire to be and I have been incredibly lucky to work with him. I hope we will continue working together in the future.

I have always been fortunate with the places where I have lived and studied, but SATSU (the science and technology studies unit at the University of York) has no doubt been the most active, dynamic, and international unit. I would therefore like to thank all other members of SATSU (Nik Brown, Luana Pritchard (I have learned much about life during our dangerously long chats), Stephanie Gant (thanks for helping to ensure the anonymity of the photos used in this thesis), Gillian Robinson, Graham Lewis, Paul Rosen, Brian Woods, and Richard Tutton) who made me feel very welcome and who provided a very inspirational and friendly environment both within and outside work hours. My thesis advisory panel members have watched my progress and been very helpful with commenting on my chapters. I would therefore like to thank Anne Kerr and Neil Carter. The Marie Curie students brought new knowledge and a flow of social activities; I want to thank them for this. I would also like to thank the wider sociology department for giving me the opportunity to develop my teaching skills, for organising the departmental seminars, and for many nice informal chats about research and other things. A special thanks to Steve Yearley (who believed my research was almost finished long before it actually was), Betty Vickers and Lynn Kilgallon for their help in organising my teaching and scanning the photos used in the PhD.

The other PhD students in the department have been incredibly important, both for maintaining confidence in and motivation for research and teaching and for an active social life. Many of them have become my friends. In particular, I would like to thank Tom Hope, Yu Wei Lin, Chiara Monzoni, Trine Heineman, Iris Halldorsdottir, Thomas Heimdal, Martin Hand, Olga Restrepo Forero, Yuri Jack

Gomez-Morales, Inna Kochetkova, Daniel Nelson, Maria Rovisco, Melissa Dearey, and Eugenia Rodrigues. If nothing else, my PhD research has brought me some very valuable friendships. I would also like to thank my kung fu brothers (a special thanks to Alex Lishman; no snow, rain, and wind could stop us from training) and sifus for teaching me the art of chi sau which really is a bit like a doing a PhD: sometimes you might get hit, but you will learn from it and either adopt a different movement or learn to defend yourself more effectively. Wing Chun (the only non-human actor I mention, although I am grateful to many others who have helped me to finish this PhD) has given me tools to remain calm and flexible in all sorts of situations and has relaxed mind and body after long days behind a computer screen.

I am very grateful to everyone who participated in my research as interview respondent. I would especially like to thank the person who made my fieldwork in a water company possible and those who have assisted me in the field and patiently answered all my questions. Some of them have even read part of my work to make sure I had understood the technical issues. Without them, there would not be a dissertation.

I would also like to thank Peter Groenewegen and Willem Halffman for allowing me to finish the PhD dissertation while the postdoc project had already started. Last, but not least, I would like to thank my housemates (Tania, Leendert, and Tami) who were always up for a chat and my family (Els, Auke, Frank, opa, and oma) for supporting me at a distance.

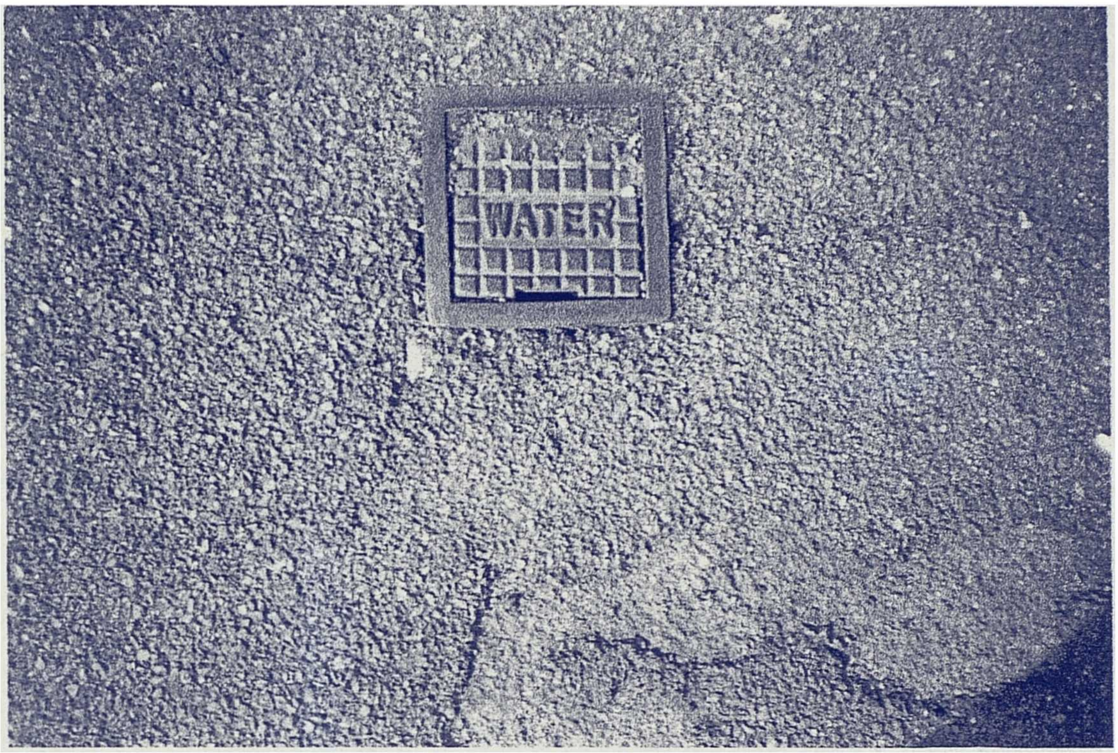
Author's Declaration

I declare that this thesis has been composed by myself alone from the result of my own research and any work that is not my own has been clearly referenced.

Original in colour

1 Introduction or Making the Invisible Visible

Photo 1.1: The invisibility of water: Water Crane Lid



Making a photograph. A normal action. Yet, when I started taking photographs of water crane lids and water meter pits in various cities in and outside England, bending over them on the middle of the pavement, I attracted some attention from people walking by. Often they stopped to look at what I was photographing, because one only takes a photograph if there is something worth photographing. However, they did not see anything. I am not even sure if they always saw the lids and pits that were sometimes covered in chewing gum, mud or other things and substances that one encounters on pavements of cities in western societies. At that point their attention turned to me, sometimes with a look of curiosity, sometimes even a bit annoyed about the fact that I had (unintentionally) distracted them.[2]

[2] In a way, this can be considered to be what Garfinkel (1963, 1967) calls a 'breaching experiment'. People walking along the pavement have certain expectations of behaviour of other people at the pavement. My behaviour and interest in something that was apparently not of interest to my fellow pavement-walkers was regarded as unusual and made therefore obvious and visible the underlying expectations and norms people maintain of what is 'normal' social order at the pavement.

This illustrates something about our relationship to our drinking water. We take it for granted; it is invisible and mundane as Michael (2000) would put it. We expect water to come out of the tap as soon as we turn it on and we expect this water to be of a certain quality, that is, it should be clear and have no adverse health effects. A quote from Sesame Street (Klostermann, 2003: 65) illustrates this nicely:

> Bert: 'Do you know what light is, Ernie?'
> Ernie: 'Light comes from a lamp, or from the sun, just like water from a tap.'

In a society where most of our food comes from supermarkets and not everyone has a well behind the house or has to walk for hours to collect water, people may not know and not be interested in where this water comes from. In the words of Kinnersley (1994: xi): 'Using water is still largely a matter of unthinking habit for most people for whom fetching it first is not a time-consuming daily chore'.

Much (anthropological and sociological) research has been done on cultures of and practices around water in Third World countries. Finding research on western relations to water is a much harder task. It has often been suggested to me to change the geographical focus of my research; people were genuinely worried that I would not find anything of interest by concentrating on England. Yet, what do we actually know about our water? Occasionally, although not often, we may come across headings like:

> Anglian awaits sentence over untreated drinking water
> (ENDS Report 288, 1999)

> Yorkshire loses challenge over "unfit" water
> (ENDS Report 297, 1999)

> South East Water fined for "thick brown" drinking water
> (ENDS Report 295, 1999)

> Yorkshire fined for supplying "muddy" water
> (ENDS Report 325, 2002)

> Drinking water improves again
> (ENDS Report 342, 2003)

Do we know what these headings mean? Can we understand them without knowing what is classified as 'muddy', what it means for water to be regarded as 'unfit', or what the underlying standards are against which water can be said to improve?

Like water, also the underlying classifications and standards that define the quality of the water are invisible. This dissertation is about making the invisible visible. As Kinnersley (1994: xii) states, the management of water has changed over recent years:

> The management of water requires a large technical input for which the skills of engineers and scientists are still crucial. But the conspicuous change in the last fifteen years or so is how prominent and compelling economic, social, and legislative, or regulatory, issues have become.

Water quality standards thus operate in complex environments consisting of regulators, consumers, customers, treatment technologies, scientific analyses, distribution systems, and a variety of classification systems. The purpose of the dissertation is to explore the role of standards in these environments. It offers a detailed, although necessarily limited, analysis of what I call the 'waterworld', which refers to the world in which all of the above mentioned elements or actants play a role. The co-constructions of relationships between standards and materiality in the current waterworld are the main concern of the thesis. The thesis can therefore be read as embodying a number of reflections on the status of and possibilities for investigating materiality; it reflects on and makes a small contribution to the realism-constructivism debate and approaches that try to avoid this distinction. It can also be seen as an exploration of the role of (regulatory) standards in a specific environment of 'regulated science' where the science itself has become heavily regulated. The science is not aimed at producing new knowledge but instead at routinely testing for compliance and notions like 'quality assurance' and 'regulatory assurance' become crucial. To a lesser extent the thesis is about trust and expertise.

Chapter 2 critically reviews the existing 'standards literature'. I draw mainly on work from science and technology studies, but some attention is paid to studies in political science and wider sociological research. The literature review does not form the framework within which the rest of the thesis is written; yet it forms a starting point and helped me to both develop a conceptual toolkit with which I could explore and analyse my empirical data and formulate meaningful research questions. In chapter 3, I operationalise the research questions and critically discuss the methods I used to collect empirical data and the ways in which the data are consequently used in the thesis. Chapter 4 then is a historical and cultural analysis of water. The chapter hints at the ways in which water can be constructed and tentatively investigates relations between waters, materiality, and constructions. Chapter 5 concentrates on the construction of the current water quality standards and the ways in which they can be mobilised in an environment of 'regulated science'. It introduces the notions of 'quality assurance' and 'regulatory assurance', which are then further explored in chapter 6. Whereas chapter 5 focuses largely on the institutional and organisational environment in which standards operate, chapter 6 locates the regulations specifically in their physical/material environment. It explores how standards and materiality are co-constructed in day-to-day practices. In chapter 7, I return to some of the theoretical issues and the research questions raised in chapter 2. By drawing together elements from the previous chapters I develop a fuller understanding of the 'waterworld' and the role of standards in an environment of 'regulated science'. I will conclude by outlining some areas of interest for further research.

2 Theorising standards

2.1 Introduction

> *Our lives are henged round with systems of classification, limned by standard formats, prescriptions, and objects. Enter a modern home and you are surrounded by standards and categories spanning the color of paint of the walls and in the fabric of the furniture, the types of wires strung to appliances, the codes in the building permits allowing the kitchen sink to be properly plumbed and the walls to be adequately fireproofed.*
>
> (Bowker and Star, 2000: 1)

Our world is increasingly ordered by standards. However, standards are not a new phenomenon. Throughout history people have agreed on measurements, currency, symbols, the quality of products, and so on. Yet, the intensification of trade, traffic, communication, and travel has resulted in an increase in the scale and scope of standards. Ewald (1990: 149) claimed that 'in modern society people have started to actively seek to direct and manage the process of standardisation in order to –in the broadest sense of the word– create order in a given context'. Nevertheless, this active role of people in managing standardisation did not prevent them from taking standards for granted. We assume that our blood pressure and weight mean the same thing to different doctors in different places. We also take for granted that the temperature measured in one part of the world is comparable to the temperature measured in another part of the world (O'Connell, 1993). Through this 'taken-for-grantedness', standards often become invisible and blackboxed. Yet, they influence and order our lives and societies and are hard to ignore. As an experiment, Bowker and Star (2000: 3) ask their readers to try and ignore their gender classification and use instead toilets that are the nearest; to locate a library book shelved under the wrong catalogue number, and to arrive in a different country without an adapter that translates between electrical standards. These experiments show that it is difficult, if not impossible, to ignore the standards that order our world. The roles that standards play in modern society are therefore an important topic for sociological studies.

Much of the literature on standards has been very 'technical', dealing with practical questions of how to implement standards, or render different systems or artefacts compatible. These studies regard standards as simply technical measures.

Since the political and economic importance of standards with regard to global competitiveness has been recognised, Schmidt and Werle (1998: 1) state that academic research on standards has expanded. However, as they acknowledge, most research 'has been purely economic in perspective, focusing on models and paying little attention to the social shaping of standards or to their social and political implications'. These studies focus on questions like 'how do standards affect market development', 'what are the costs and benefits of standards', and 'when to standardise' since early standardisation minimises diversity but also prevents one from gaining experience with alternatives and late standardisation complicates standards agreements (Egyedi, 1996). Fortunately, there is an increasing body of literature that does deal with the various roles of standards in wider society. Historians have studied emerging classifications in natural history and medicine in the eighteenth century and anthropologists have used classification as a device to study and understand other cultures (Bowker and Star, 2000). It is only more recently that scholars have focused on topics like the 'creation and maintenance of complex classifications as a kind of work practice' (ibid: 5) and the reconfiguration of people, instruments, and interventions 'to foster new notions of autonomy, objectivity, medical jurisdiction, and risk' (Timmermans and Berg, 2003: vii-viii) in today's society as a consequence of standardisation. It is mainly this literature that I will review in section 2.2 *Standards and standardisation debated* and to which I hope this thesis can be a valuable contribution.

The chapter consists of five sections, of which the most extensive is section 2.2, the literature review. The review serves two explicit purposes. First, the overview of the relevant literature will form the background for the rest of the thesis. It both provides a broad understanding of the wider literature on standards within which the contribution of the thesis can be placed and a reference point of specific issues and literature to which later chapters can refer back. The chapter can be used as a point of reference either for purposes of comparison (and critical discussion) with the empirical material that will be discussed in chapters 5 and 6 or to suggest (plausible) explanations for issues that will be encountered later in the thesis, but which I have not been able to investigate in detail myself during my research. In the latter case, I may rely on the literature presented here as possible explanations for certain processes and developments. Second, by placing the thesis within a frame of wider literature, it becomes possible to identify theoretical issues that have not been (extensively) addressed within the existing literature. This will enable me to point to both the theoretical issues and the (theoretical) limitations of the thesis (the empirical issues and limitations are discussed in chapter 3). I want to make the case that literature on standards and standardisation has generally overlooked or not wanted to engage with the relation between standards and materiality. Both quality standards (that may regulate food, air, water, and transport) and compatibility standards (that may apply to ICT systems) deal to a greater or lesser extent with materiality. However, few people have focused on the role(s) of this materiality in 'making standards work'. I suggest that a focus on materiality may help to address another under-researched question, namely that of 'resistance' to standardisation.

After the literature review, I will introduce the empirical area (the drinking water industry) in which I will explore the identified questions (section 2.3). In section 2.4 I will provide a methodological toolkit which can help me to gather and investigate my empirical material and to study relations between standards, standardisation processes and materiality empirically in chapter 5 and 6. In the conclusion I will point to some limitations of the thesis and to the area I will explore in the rest of the thesis: the complexity of standards in relation to materiality in the UK water industry.

2.2 Standards and Standardisation Debated

2.2.1 Standardisation and the claims of modernism

Timmermans and Berg (2003) describe standardisation, in its historical context, as an essentially modernist project. Standards were, in their words, 'one of the hallmarks of rationalisation' (ibid: 8). In the late nineteenth and early twentieth century rail and telegraph companies were amongst the many others that started to use standard networks and components to increase compatibility between different systems or turn them into one large system. There was a strong belief that predictability, efficiency, accountability, and objectivity would follow uniformity. However, in the words of Barry (2002: 144-45): 'the ideal of standardization has, in practice, simply proved impracticable'. In the next sections I will take up and problematise some of the above claims of modernism. I will start by complicating the widely used notions of 'standard' and 'standardisation'.

2.2.2 Complicating standards

So far in the thesis, I have not addressed the question of what exactly is a standard. Standards and standardisation processes have been defined differently by different people and in different contexts. As Timmermans and Berg (2003: 24) say: 'not much is standard about standards'. The literature has distinguished different types of standards and standardisation processes. Table 2.1 (see next page) gives just a few of the possible classifications that I have identified in the literature.

Table 2.1: Classifications of standards

	Egyedi (1996)	Timmermans and Berg (2003)	Krechmer (2001)	Salter (1988)	Occupational Safety and Health Act (in Bal, 1998)	Leveque (1995)
Classifications of standards	*De jure standards* (voluntary consensus standards derived from committee-based standardisation)	*Design standards* (set specifications for individual components of social and or technical systems: ensure uniformity and compatibility)	*Unit and Reference* standards (define physical and virtual properties, e.g. a number system to express codified units of weight and measure)	*Registration standards* (or product specific standards; products subject to registration standards must have permits before they are allowed to enter the market)	*Interim standards* (produced by a recognised standards-producing organisation on basis of agreement; take effect immediately after publication)	*Compatibility standards* (exploit network externalities and increase the variety of complementary goods)
	De facto standards Subdivision: 1)unsponsored standards (no identified originator); 2) sponsored standards (sponsoring entities hold direct or indirect proprietary interest); 3) grey standards (publicly available, developed by consortia, professional organisations and user groups)	*Terminological standards* (ensure stability and meaning over different sites and times)	*Similarity standards* (provide common physical properties of one or more entities to provide inter-changeability, safety, and so on, e.g. for gun parts, train track gauges, emergency exit signs)	*Regulatory standards* (generally applicable rules set in advance; e.g. the amount of peanuts in peanut butter)	*Permanent standards* (replace or add to interim standards; after publication there is a chance to comment on the standard)	*Quality standards* (reduce uncertainties about the performance or quality of the good and therefore transaction costs)
		Performance standards (set outcome specifications)	*Compatibility standards* (define a local or remote physical relationship between two or more entities for the purpose of interworking (physical connection) or information communications)	*Voluntary standards* (guidelines, objectives, codes, or criterions; do not relate to products or activities, but to behaviour and are related to self-regulation)	*Temporary emergency* standards (immediately valid, for 6 months, then replacement by a permanent standard; formulated in case of 'grave danger'; possible to appeal)	*Social standards* (set to reduce negative social externalities, for example related to health)
		Procedural standards (guidelines and protocols that guide the process)	*Etiquette standards* (define an adaptive mechanism to select among different compatibility standards or specifications for the purpose of communications)			

Some of these classifications focus on where and when standard setting takes place (Egyedi, 1996), others may distinguish standards not by the process by which standards are initiated but by the process of implementation and enforcement of standards (Salter, 1988) or by the period of time for which they are valid (Occupational Safety and Health Act (OSHAct), 1970, in Bal, 1998). Yet other classifications are based on the functions standards (can) perform in specific settings (Leveque, 1995) and throughout different periods (Krechmer, 2001). Timmermans and Berg (2003) distinguish between types of standards that standardise different things (components of a system, concepts, outcomes, and procedures).

These different classifications are not strictly separated. Egyedi for example notices a shift from *ex post* standardisation (standardisation of a product when it is already on the market) to *ex ante* standardisation (standardisation before products have been developed and marketed) in which performance specifications influence the length of the process of *ex ante* standardisation. These performance specifications have much in common with the performance standards of Timmermans and Berg. Krechmer's unit and reference standards are related to terminological standards, and his similarity, compatibility, and etiquette standards can be considered as a subdivision of Timmermans and Berg's category of design standards. These are often also referred to as 'technical standards'. Salter (1988: 27) argues in addition that not all standards, not even all registration or all regulatory standards are set in the same ways. Registration standards can therefore have emerged as voluntary, consensus, or governmental standards (or *de jure* and *de facto* standards). Consequently, the classifications of standards in standard setting, standard implementation, and enforcement do not have to exclude each other.

The classifications are not only overlapping and intertwined, they can also be drawn up in different ways, referred to with different terms (talking about terminological standards), or added to. They can exclude and include. Some will refer to standards as 'documents developed, distributed and maintained in an open manner' (Krechmer, 2001: 167) and thus exclude specifications that are proprietary; others may draw boundaries between standards and non-standards in a different way, for example by excluding regulatory standards. David (1995: 17) classifies standards in a similar way as Egyedi as unsponsored standards, sponsored standards, and standard agreements emerged from voluntary standards-writing institutions, but then adds mandated standards which are circulated by governmental agencies that have some regulatory authority. He calls the first two *de facto* standards and the latter two *de jure* standards. He then remarks that the mandated standards are perhaps better referred to as technical 'regulations' since they have the force of law behind them. This is an important remark since it shows that he does not regard specifications that are enforced by law as standards. However, Leveque (1995: 108-109) provides three categories of standard setting in which regulatory standards do play a role. He distinguishes between the command-and-control process in which regulations are designed and which is based on the coercive power of the government, self-regulation by firms (they set their own standards), and the flexible governance regulatory process in which both government and industry are involved. Hawkins (1995) offers a similar classification (judication, coalition, and negotiation) of standard setting based on work in political theory (Zartman, 1977) and, like Leveque, includes the regulatory area as a domain of standard setting. Salter (1988: 27-28) complicates the matter by arguing that 'voluntary or consensus standards can be, and often are, adopted for use by regulatory agencies or government departments'. She argues that it becomes even more confusing when one realises that 'standards developed by government departments or agencies can be viewed as voluntary, and used as guidelines not regulations for conduct'.

What is and what is not regarded as a standard and how standards are classified can thus be subject to debate. According to Mansell (1995) a dominant definition in what she calls the 'standardization literature' has been formulated by David and Steinmueller as

> a set of technical specifications that can be adhered to by a producer, either tacitly, or in accord with some formal agreement, or in conformity with explicit regulatory authority.[3]

This is quite a narrow definition that regards standards as a purely and simply technical matter and disregards both other types of standards and insights into the socio-technical complexity of standards and technologies provided by STS and the wider 'standards literature', which will be reviewed in this section of the chapter. It is a definition that may be useful for the study of specific technological

[3] David, P.A., Steinmueller, W.E. (1993). "Economics of Compatibility Standards and Competition in Telecommunications Networks". Paper prepared for the International Telecommunication Society European Conference, Göteburg, 20-22 June, page 3. In: Mansell (1995: 217).

developments and innovation, but one that does not address the role of standards in creating new and different worlds and work practices. The Encyclopaedia Britannica (in Ewald, 1990: 148) defines a standard in a broader way as 'that which has been selected as a model to which objects or actions may be compared'. In other words, a standard is 'a set of specifications to which the standardised product, process, format or procedure has to conform' (Tassey, 2000, in Van Wegberg, 2001: 217).[4] Unlike David and Steinmueller, Tassey stresses the importance of something being standardised and includes the performance, terminological, and procedural standards of Timmermans and Berg. A perhaps even more inclusive and therefore longer definition comes from Harriman (1928, in Ewald, 1990: 148):

> A standard may be concisely defined as a criterion, measure or example, of procedure, process, dimension, extent, quantity, quality, or time, which is established by an authority, custom, or general consent, as a definite basis of reference or comparison.[5]

Bowker and Star (2000: 13-14) distinguish between several dimensions of the term standards which refer to the particular way in which standards classify the world.

1. A "standard" is any set of agreed-upon rules for the production of (textual or material) objects.
2. A standard spans more than one community of practice (or site of activity). It has temporal reach as well in that it persists over time.
3. Standards are deployed in making things work together over distance and heterogeneous metrics.
4. Legal bodies often enforce standards, be these mandated by professional organizations, manufacturers' organizations, or the state. We might say that Esperanto shall be the standard language for international diplomacy, however, without a mechanism of enforcement or a grassroots movement, we shall fail.

[4] Tassey refers to industrial standards, but in my opinion this can be extended to other standards as well. Tassey, G. (2000). "Standardization in technology-based markets". *Research Policy*, vol. 29:587-602.

[5] Harriman, N. F. (1928). *Standards and standardisation*. New York. In Ewald 1990, p. 148. The reference did not state a publisher.

5. There is no natural law that the best standard shall win. (see later in this chapter)
6. Standards have significant inertia and can be very difficult and expensive to change.

Salter (1988: 24) also defines standards by the several features they have in common. According to her:

> They involve measurement and are perceived to be scientific or technical in nature. They involve two different kinds of non-scientific judgement, even before they are adopted by governments or regulators – a judgement about acceptability and a judgement about the economic consequences of adopting particular standards. They reflect an average level of performance for a class of contaminants, products or activities. Thus, standards provide norms for performance but also for acceptable deviations from it. Finally, standards are closely linked with social values, including values concerning trade as well as health and the environment. They are not measures of excellence, but standards become associated in the public mind with excellence once they are used.

It seems that the more one wants to do justice to the complexity and variety of standards, the longer the definitions have to become. However, for specific purposes one can narrow down a definition of a standard and make it fit for what one wants to study. David and Steinmueller's technical definition of a standard is one example. Jasanoff's (1998: 174) stress on a standard as a 'negotiated form of social understanding' rather than as a simple technical measure, is another. In light of this, I will not attempt to provide a standard definition of standards. Rather, I will take this discussion and its complexity with me to heading 2.3 where I will then talk about the specific settings in which I want to study the role of standards and clarify the types of standards I will explore and how I can explore them. However, first I will review how some of the standards literature has dealt with some of the modernist claims about standards and standardisation.

2.2.3 Constructing standardised systems and standards

In this section some of the modernist claims about standards and standardisation will be further complicated. In the last section we have already seen that it is very difficult to speak about 'a standard' and assume that everyone attaches the same set of meanings to this concept. In this section it will become clear that standards are never purely technical and objective; instead, they always emerge from an environment in which social, economic, technical, and political factors play a role. Unlike physicists and other natural scientists who deal with homogenous classes of objects (every hydrogen atom is identical to every other hydrogen atom), standard setters deal with highly heterogeneous situations (Majone, 1984: 19). In the words of Timmermans and Berg (1997: 282), standards or protocols are 'the contingent outcome of processes of negotiations between heterogeneous actors'.

Standard setting (and construction) processes are related to many interesting issues –differences in policy styles, alternative (regulatory) instruments, increasing Europeanisation are just three of them[6]– which, to a greater or lesser extent, are all relevant for this study, but would each, if they were to be the main focus of this dissertation, lead to very different dissertations. The literature on standard setting and the construction of standards is however extensive and cannot be reviewed here in its entirety. I have therefore chosen to focus explicitly on a few cases that illustrate –but do not provide a full review of– the extent to which social, economic, technical, and political factors are intertwined in the construction of standards. I deliberately use the phrase 'construction of standards' rather than 'standard setting', since the latter has some explicit denotations towards (mainly policy studies and organisational sociology) literature which I will not be able to review for reasons of time and space. However, since some of the literature is significant with regard to insights on standard setting processes, which are part of standard *construction* processes, I will say a little more here and briefly come back to this in chapter 5. Although I am interested in the question of how standards originate, I will not look into the specific (organisational and structural) conditions under which standard setting takes place such as possible differences in the construction of standards between market-based and committee-based standardisation and between *ex ante* and *ex post* standardisation. I will thus not focus explicitly on classifications like *de facto* standards, *de jure* standards, or voluntary standards, consensus standards, and governmental standards in discussing the emergence of standards, even though these are or can be closely related to the development of standards in terms of the economic, technical, social, and political factors that influence standard setting. This is demonstrated by, amongst others, Egyedi (1996), Schmidt and Werle (1998), and Bal (1998). In addition, I intend to complicate what is perhaps thought of as a straightforward process of standard setting, and will therefore not address the question of whether and how standard setting can become less complicated and, in the case of scientific and regulatory standards, whether science can be of use to policy and if so how. Neither will I discuss (literature that examines) the 'proper' basis for standard-setting, that is, whether it should for instance explicitly incorporate cost-balance considerations or focus solely on compatibility, health, or safety.[7]

Below I will address two distinct issues that illustrate the interrelations between the social, economic, technical, and political aspects. With help of examples from existing literature I will first show how so-called technical standards (or standard artefacts) are constructed and how one standard or technical artefact can become dominant in an environment where different competing standards strive to become the leading or dominant standard. This is what one can call the 'hard case'. If one can show that even these, often regarded as technical, standards are in fact not just technically, but also socially, economically, and politically constructed, it will be easier to accept that other standards, for instance Leveque's social standards, are constituted of many heterogeneous aspects as well. Secondly, I will focus on what I call 'regulatory' standards. These are standards that are set in a regulatory environment (often a regulatory agency) and often relate to health, safety, and economic concerns.[8] They often fall into Leveque's category of social standards and

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[6] See for more information on these issues for example Jordan (2003), Jordan et al (2003a), Jordan et al (2003b), Zito et al (2003).

[7] According to Majone (1984: 18) the Soviet Union and western countries differ (or differed) in what they regard as good standards. Apparently the Soviet authorities base health standards on health effects alone 'without regard to the availability of adequate control technology, to economic feasibility, or even to the ability to measure adequately the concentration in practice'. Because these standards could not always be achieved, they would set secondary ('sanitary') standards that may modify the primary ('hygienic') standards for a limited period of time. Western standards tend to incorporate existing economic and technical conditions into the standards that are set. According to Majone this has made the standards ambiguous with respect to whether it is set as a policy goal or comes out of a scientific judgement.

[8] For a discussion on incentives of government to impose constraints on individual freedom (whether they are constructed to protect the community –perhaps from abuses of industry- or to serve the interests of industry), see Abraham and Lewis (2000). I will touch on this discussion in chapter 5.

are likely to be terminological, performance, or procedural standards. Once set, these become David's mandated standards. I will explore how these 'regulatory standards' are formulated when the scientific information, which provides their basis and legitimacy, is uncertain. The examples will show that the boundaries between science and policy are not self-evident, but often part of an active discussion during the standard-setting process. The boundaries between the technical, the social, the scientific, the economic, and the political are thus drawn and redrawn during standard-setting processes to order our worlds in particular ways and an *a priori* distinction between the different areas becomes difficult to maintain.

Social Aspects of Technical Standards: Success and Failure

Let me start with the 'hard case'. A well-known example is a study by Bijker (1997) about the construction of a standard bicycle. He demonstrated that the high-wheeled Ordinary bicycle that was patented in 1870 did not develop as a consequence of an internal and unavoidable logic, independently from other (social, political, economic) factors. He argued that the Ordinary had an 'interpretative flexibility' to it, that is, it was a different bicycle to different groups of people. Some regarded the Ordinary as a 'Macho Bicycle', which was used to show off by 'young men of means and nerve' (ibid.: 41). Others saw the bike mainly as an 'Unsafe Bicycle': 'the Ordinary rider was liable to go head over heels when encountering a small obstacle like a stone, a hole in the road, or an animal wandering about' (ibid.: 43). The bike was not only unsafe to the rider (who did not want to use the artefact to show off), but also to the pedestrian. In addition to that, some groups could not (older men) or were not supposed (women who were not supposed to sit in such a masculine and revealing posture) to ride the bike. The Ordinary was thus deconstructed into two different artefacts which both developed in different ways. The front wheel of the 'Macho Bicycle' was made even larger to stress the challenges of riding the bike, whereas the 'Unsafe Bicycle' was further developed in an attempt to make it safer. Once most relevant social groups defined the Ordinary as 'unsafe', there was a need for safer alternatives. Changes in the design of the bike made the bike safer and accessible to more groups and cycling became a popular activity amongst certain social groups. With the closing of the 'interpretative flexibility', the dominant design was established as well. What was considered the 'best available technology' and what became the standard bike, depended on what social groups defined as the purpose of the bicycle.

This example demonstrated that social and economic factors (competing interests for example) can influence technology development and standardisation.[9] Development of technology and innovation is therefore not a purely technical matter. However, to complicate the modernist claims even more, sometimes standardisation does not work. Standardisation can be unsuccessful or the 'interpretative flexibility' cannot be closed and two or more competing standards have to be accepted. Schmidt and Werle (1998) provide examples of both unsuccessful standardisation and the simultaneous acceptance of two competing standards.

Videotex, a telecommunications service comparable to the Internet, was very promising in the late 1970s and early 1980s. However, the economic expectations and the fact that, as Schmidt and Werle (ibid.: 147) say 'their future market shares were tied to the success of their standards proposals', prevented the actors from agreeing on a single standard. One of the consequences was that markets stayed fragmented and economies of scale could not be achieved. This complicated the diffusion of videotex and led to 'incompatible technical variety' and contributed to the 'death' of videotex (ibid.: 147). This issue of 'unsuccessful' standardisation is very interesting and I will come back to it when I talk about *Standards at Work.* Yet, first I will briefly discuss Schmidt and Werle's (1998) example of a situation in which none of the competing standards becomes the dominant standard.

Facsimile technology, a service for text telecommunications, was, surprisingly, already patented in 1843. During its development different groups of facsimile machines were developed which were incompatible and could not interoperate. They were divided into different groups which all had their own standards. Group 1 and 2 used analog techniques, Group 3 and later 4 digital techniques. At the end of the 1970s facsimile compatibility was made possible and

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[9] There are many more studies that address similar issues and which I cannot discuss here. A famous example is for instance Hughes (1983) who by looking at a large technical system, the electricity system in America, showed that standardisation processes were not a straightforward and linear development. For example, different companies competed with different versions of system components. Cowan (1996) analysed how the electric refrigerator became the standard fridge in today's households. She showed that demise of the gas refrigerator, which was the competitor of the electric fridge, was not due to inherent (technical) deficiencies in the gas refrigerator itself. Rather, it were social and economic reasons that allowed one fridge to start dominating the other. Unlike the gas refrigerator manufacturers, the companies that encouraged the development of the electric refrigerator could draw upon vast technical and financial resources and this fridge was put on the market earlier. Also the overall climate between the 1920s and 1950s favoured electric utilities which were in a period of growth and almost ensured profits. Also see Winner (1977) on the politics of artefacts and various (other) articles in MacKenzie and Wajcman (1996).

the demand for the equipment increased. In the period 1989-1992 the relatively smooth standardisation process that could be witnessed until then, saw the emergence of a conflict between Group 3 and Group 4 standards. These two Groups had developed in very different ways and Group 3 had become successful while Group 4 had not taken off at all. A few proponents of Group 3 proposed to modify the Group 3 standard to use it as a cheaper and more pragmatic alternative to Group 4 terminals. I will not go into the technical details, although it is important to note two things. Group 4 standards were more closely connected to basic architectural considerations than the other standards and network operators started to become the dominant group of actors whereas before that had always been the facsimile manufacturers. As a consequence, not just ongoing development work and market plans, but also planning over much longer periods and on the implications for applications other than solely the facsimile had to be discussed during the standardisation process. The controversy was thus partly based on the question of what would be the best architectural and strategic choice (technically and economically) in telematics. Companies (typically western), which would be able to manufacture a modified Group 3 terminal much easier than a Group 4 facsimile, became involved in this field that was otherwise dominated by Japanese companies. The opponents and proponents of the proposal could not agree with each other and did not try to find a more acceptable middle ground. In fact, due to the 'genuinely incompatible architectural models' the two Groups adhered to, 'there was no basis for agreement on common criteria for assessing the technical performance and efficiency of the competing proposals' (Schmidt and Werle, 1998: 227). In the end, both were approved, even though they were incompatible.

The three examples mentioned above show how social, technical, and economic factors are interrelated and that standardisation processes are not always successful.[10] Uncertainty about the future, as in the case of both videotex and the

[10] There are discussions about the extent of interrelation between the social, technical, political, and economic factors that influence technology development and the development of standards. Hughes (1986) argued that all these factors together form a 'seamless web'. Bijker (1995: 6) is perhaps more careful and uses the term 'seamless web' as a metaphor 'which is meant to remind the researcher not to accept at face value the distinctions between, for example, the technical and the social as these present themselves in a given situation'. Schmidt and Werle (1998: 306), on the other hand, seem to interpret the 'seamless web' more literally and argue that technology, economy, politics, and science, although they all affect standardisation, do not form a 'seamless web'. They state that 'in many cases of institutionally embedded, organized standardization, a technical perspective is systematically privileged'. However, that economic reasoning is translated into technical argumentation, does not mean that the economic reasoning is not there. Their findings that the technical is

facsimile, can make it difficult to decide on one dominant standard. I will now turn to 'regulatory standards', which often have to derive their legitimacy from uncertain scientific knowledge. However, whereas incompatible 'technical' standards can exist next to each other if necessary, this seems to be more problematic in the case of 'regulatory standards'. Faulkner et al (2003) show for instance that in tissue engineering various regulatory standards exist currently next to each other: 'Tissue engineered products lie between existing regulatory systems' (Faulkner et al, 2003: 1160). They argue that tissue engineered products cross the borderline between medicines and devices and that therefore the 'regulatory status of borderline technologies is uncertain' (ibid.: 1159). A new regulatory regime based on these borderline products is expected; it is uncomfortable to have different regulatory standards that regulate the same material.

Science and Policy up for Debate: Standard Setting as Boundary Work

Many standards, especially the ones developed in what can be called public policy, rely increasingly upon information and methods derived from the physical, biological, and social sciences. These are (regulatory) standards that are often developed for 'invisible' hazards like PCBs, radiation, and carcinogens in food additives. Nelkin (1985, in Nelkin, 1995: 449) states that the risk disputes surrounding these hazards focus on 'balancing competing priorities in decisions about regulation and the setting of safety standards, and on ways to best protect the public and those working in hazardous occupations'.[11] These standards are often contested in terms of rights. If government regulation requires universal vaccination or constrains the use of a pharmaceutical product, everyone has to accept the decision and share the consequences. In this respect these standards often differ in scale from the 'technical' (and often voluntary) standards discussed above, although there are exceptions. Hawkins (1984: 24) writes for example that water pollution standards were 'defined locally by each water authority and are specific in application, with each consent negotiated on an *ad hoc* basis'.

In 1984, a special issue of *Science, Technology & Human Values* focused explicitly on the role of scientific and technical knowledge in regulatory decision-

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privileged are not in contrast with Bijker's notion of a seamless web. They may have started their research without *a priori* distinctions between the economic and the technical and their finding suggest that certain seams have been made.

making. In the introduction to the issue Schmandt (1984: 14) listed some of the questions the articles in this issue addressed. I will give a few examples: 'How is scientific evidence prepared and used in different institutional settings?' 'Can we define quality standards for science assessments and other analyses intended to guide decisionmakers?' 'What makes assessment documents both scientifically sound and politically useful?' 'How do different types of decision analyses – scientific, economic, legal – contribute to the decision process?' 'How do legislative, regulatory, and judicial organizations differ in the use they make of scientific evidence?' The issue may be twenty years old, but the above questions are still relevant. These questions may have to be addressed differently or may lead to different answers with respect to changing institutional settings, like the increasing role of the European Union in the setting of regulatory standards.

I will now give a few examples that address some of the above issues and show that boundaries between science and policy can be up for debate, especially in cases where the scientific information on which a regulatory standard should be based is uncertain. In these cases actors perform what we can call 'boundary work'.[12] Halffman (2003: 2-3) defines this type of boundary work as:

> It distributes what will be considered the domain of science and what the domain of policy, to what extent and how the two should be distinguished in the first place, while simultaneously it negotiates the conditions for interaction between expertise and policy.

The first example is the fluoridation debate in which one of the issues is possible government regulation.[13] Fluoridation aims to achieve the optimal level of fluoride for dental care in public water supplies. This is not an easy task since people drink different amounts of water and may have a fluoride intake from other sources as well. Martin (1991: 8) analyses scientific knowledge claims made by proponents and opponents of fluoridation and argues that 'what is counted as knowledge depends on

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[11] Nelkin, D. (ed.) (1985). *The language of risk: Conflicting perspectives on occupational health*. Beverly Hills: Sage.

[12] The concept 'boundary work' was first used by Gieryn (1983). Weinberg (1972) talks about 'transscience' which he understands as an activity that 'engages scientific expertise but is not fully scientific' (Yearley, 1995: 466).

[13] A few examples of other studies on 'scientific' controversies are Richards (1988) on vitamin C as a treatment for cancer, Collins (1981) on the dispute around the existence of high fluxes of gravitational radiation, and Pickering (1984) on particle physics.

getting agreement from other scientists, and this may involve funding, status, or persuasive ability'. Science is thus regarded as an activity like any other and not as an activity that may provide exclusive access to the truth. He makes another claim that is, like the former, supported by much other research in STS (see for example Kuhn (1996), Latour (1987)). Often science cannot offer the solution to a debate, because 'scientific consensus (if it were possible) cannot resolve disputes over value judgements and social priorities' (Martin, 1991: 189).[14] In other words:

> Far from being an almost mechanical process safely relegated to technicians, the setting of health, safety, and environmental standards is in reality a microcosm in which conflicting epistemologies, regulatory philosophies, national traditions, social values, and professional attitudes are faithfully reflected.' (Majone, 1984: 15).

Majone, like others, argues that these conflicting epistemologies cannot only be seen with regard to what can be considered a health risk but also with regard to scientific methods that 'are influenced deeply by biological and philosophical assumptions, and by scientific traditions' (ibid.: 16). Here, according to Halffman (2003: 3), a second type of boundary work comes into place with regard to regulatory decision making, namely boundary work that negotiates the division of labour between the knowledge that is directly relevant for regulatory decision making and the knowledge that is not (knowledge that is considered 'unscientific', 'purely academic', or 'impractical'). He discusses an example of this type of boundary work in which ecologists argue that the potential detrimental effects of chemicals should be tested in (artificial) ecosystems. Environmental toxicologists dispute this and contend that 'single-species toxicity tests' that focus on physiology are the best way to study the effects of chemicals. These various claims to what is relevant science or knowledge for regulatory decision making lead to uncertainty. Majone adds to this that it is still contested which animal species best predicts the response of man and which animal

[14] If we accept that scientific activity is not different from other activities, we may have to rethink the distinction between experts and lay people. Whenever a public debate or controversy emerges about a scientific claim, it is often argued that 'the public' simply does not understand the science. However, the disputes often evolve around the above mentioned value judgements and social priorities. Learning about the technicalities of science, will then not help to make anyone more 'objective' with regard to science. I cannot address this issue here, but further information can be found in amongst other Collins (1987), Wynne (1989), Webster (1991), Irwin and Wynne (1996), and Collins and Pinch (1998). I will also touch on this issue in chapter 6.

model would best simulate a pregnant woman or someone with special requirements. However, regulatory standards have to be set: 'unable to find clean theoretical solutions, standard-setters must use various rules of thumb to deal with the uncertainty of toxicological predictions' (Majone, 1984: 17). One of those rules of thumb, he argues, is to set a 'safety factor'. Test animals should for instance not show any adverse health effects when they are exposed to doses that are at least 100 times greater than the likely human dose. The continuous evolution of the scientific basis of regulation results in a further increase in uncertainty and a further complexity of the regulatory decision making process. In situations of uncertainty or disagreement possible 'solutions' for 'technical' standards were to accept competing standards or to set no standard at all. However, when it comes to standards that are believed to protect the public from for instance hazardous chemicals, one cannot accept competing standards and it would be hard to legitimate a decision not to set a standard for a chemical that many believe has adverse health effects because there is disagreement about the extent of the adverse health effect. Legitimacy of regulatory standards therefore becomes an important issue.[15]

Jasanoff (1992) illustrates the various (successful and unsuccessful) strategies the American Environmental Protection Agency (EPA) uses to legitimise its decisions with regard to, amongst others, standard setting. The EPA, like the examples above, deals with uncertainties: 'quantities that are hard to measure, physical phenomena that are highly interactive, and diseases that occur over the course of a lifetime and for which there may be many plausible causes' (Yearley, 1995: 467). Another uncertainty is that the EPA has a 'protective mission' and has to identify and regulate chemical substances before there was certainty that these were actually harmful to humans. In a sense, the EPA could therefore 'create' those

[15] Greenwood (1984) argues that regulatory agencies can do three things when they are faced with uncertainty. First, they can distinguish good and relevant information or analyses from bad or irrelevant ones; they can seek to settle disputes over purely scientific, technological, and economic issues; and thirdly, reach consensus that lies within the zone of reasonableness defined by the knowledge available. From this, he then develops a way to judge the competence of a regulatory agency. Although some of his suggestions can indeed be useful in evaluating the competence of a regulatory agency, I would like to stress that, as this chapter hopefully shows, these issues are not as straightforward as Greenwood sometimes puts it. He argues for instance that only when there is insufficient good information available, the agency should exercise discretion. Although he acknowledges that it is sometimes hard to distinguish between when for instance information is easily available and when only with substantial effort, he maintains that there is a boundary between the two categories. I would argue that in many cases no agreement can be reached on what 'insufficient good information' means, because different actors from different (scientific) backgrounds and with different interests will understand this concept differently.

harmful substances in the same sense that water authorities create pollution 'by making the rules whose infraction constitutes pollution' (Hawkins, 1984: 23). In addition to these uncertainties, Yearley (1995) argues that when environmental safety is concerned, huge commercial and political interests, which are for the greater part absent in 'pure' science, are involved too. The EPA set standards for chemicals on the basis of novel, untested, and sometimes controversial methods. In an environment where industrial interests were large, this gave rise to disputes. The EPA tried to legitimise its standards not by 'stating a knowledge claim of regulatory significance (substance X is a carcinogen)' but by 'giving intricate explanations of the process by which it came to that factual conclusion' (Jasanoff, 1992: 202). EPA deconstructed 'scientific' claims that are usually considered 'black boxes' and its legitimation for standard setting became increasingly political: 'instead of putting the claim into the black box as in normal science, EPA exposed its contents, as required by the rules of political and legal legitimation' (ibid.: 203). However, this 'openness' made it possible for many other actors to intervene and criticise EPA's actions. According to Greenwood (1984: 94) it is not always possible for a regulatory agency to rely solely on science, however, reliance on policy leads people to believe that regulatory agencies do not have (enough) scientific competence:

> When agencies base their risk assessments partly on policy considerations, through the necessary exercise of discretion, they are often falsely accused of lacking scientific competence.

EPA then changed its strategy and sought to bring scientific evidence partly back into the realm of science by turning to consultations with scientific experts from outside the EPA. In doing so, the agency tried to gain scientific legitimacy when it was clear that the political legitimacy it had striven for had not had the desired effect. Boundaries between science and policy became contested in criticisms that faced the EPA. Jasanoff (1992) describes how EPA's interpretation of 'adverse health effects' when setting air quality standards was regarded by some as masking policy as science:

> The EPA thus manages to get the best of both worlds: standard setting is not a political act, but a technical task that must be performed by an expert agency; yet the uncertainty of the task frees the agency from the dictates of scientific

> evidence and its political executives from responsibility for the economic and social consequences of its determinations. (Melnick, 1983, in: Jasanoff 1992: 209)[16]

Jasanoff claims that the EPA is most convincing when both science and politics are taken into account: political legitimacy and external scientific advice combine.

This case has shown that when no straightforward scientific evidence is available and various parties have different interests, the boundary drawing itself can become highly political in an attempt to justify the decisions an agency makes.

Standards and Regulatory Science

There is one more aspect of 'regulatory' standards I would like to discuss briefly. The case of the EPA has shown that regulatory standards are often (but not always) legitimated by reference to science. In many cases, this is 'regulatory science' that is developed especially in response to 'external' regulatory demands (Irwin et al., 1998: 231). Jasanoff (1990: 76-83) coined the term 'regulatory science' which refers to knowledge that is produced in a particular institutional context rather than a distinctive type of knowledge (Irwin et al., 1998: 233).[17] The knowledge produced is meant to 'fill the gaps' in the knowledge base that is relevant for regulation and assess risks and benefits of new products. Therefore it has to be politically accountable, is often subject to time constraints, and is less concerned with discovery and new knowledge than 'academic science'. Once the gaps are filled, standards can be developed. Regulatory science is therefore an important aspect of the development of regulatory standards. Regulatory standards, in turn, can then govern scientific practices that are developed in response to regulatory demands, as we will see below. Yet, regulatory science and therefore its relationship with standards and standardisation, have not received much attention from the academic world. In the words of Halffman (2003: 14):

> Although the organisation and dynamics of expert committees and the problematic role of regulatory science in decision making are well studied,

[16] Melnick, R. S. (1983) *Regulation and the Courts: The Case of the Clean Air Act*. Washington: Brookings Institution, page 257.

[17] Others have used the notions of 'trans-science' (Weinberg, 1972), and 'mandated science' (Salter, 1988) for knowledge produced for regulatory purposes.

> very little attention has been paid to the detailed organisation and dynamics of regulatory science. Only a few studies have looked at the organisation of laboratories that perform research for regulatory purposes, at the construction of their research agendas, or the role they play as sources of expertise in policy. Hardly any research has been done on the development and implementation of tests and decision-making tools *in direct relation to* regulatory decision making.

One of the 'few studies' mentioned by Halffman criticises the distinction made between 'academic science' and 'regulatory science' in which academic science is innovative and subject to peer review whereas regulatory science is bounded by external pressures of time and politics, proprietary, and directed towards closure rather than to advancing knowledge (Irwin et al., 1997: 20). Irwin et al. argue that the view of academic science portrayed here is an idealised view and that the variety of regulatory science (institutional settings, activities, etc.) in different countries undermines such a distinction. Yet, they see the term regulatory science as a useful heuristic device under which they classify different activities that transgress the context/content boundary: speculative research, development and validation of regulatory tests, regulatory compliance testing, investigative problem-solving, and regulatory submission. Regulatory science as a concept suggests, they argue, empirical and policy issues that might otherwise be neglected. It also 'allows a sense of the emerging scientific and regulatory context within which key innovatory and environmentally-related decisions are being made' and takes us beyond the traditional focus on 'laboratory science' (Irwin, et al., 1997: 29). In addition, it is a term that is now used by practitioners, at least in the agrochemical industry. The last reason they give to demonstrate the usefulness of the concept of regulatory science is that it draws attention to the social and regulatory pressures on industry and government which are currently emerging (for example the tension between rule-based standardisation and flexible patterns of innovation and scientific investigation within regulatory science).

This study points to what Abraham and Lewis (2000: 19) see as an aspect of regulatory science that had not been addressed by Jasanoff's initial definition:

> Because of the heavy influence of industry in the production of science-based products, whose development and success partly depend on meeting

regulatory standards, regulatory science should also be seen as including the industrial scientific practices specifically geared to regulatory requirements.

Instead of focusing on standard setting in regard to the collecting and 'creating' of relevant scientific information, Abraham and Lewis stress in this quote the role of standards in governing (industrially-based) scientific practices that are geared to regulatory requirements. This is similar to what Irwin et al. (1997) understand as regulatory compliance testing.

Both this article from 1997 and an article from 1998 develop an empirical approach to the study of regulatory science. The 1998 study is similar to the 1997 study in addressing the relations between context and content. Irwin et al. (1998) argue that institutional factors can have a 'conservative' influence on the development of new knowledge, because scientists may not be motivated to identify new areas of research, and result in addressing only short-term questions. However, at the same time the government agency provides useful feedback on 'best practice' to agrochemical companies, the object of the study, which in turn 'examine their products critically before release rather than face problems later on' (ibid.: 247). Regulatory science can thus be said to be a 'hybrid area of activity in terms of both its content and context' (ibid.: 234). Shackley and Wynne (1995; in Rothstein et al., 1999: 243) have argued that regulatory science should be regarded as a process of mutual construction of science and policy rather than just a 'sort of hybrid of science and policy'.[18] Rothstein et al. (1999: 261) add that 'regulatory science represents not just an area of partial (or temporary) overlap between science and policy but has its own –albeit heterogeneous– institutional and technical practices'.[19] As we have also seen above in the case of EPA, Rothstein et al. (ibid.: 242) stress that a generalised treatment of the relationship between science and regulation, in which 'the actual standards adopted are generally legitimated in *scientific* terms' and become a policy foundation that is universal, does not do justice to the 'local negotiations,

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[18] Shackley, S., Wynne, B. (1995). "Global climate change: The mutual construction of an emergent science-policy domain". *Science and Public Policy*, vol. 22(4): 218-30.

[19] Abraham (2002) argues that the regulatory context should not mainly be understood by referring to inter-institutional contexts and interest-based instrumentalism as many studies do, but that instead regulatory science, or better the culture of regulatory science, can be characterised by four key cultural dimensions: the politics of technology as progress versus hazard, productivity goals, trust and knowledge validation, and disciplinary commitments and professional interests. He (2002: 310) states that also 'theoretical and empirical researches on the *culture* of regulatory science (...) are in their infancy'.

institutional structures, social relationships, and professional judgements that lie at the heart of regulatory science'. Regulatory science thus does not offer a 'universal and objectively determined basis for common standards', but will instead vary across different national policy settings (Rothstein et al., 1999: 243). I will come back to the claim that standards are universal and objective in the next section. First, it is important to note that Irwin et al. (1997: 29) also suggest that more (empirical) research into the field of regulatory science would be valuable: 'it would be especially helpful to explore the overlap between the analysis here of agrochemicals and other sectors'. Although they stress pharmaceuticals, the topic Abraham and Lewis (2000) discuss, as an especially strong candidate for comparative analysis, I believe that other sectors could form a contribution to this under-researched field of study as well.

To conclude this section, we have seen that the construction of standards, whether this involves 'technical' or 'regulatory' standards, is a complicated and not purely technical process in which social, economic, political, technical, and scientific aspects play a role and boundaries between these different aspects are continuously and actively drawn, deconstructed, and redrawn. The scientific expertise clearly does not 'enter the regulatory arena as a neutral, mediating force, contributing to good or even 'correct' decisions', no matter how much citizens, scientists, and politicians would desire this (Cozzens and Woodhouse, 1995: 542). The studies that were discussed show that the modernist claims to objectivity and universality of standards do not hold. In the words of Jasanoff (1998: 173) standards 'incorporate not only 'objective' assessments of technical evidence but also collective, often tacit, cultural judgements about the appropriateness of particular social roles, power relationships, institutional forms, and styles of governance'.

2.2.4 Local universalities, universalised locals and a discussion of (im)mutable mobiles

Standards have become a pervasive, cross-sectoral and transnational phenomenon and are directly relevant to the design and governability of our complex technical system. (Lundvall, 1995: 12)

Standardization or uniformity in performance as a result of standards is more of a fiction, strategy or proposal for action than it is reality. (Salter, 1988: 26)

Common standards sometimes turn out to refer to different things. "Bad air" in London is not the same as "bad air" in Paris, even when it is measured against the same European standards. (Barry, 2002: 145)

Although standards are often outcomes of contingent negotiation processes between heterogeneous actors, there is still the persistent claim that standards are or can be somehow universal. This is the claim I will explore in this section.

Definitions of standards often stress standards as a basis of comparison (think of the metre as measuring device) over both time and space. Some standards, mainly compatibility standards, render different systems or artefacts compatible. The latter process can be called 'harmonisation' (different standards are made compatible, but not identical, for the purpose of trade) as opposed to 'standardisation' (acceptance of an identical level of performance) (Salter, 1988: 28).[20] Below, I will mainly discuss studies of standardisation, some of which have shown 'the methods by which these hybrid, socio-technical products can be made to cohere across widely dispersed geopolitical and cultural spaces' (Jasanoff, 1998: 179). I will focus on standardisation processes as *deliberate attempts to achieve universality.* Studies like Bijker's study (1997) on how several bicycles were reduced to one bicycle therefore fall outside the scope of this section: the standardisation that occurred there was more a matter of convergence than a deliberate process. However, not concentrating on compatibility standards and 'unintended' standardisation, does not mean I direct my attention to a minor part of standardisation processes. As Berg and Timmermans (2000: 31) remark:

> Attempts to formalize, standardize, and rationalize are ubiquitous in Western worlds. Work practices are made more "efficient," professional practices are supposed to become more "scientific," and technical practices should obey "universal" standards. The disorder of current practices, according to such

[20] It may be unnecessary to explain that 'harmonisation' and 'standardisation' have been defined differently by different people and that like standards, there is no standard definition of them. They are often used interchangeable as well.

discourses, should be replaced by scientifically established, rational, and universal modes of working and understanding.

The last sentence of the quote above hints at unease with the discourses that regard standards as a means to make practices more efficient, scientific and universal. Within STS, these discourses, which often assume that standards have inherent characteristics that will help to produce efficiency and universality, have been questioned. Instead, social-constructivist studies have looked into how standards produce or are being made to produce universality.

In actor network theory (ANT), or, as many prefer, actor network approach, the making of universality has been a central issue. Latour, one of the main proponents of ANT, argues in both *Give me a laboratory and I will raise the world* (1983) and in *The Pasteurization of France* (1993 [1988]) that in order for specific medical and scientific laboratory practices to work, the world itself has to be transformed into a laboratory. The standards of cleanliness, accuracy and so on adhered to in the laboratory have to be followed outside the laboratory as well. In his own words (1983: 155): 'Scientific facts are like trains, they do not work off their rails. You can extend the rails and connect them but you cannot drive a locomotive through a field'. Universality is thus not an inherent characteristic of the standards themselves. Standards have to be mobilised in order to achieve universality and universality is then an 'acquired quality; it is the effect produced through binding heterogeneous elements together into a tightly coupled, widely extended network' (Berg and Timmermans, 2000: 31).[21] Universality can be produced for instance through relevant social actors defining the standards or artefact in the same way (as Bijker's study shows) or through 'establishing the authority of a particular representative, circulating it, and assuring that comparisons are made to it' (O'Connell, 1993: 165).

O'Connell, who explores the standardisation of electrical units in the late nineteenth century, gives an example of the latter way of producing universality. He discusses how several material representatives of the unit were contested once the need for standard electrical units was acknowledged. The debates about the best

[21] It is important to note that Timmermans and Berg seemed to have a slightly different view of how standardisation worked in their earlier work. In an article published in 1997 (p. 298) they argued that 'rather than being the product of ever increasingly tightened networks, medical protocols can coordinate activities over space and time *because* of the non-docility of the actants which populate these practices'.

standard were rather similar to the debates Schmidt and Werle (1998) describe around the several standards for telecommunication. A requirement of the eventual unit was that it was 'realized in a form that could be carried around, readily compared to the resistance of a telegraph cable, or incorporated into measuring instruments' (O'Connell, 1993: 140). Only then the standard would be adopted on a large scale. However, carrying a unit around is not a simple task. Scientists can 'lose the volt' and have to ask other scientists to send couriers who need to carry the volt. They have to be careful, because even a small shock can change the unit. At the place of arrival the scientists therefore have to try to ensure that the volt that arrived is the same volt as the one that was put into the transport box. O'Connell convincingly shows that standardising processes are not a matter of formulating a standard and then sitting back and watching the standard do its work. Rather, after a standard has been set, it requires a lot of maintenance work. Primary standards ('the volt', 'the metre', 'the kilogram') 'are the source of all accuracy in the world of standards', however they tend to change when they have too much contact with the 'profane' world (ibid.: 151). Therefore, instruments often drift from the standard until they are allowed to be compared to the original standard again and secondary standards are set to mediate this.

Latour may argue that the creation of the above mentioned primary standards was an attempt to produce 'immutable mobiles'. Specimens, maps, diagrams, logs, questionnaires and paper forms are all stable (immutable) and mobile and can therefore be put to use in every place and period 'no matter whether they are twenty centuries old or a day old' (Latour, 1997[1987]: 227). 'Immutable mobiles' is a concept that needs to be explained in an academic environment where the notion of transformations reigns more or less unchallenged. Literature on standards, scientific facts, and artefacts, and even the reading of texts has often stressed the different ways in which they can be interpreted across cultural, political, national, scientific, and economic settings. Also Latour (1997) himself has stressed notions like 'negotiation' and 'translation' which he opposes to a notion like 'diffusion' that assumes that people pass objects and scientific claims along, reproduce them and buy them forgetting that this 'passing on' is what makes the claims durable and robust and transforms them into facts. And yet, here is a concept that refers to objects and standards as things that are not transformed anymore, only transported and mobilised. As Latour later argues 'immutable mobiles' are mobile inscriptions that allow new translations and articulations while keeping some types of relations intact

(Latour, 1999: 307). O'Connor's case demonstrated that these immutable mobiles have to be carefully maintained and do not simply remain 'immutable mobiles'. Once they have been established, like black boxes after closure, they can be opened up again or become entrenched. Both require a lot of work. There are cases in which the immutable mobile is not further transported:

> The black box moves in space and becomes durable in time only through the actions of many people; if there is no one to take it up, it stops and falls apart however many people may have taken it up for however long before. (Latour, 1997: 137)

In a network in which the focus lies on negotiations, translations, transformations, and mobility, this could be regarded as an example of unsuccessful mobility; a case where something is not mobile anymore. However, Mol and Law (1994) offer an alternative explanation. In their study of anaemia they analyse how doctors in the Netherlands and in Africa establish anaemia in different ways. The haemoglobin measurements that are so important for Dutch doctors are not or hardly used by tropical doctors. This would point in the direction of a failing network of haemoglobin measurements: they did not manage to become immutable mobiles and to be put to work in Africa. Instead of explaining this with reference to another network that deals with haemoglobin in a different way, Mol and Law (ibid.: 658) use the metaphor of 'fluids', which allows simultaneously for movement and change without falling apart: 'fluidity generates the possibility of invariant transformation' (original in italics). Coopmans (forthcoming) discusses the text of Mol and Law by focusing on the notion of mobility. According to her Mol and Law 'remind us that any notion of mobility presupposes (as well as reinforces) a particular type of space'. This means that objects or concepts that do not fit in with familiar types of space (regional and network space for example), behave more like mutable than like immutable mobiles. The concept of mutable mobiles has also been used by Moore and Clarke (2001) to emphasise that the meanings of and the ways in which these 'mobiles' are used can vary between different contexts. In that sense they can be regarded as a 'boundary object': an object that can have different meanings in different social worlds but can at the same time be recognised in the different worlds and therefore serve as a means of translation (Star and Griesemer, 1989).

Coopmans (forthcoming) criticises both the concepts of immutable and mutable mobiles for being explanatory and for not explaining what it takes for things to 'circulate' and be mobile: 'where analysts have theoretically interrogated the immutable mobile, they have generally not touched on the assumption that it moves'. According to her these concepts often carry 'a hint of technological determinism' since the mobility of an object is seen as intrinsic to the object and seems unaffected by expectations, perceptions, practices, and circumstances. I share Coopmans' criticisms. An exploration of where, when, and in what ways objects become mobile includes in my eyes theorising when and where they are *not mobile*, an issue that has not been explored extensively. Some stress that 'tinkering' with protocols and standards to make them workable in practice (see for an example *Standards at Work*) does not show the limits of standardisation in action. Rather than demonstrating the resistance of actors to standardisation, the (re)negotiation and (re)articulation of standards is essential, a *sine qua non*, for the functioning of the standards and thus for universality in practice (Timmermans and Berg, 1997).[22] Others (Mol and Law, 1994) use the notion of fluidity to emphasise the continuous movement. ANT, as mentioned above, focuses on movement: on the spreading of networks and on how actants are enrolled in networks and networks themselves are 'a series of *transformations*-translations, transductions' (Latour, 1999a: 15).[23] In the words of Watson-Verran and Turnbull (1995): 'Failing to recognize the plasticity that goes along with the integrity and coherence of black boxes, Latour (1983) (...) [has] standardized forms of knowledge swarming unimpeded out of the laboratory. As [he sees] it, resistance is useless'. Non-mobility thus either does not exist or is not the focus of attention of many of the existing approaches. One could be tempted to ask what the explanatory or even just methodological power of an approach is if networks can be broadened as far as the researcher wishes to and if by negotiation and appropriation any new technology or standard can be regarded as implemented

[22] This may however refer more to the way in which standards are mobilised for different purposes (the same medical protocol can be used to revive a patient, to give the family time to come to grips with the impending death or to avoid discouraging paramedics who worked hard to try to keep the patient alive) than to the mobility of standards as such.

[23] Like universality is an outcome and not an inherent characteristic of a network, actors (humans) and non-humans are an outcome of a network as well and cannot be referred to *a priori*. The term actant is a solution to refer to 'whoever and whatever is represented' (Latour, 1997: 84).

or domesticated. The bed of Procrustes seems an interesting metaphor here.[24] As we have seen, non-mobility would however be a complex topic of research, because what can be seen as a failed network in one approach can be successful fluidity in another. In addition, mobility, as Mol and Law argue, has to be placed within a specific type of space and should therefore be precisely defined.

The focus on the construction and spreading of networks within ANT has led to another point of discussion. The enrolment of actants in a network is portrayed as mostly successful and therefore not much attention has been paid to the question of who are excluded from these networks. This is a logical consequence of the 'following the actor' approach that is used in ANT studies and of the obscurity of the borders of a network. By following one actor, other actors who are excluded from but affected by the network are left out of consideration. Power in and between networks is regarded as an outcome of the network; it is something that emerges when the network is founded and transformed. Power in ANT can therefore not be used as an explanatory and *a priori* factor to clarify why and how some human perspectives win over others and why and how some human actors resist being enrolled (Fujimura, 1991, in Star, 1991: 29).[25] It seems that enrolment is (nearly) always voluntary and a consequence of the convincing 'power' of the actor that is followed.

In addition ANT has been criticised for having a bias towards the successful actant, who is the one that is followed:

> The political order described in actor network theory, or in descriptions of the creation of scientific facts, they [some writers in the science studies area] describe an order which is warlike, competitive, and biased towards the point of view of the victors (or the management) (Star, 1991: 33).[26]

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[24] Procrustes who, according to Greek mythology, was a thief and robber in Attica and forced passing travellers to lay down on a bed. He then adjusted their length to the length of the bed by stretching them out or by chopping off a part of their legs.

[25] Fujimura, J. (1991). "On Methods, Ontologies and Representation in the Sociology of Science: Where Do We Stand?". In: Maines, D. (ed.). *Social Organization and Social Processes: Essays in Honor of Anselm L. Strauss*. Hawthorne, NY: Aldine de Gruyter.

[26] To be fair, Latour (1997: 155) does recognise how important it is to choose whom to study, because with choosing different people 'completely different pictures of technoscience will emerge'. This has become a 'problem' for some ANT scholars. Choosing whom to study is of the utmost importance, but it is impossible, or at least hard, to know in advance what the outcome will be.

This is also noted by Timmermans and Berg (1997) who suggest that by focusing on a 'prime mover', it seems that all entities that are enrolled in the network are docile points in this network. They argue instead that a central actor is not required for standardisation efforts and that achieving universality can be seen as a *distributed* activity in which many actors simultaneously play a role, examples of which we have seen above.

However, it would not be fair to portray ANT as being occupied solely with continuous transformations. Latour talked about elements in a network that become stable (immutable mobiles) and do not transform anymore and Callon (1991) has discussed how networks can become 'irreversible' and therewith robust. In tight networks where many interrelations exist between the different elements of the network, a modification of one element would lead to a retranslation of the entire network, therefore:

> The more numerous and heterogeneous the interrelationships the greater the degree of network co-ordination and the greater the probability of successful resistance to alternative translations. (ibid.: 150)

Resistance to translations is here explained by referring to tight interrelations between the different parts of a network. When the network becomes robust and durable, it also becomes normalised and standardised. Elements and expectations within and of the network are standardised and made compatible, which in turn leads to an even greater irreversibility: 'the more precise and quantified these standards, the more a successful translation becomes irreversible' (ibid.: 151). A network then starts to resemble a black box: its behaviour is known and predicted independently of its context. Star (1991) adds that once a network has become stable and irreversible, creating an alternative network or new and alternative standards may be expensive or impossible. These developments do not only have consequences for the network, but also for the standards themselves, the standards that are seen to stabilise the network:

> Once embedded within a network of discourse and technical practices (...), standards lose transparency and acquire a taken-for-granted status that resists criticism by actors who did not participate in the original standard-setting process. (Jasanoff, 1998: 180)

Standards have become taken for-granted black boxes and their origin is hidden and will be forgotten. Possible errors of translation are no longer retrievable (Mol, 2002: 221) They can now appear as being universal, even though we know that they are 'the result of negotiations, organizational processes, and conflict' (Bowker and Star, 2000: 44). This takes us back to Latour's immutable mobiles. We have seen that the immutability of the mobiles has been criticised, but perhaps we can also ask the question whether standards that have become so entrenched in a stable network are still mobile. If empirical research, which would have identified a specific definition of mobility, would find that a standard is not mobile, what would this mean for the standard? Does a standard have to be mobile in order to function? In order to achieve universality? If it does, how can we theorise these non-working standards?

When a network or standardised and entrenched system is in place, it becomes clear that it cannot incorporate the needs of all individuals. They may provide sameness and stability for many people, but for others, who do not fit in, the system is a source of chaos and trouble. As an example Star (1991) discusses how a person allergic to onions enters MacDonalds. Instead of being served promptly (which is one of the service standards and characteristics of MacDonalds), it takes half an hour for her burger to arrive. Preparing a burger without onions may not seem a difficult task, but in a highly standardised system the place for unstandardised or unconventional behaviour and actants seems to become smaller. Like Star, Bowker and Star also ask the question of what happens to cases that do not fit classification or standardisation systems. One of their examples (2000: 265) is that nurses 'are trying to situate their activity visibly within an informational world that has factored them out of the equation'. They state that 'each standard and each category valorizes some point of view and silences another' (Bowker and Star, 2000: 5). The nonstandard or unclassified can either be part of the space in between standards and classifications or an actant that resists classification and standardisation. As we have seen above, ANT does not provide an explanation for how actants can resist classification and standardisation; they simply fall outside the network because they were not enrolled. According to Timmermans and Berg (1997) without the 'resistance' there would not be standardisation or universality. I will now discuss their approach in a bit more detail.

Berg and Timmermans (2000: 33) note that most social-constructivist studies are ordered in a certain way: 'disorder pre-exists and precedes the emergence of order'. Star (1991: 47) puts this as follows:

> A set of uncertainties are translated into certainties: old identities discarded, and the focus of the world narrowed into a set of facts.

Berg and Timmermans (2000) criticise the use of opposing categories like order-disorder, stable-unstable, formal-informal, and universal-local. This is a criticism also expressed by proponents of ANT, who do not make a distinction between the local and the universal: 'contexts too flow locally through networks' (Latour, 1999a: 18) or in other words:

> The social is a certain kind of circulation that can travel endlessly *without* ever encountering either the micro-level -- there is never an interaction that is not framed -- or the macro-level -- there are only local summing up which produce either local totalities ('oligoptica') or total localities (agencies)' (ibid.: 19)

Berg and Timmermans (2000) argue that the local, which is unquestioned, is often favoured above the universal. However, these opposing categories cannot exist without each other. There is no order without disorder. They then argue similarly to Star that what is order within one uniformity (MacDonalds for the meat-eater who has no onion-allergy) becomes disorder within the other (Berg and Timmermans, 2000: 47). This assumes that a multiplicity of universalities exist. Berg and Timmermans explain indeed that if the local has a corresponding universality and the local is plural, one should also speak of different universalities. They (1997: 275) coined the notion of 'local universalities' to describe that 'universality always rests on real-time work, and emerges from localized processes of negotiations and pre-existing institutional, infrastructural, and material relations', for it is the link with local contexts that make universalities meaningful. These universalities or orders do not arise from disorders, but instead produce disorders and are in that sense not a solution to a problem of disorder. Studying standardisation processes in this light would mean that neither standard-setting processes (as discussed above) nor standard 'implementation' processes (as will be discussed under *Standards at Work*) can be seen as creating order from disorder. Rather, they have to be studied as processes that simultaneously produce orders and disorders, localities and universalities:

> When the 'local' is seen as always part and parcel of everything universal, the latter need no longer be perceived as a necessary (latent) threat. We can then stop unifying 'standardization' and 'formalization,' and scrutinize the politically relevant axes of difference that run *through* these categories. (Berg and Timmermans, 2000: 60)

Studying standardisation processes this way, would allow scholars to create alternative universalities. If necessary, an informed and critical choice can be made between these alternative universalities. However, Hartswood et al. (2001: 118) argue that, taking the above into account, one can still study the way in which '*universalities emerge from locals* (local practices, technological innovations, etc.), how locals are re-shaped to make them more widely applicable through distributed learning processes and how they are linked to other locals'. They call systems that are developed 'in locally meaningful ways' and 'have the potential to gain wider importance through processes of social learning' 'universalised locals' (ibid.: 117-118).[27]

In conclusion, we have seen that the universality is not an inherent characteristic of standards. Universality arises, together with locality, in networks in which it also has to be maintained. ANT, that has regarded the making of universality as a central issue, has offered some very valuable insights, but has also been criticised at a number of points. It has not answered what it means for a standard to be mobile (or non-mobile); it does not deal with actants that resist classification, because they are simply left out of the (network) analysis; 'power' cannot be used as an explanatory concept; and it has focused only on successful actants and forgotten about the unsuccessful ones, whereas, according to Timmermans and Berg (1997) achieving universality should be seen as a distributed activity rather than as an activity of one central actor.

2.2.5 Trust, Expertise, and Objectivity

[27] The concept of 'universalised locals' is akin to that of 'cosmopolitan regimes' developed by Disco et al (1992). According to them 'the knowledge, skills and artefacts that go into the design of new products may seem to depend only on the capacity of the local situation (...) [yet] the quality and scope of the knowledge and skills in non-local in origin' (Disco et al, 1992: 495).

> *The bureaucratic imposition of uniform standards and measures has been indispensable for the metamorphosis of local skills into generally valid knowledge.* (Porter, 1995: 21)

The previous section has demonstrated that the modernist claim that standards automatically lead to universality does not hold. Achieving universality, even if it creates a locality to go with it, is hard work and work that has to be maintained continuously. Therefore, it will not come as a surprise that standards do not (automatically) lead to objectivity either. In the literature that will be discussed below objectivity has been linked to a greater or lesser extent to the creation of trust and the importance of specific types of expertise. For understanding the possible roles standards play in society, it is important to explore this literature in more detail.
I will start with Sismondo (2004: 71) who explains why trust is so important in scientific and technological practices:

> Trust is an essential feature of scientific and technological work, in that researchers rely upon findings and arguments made by people they have never met, and about whom they may know almost nothing.

Trust is often established through faith in a common culture or disciplinary background which provides people with a (perceived) common understanding and shared references. Trust is also seen as related to perceptions and experiences of the relevant actors or institutions, rather than to an understanding of technical knowledge.[28] However, although most STS scholars would agree with the above-mentioned ways in which trust comes about, trust is a contested concept as well. The emergence of trust is explained in different ways and in addition to that trust is not something that can be measured easily. People may for instance act as if they trust a person or institution, while they are simultaneously looking for evidence that points to the trustworthiness of the person or institution. In the words of Wynne (1995: 381):

[28] See footnote 14, this chapter. Much of the literature focuses on trust between scientists and 'lay people' rather than on trust among scientists.

Reifying trust into an objective parameter that can supposedly be measured (and manipulated), like understanding, is in this view fundamentally mistaken.

Below I will explore a few positions on the relationship(s) between trust, expertise, and objectivity with regard to standards and standardisation processes.

Objectivity, like other concepts, has many meanings, the most well known of which refers to truth to nature. A disinterested person, preferably a scientist, who tells us what the world out there is really like, is commonly regarded as objective. However, objectivity to Porter (1995) is not about 'truth' claims, but has to do with legitimations of judgement. He distinguishes two types of objectivity: disciplinary and mechanical objectivity. Disciplinary objectivity is objectivity that comes about through trust in expertise that comes about through experience and belief in the possibility to reach consensus amongst a number of experts. As Timmermans and Berg (2003: 138) say: 'Disciplinary objectivity is associated with the valuation of tacit knowledge, with the artful application of insight that comes only with learned experience among peers, and with a disdain for standard solutions to complex problems'. Mechanical objectivity, on the other hand, is associated with 'following the rules', rules which are thought to ban personal biases and thus subjectivity and will lead to quantification and standardisation (Porter, 1995: 4). In the words of Sismondo (2004: 116) this kind of objectivity 'is a form of regulation that limits the discretion of knowledgeable experts'.

However, other literature (see also *Standards at Work*) suggests that protocols and standards are always interpreted to a certain extent. ANT opposes the simple deskilling-of-professionals account. Rather, their skills are redelegated. However, ANT is criticised by Timmermans and Berg (1997) for implying that 'as the central network-builder gains strength [the protocol designer], as the network tightens, the individual elements in the network are made increasingly docile'. We have seen in the previous section that Timmermans and Berg argue that non-docile elements are necessary for the functioning of protocols and standards. Opposing some of the previously mentioned interpretations of mechanical objectivity, they suggest that discretion is even necessary to make the protocols and standards work. Timmermans and Berg (ibid.: 292) imply that: 'by 'working to the rule', nurses can create total chaos; or by informing patients in the 'right' way, they can ensure that no patient gives permission for a certain research protocol to be used on them'. They argue that the contention that protocols and standards render skills and discretion superfluous and that people merely have to follow a cookbook does not hold. The protocol or standard is adjusted to the primary work task of the medical staff and is dealt with in terms of local specificities. In other words, protocols and standards can be regarded as boundary objects (Star and Griesemer, 1989). After this discussion on different interpretations of mechanical objectivity, I will now briefly explain Porter's main argument.

Wise (1995: 5) argues that an explanation for the 18th century shift towards measurement, precision, and quantification can be found in the 'requirements for regulating society and its activities [rather] than in the search for mathematical laws of nature'. Porter agrees and states that quantification did not simply become desirable for social and economic investigations because of the success it had in the natural sciences. He proclaims that the administrators who for instance measured population and registered births, marriages, and deaths brought 'a kind of objectivity-measurement that aspired to independence from local customs and local knowledge' (Porter, 1995: 22). However, to understand the move towards mechanical objectivity in more detail, we have to look at expert communities. Porter's main argument (ibid.: xi) is that the transition from expert judgement (disciplinary objectivity) to explicit decision criteria 'emerged as a strategy of impersonality in response to their exposure to pressures from outside'. It is therefore a transition that took place in 'weaker' professions and disciplines, that is, they suffered for example from internal disunity and permeable disciplinary boundaries.[29]

Porter has been criticised for being a postmodern romantic who believes that the quantifying mechanical objectivity is threatening and taking over the pre-modern trust (Forman, 1995, in Hagendijk, 1999: 632).[30] Hagendijk (1999) does not agree with this criticism. He argues that, although Porter has reservations about quantification and standardisation because substance and authenticity can be

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[29] Nowotny (2001: 167) argues the opposite: 'under contemporary conditions the more strongly contextualised a scientific field or research domain is, the more socially robust is the knowledge it is likely to produce'. In a case where I applied Porter's analysis to the historical development (1920-1970) at a district water board in the Netherlands (where indeed a shift towards standardisation and quantification took place), I learned that, although external pressures could be identified, the standardisation process was also influenced by the number of staff, number of measurement instruments, and financial situation of the district water board itself. Most importantly, there was one person who was very skilled in convincing people that research should be standardised. Others, who were either considered unsympathetic or too much of a scientist (that is, they lacked political skills) could not have achieved this.

[30] Forman, P. (1995). "Truth and Objectivity". *Science*, vol. 269: 707-10.

sacrificed in the process, he also mentions the liberating and emancipatory effects of these processes. Another criticism made is that Porter ties quantification too tightly to issues of trust, whereas quantification is much more about power and the control of economic and political élites (Fligstein, 1998, in Hagendijk, 1999: 634).[31] From this short discussion we can already see that the relationship between standardisation, trust, expertise, and objectivity is contested. Let us now focus a little more on the role of expertise.

Although Porter (1995: 5) acknowledges that 'mechanical objectivity can never be purely mechanical', for analytical reasons he treats them separately in his work. Timmermans and Berg (2003: 139) (and Berg et al. 2000: 785) however believe that Porter sees the two types of objectivity as 'exclusive categories' and state that guidelines, in some cases, can strengthen disciplinary objectivity instead of replacing this with mechanical objectivity:

> The authors and users of the guidelines actively created a space for the weighing of a broad array of diverse elements. The guidelines defined this activity as objective medical evaluation – to be performed and judges only by the qualified members of the profession of insurance physicians.

They stress that this was not a case where the guidelines left some space for interpretation of and deviation from the guidelines, which is common for most standards, and where they would still be part of the mechanical framework. Instead the guidelines actively created this space. After having complicated Porter's two categories, they add that Porter's two classifications of objectivity also prevent us from seeing other forms of objectivity. In the case of an insurance physician, they argue for instance that objectivity should mean being partial to the client and starting the decision-making process from the point of view of the client, rather than 'achieving equity and fair treatment through impartiality and an "impersonal" treatment' (ibid.: 140). Like Timmermans and Berg, Halffman (1998: 271) suggests that expert judgement is always necessary and that standardisation can therefore never be regarded as a purely technical process:

[31] Fligstein, N. (1998). "The Politics of Quantification". *Accounting, Organization, and Society*, vol. 23: 325-31.

> Even though an increasing number of effects and possible complications are now considered in formalized assessment schemes, these can never be complete.[32]

However, although nothing can ever be completely standardised, Jasanoff (1998: 179) explains the work of standards in terms of reducing the range of interpretations:

> Reducing the complexity of nature to universally, applicable, quantitative standards offers additional policy advantages, not least of which the possibility of ranking various bad events according to 'objective' criteria and distributing scarce resources accordingly.

According to her standards 'work' exactly because 'they provide valuable reassurance that risks are manageable'.

Halffman (1998) discusses standardisation explicitly as a trust device and argues that standardisation is a way for regulatory experts to trust other regulatory experts (trust among experts) as well as for others to trust regulatory experts (trust in experts). In and between laboratories standardisation can help to exchange data and so minimise the needs for testing (and therefore also minimise the costs and animal testing in the toxicity testing case Halffman writes about). Protocols, certification systems, and other forms of quality control help to regard test results as reliable and valid:

> The results of tests performed by commercial testing laboratories become more trustworthy to the assessors in regulatory agencies when the standardized procedures are used (Halffman, 1995: 269).

In the review of Jasanoff's study of the EPA we have seen that the division of labour between experts and political institutions has to be established and continuously maintained. It is therefore no surprise that Halffman (1995: 277) states that 'the way in which societies have organized this trust in experts differs widely between policy cultures'. Whereas the American system maintains trust in expert decision-making through procedural guarantees, the Dutch handling of pesticide assessment relied on

[32] Many other studies in STS have stressed the importance of tacit knowledge. See footnote 207.

an expert committee. Halffman uses the Dutch case as an example where a lack of trust emerged. Once the reputation of the experts came under attack, there were no ways to repair that trust. This is an example that could fit in with Porter's analysis. However, Jasanoff's study shows that under particular circumstances procedural guarantees are not sufficient and scientific expertise is needed to create trust in the regulatory decision-making. It can thus be claimed that Porter's analysis may work better for some countries and specific circumstances than for others.

2.2.6 Standards at work and 'working' standards

> *Much has been said about the development of standards, but very little has been written about what becomes of the standards once they have been developed.* (Naemura 1995: 93)

After negotiations with heterogeneous actors, standards with some universal appeal may have been constructed. In this section I will discuss what happens once standards are formulated and agreed on. It will not be surprising that standards, whether they are more or less universal, exist next to other standards, or are the dominant or the only one, have to be locally interpreted and negotiated in order to fit into a local socio-technical and political settings. First I will concentrate on literature from the fields of sociology, legal sociology, organisational sociology, political science, and STS (if these fields can be distinguished in a period in which disciplinary boundaries are blurring) to talk about the implementation of 'universal' standards in 'local' settings. I will argue that it can be more fruitful to study the role of standards in society by focusing on the way standards are mobilised and allow for being mobilised in different ways than by focusing on the concept of deviance (that is defined as non-conformity to a given rule). I will then explore the mobilisations of standards under the heading *Standards at Work.*

From Deviance to Mobilisation

One of the first studies on deviation in the execution of political decisions is a study by Pressman and Wildavsky (1979) (Torenvlied, 1996: 2). Before the 1970s these academic fields of political science and legal sociology focused more on the making of policy. Implementation of policy was seen as more or less unproblematic and self-evident. The mechanistic perception existed that if a certain policy or legislation was accepted the implementation of the legislation would follow naturally. Civil servants would always be docile executors. Pressman and Wildavsky (1979: xviii) challenged this view on implementation:

> People now appear to think that implementation should be easy; they are, therefore, upset when expected events do not occur or turn out badly. We would consider our effort a success if more people began with the understanding that implementation, under the best of circumstances, is exceedingly difficult. They would, therefore, be pleasantly surprised when a few good things really happened.

Now, as we have also seen in previous sections, it is widely recognised that many unforeseen (practical) problems have to be solved during the execution phase. Legislation or regulation is seldom implemented exactly in the way that was intended by the policy makers. However, the definition of implementation and of the exact problems that come with implementation differs within the fields of political science and legal science. Broadly speaking there are two ways of looking at implementation processes: a top-down and a bottom-up approach.[33]

Traditionally, top-down studies took the policy decision as their starting point and looked at how the goals of the policy makers were realised during the implementation process. The implementation process itself was often regarded as a neutral tool. There was a clear distinction between the policy makers who made the policy and the civil servants who simply executed the policy. General standards had to be applied uniformly to everyone, independent of their local situation. Implementation in this respect was considered successful if the results of the effort met the original intentions of the policy makers. Structural or procedural prescriptions were used to improve the effectiveness of implementation (Hanf and Downing, 1983: 1). Palumbo et al. (1981) criticised top-down approaches for making unrealistic presumptions about the legislative and administrative processes. It would suggest that decision-makers usually provide clear goals, while in reality the goals are often formulated in vague terms. In addition to that several studies have shown that implementation would almost never be successful in terms of a top-down approach since the legislation is seldom exactly implemented as the policy makers

[33] These two approaches are *Ideal Types*. In reality also many combinations of the two approaches are used.

intended. However, these top-down studies were common until Michael Lipsky published his book *Street-Level Bureaucracy. Dilemmas of the Individual in Public Services* in 1980.

With this publication and those of other authors that followed, the notion of implementation was problematised and an alternative to the top-down approach emerged. The alternative was a bottom-up approach in which implementation of regulation is bottom up where the implementation process itself is regarded as a form of policy making. According to Lipsky and his followers, successful implementation occurs in an 'evolutionary' way, that is, implementation is more than applying rules, it is part of policy making (Ringeling, 1986: 216). Policy and implementations can therefore not be treated separately. In the words of Palumbo et al (1981: ix-x):

> We now know that two of the assumptions of traditional public administration are incorrect. One is that policy is made by legislators and carried out by administrators, and the other is that the directives of top-level administrators should be carried out by lower-level people in the organization exactly as those at the top (...) intend. We have known for some time that administrators make policy. Also, we now know that policy is made by all parts of the hierarchy of administrative agencies, including street-level bureaucrats, not just by those at the top.

Consequently, the interaction between policy makers and policy executors should be studied. Lipsky was the first to study what he called 'street-level bureaucrats' instead of the role of organisations in implementation processes. The street-level bureaucrats were administrators in public services who had direct contact with individual clients. In order to be able to work with the legislation, they had to interpret it and make it suitable to particular situations (time schedules, individual clients). This is not unlike Timmermans and Berg (1997) who argued that protocols are adjusted to the primary work tasks of medical staff. Lipsky believed that street-level bureaucrats would form their own rules, routines and simplification if they had enough discretion. According to Jasanoff (1998: 180) discretionary space comes about automatically through the world where regulation applies: 'The unruliness of the real world creates discretionary space for individuals or institutions to exert their tacit knowledge and subjective moral sensibilities.' Lipsky (1980: 15) stressed the importance of discretion with the following words:

> Street-level bureaucrats work in situations that often require responses to the human dimensions of situations. They have discretion because the accepted definitions of their tasks call for sensitive observation and judgement, which are not reducible to programmed formats. (...) In short, to a degree the society seeks not only impartiality from its public agencies but also compassion for special circumstances and flexibility in dealing with them.

Legislation was thus considered successful if it was applicable to individual cases. Local (re)negotiation and translation were not automatically rejected. However, to what extent discretion was desirable was difficult to say. To determine successful implementation, people often fell back on the top-down approach:

> The degree to which the predicted consequences (...) take place we will call implementation. (Pressman and Wildavsky, 1979: xxi)

The then new ideas of Lipsky were highly valued but also subject to criticism. Lipsky did not pay enough attention to the fact that people might consider the given policy as unreasonable and are not willing to implement it as intended by policy makers. He was also accused of showing mainly negative aspects of the discretion civil servants have at their disposal, whereas a certain amount of discretion could also be considered positive (Palumbo et al, 1981: x). Harder (1981: 73) argues that discretion can lead to adjustments of regulation to local settings and that the delay that comes with this can be regarded as a positive feature:

> If it is assumed that successful implementation means *expeditious* implementation, then policies or programs that are administered intergovernmentally are likely candidates for any list of implementation failures. But if we accept the idea of *reinvention*, that is, changing a program so that it is adaptable to a local setting, and if we recognise that reinvention takes time, then delay may be perceived as the time it takes to negotiate the acceptance of a reinvented implementation plan. From this perspective, delay and the controversies that may attend it make the label of implementation failure inappropriate. A delay that is once perceived as dysfunctional may

now be perceived as a characteristic of the process of reinvention or, in other words, the process of policy or program formulation.

Considering implementation 'successful' when regulation, a protocol, a standard is dealt with in the way the policy makers or standard-setters intended, is problematic. We have seen that the construction of standards and regulation is a heterogeneous process in which many actors, –who may have (slightly) different intentions– are involved. The outcome of the process may be a standard or a protocol that has been negotiated extensively. Negotiations however do not have to lead to agreement on the total protocol. It may well be that actors give in at one place to achieve something at another. However, even if consensus has been formed, it may not be possible to know the intentions of the makers of the standard. Standards and protocols do not speak for themselves but have to be interpreted and adjusted to the local situation.

Sociological studies have focused on deviance as non-conformity to a given norm or a set of norms rather than as deviance from the intention of a policy maker. This notion of deviance is worth a small detour. The studies define norms as

> Socially accepted 'correct' or 'proper' forms of behaviour. Norms either prescribe given types of behaviour or forbid them. (Bilton, 2002: 10)

Unlike regulations, these norms are not externally imposed, but exist in the interaction between different (groups of) people. However, like regulations and (some) regulatory standards they identify some kinds of behaviour as appropriate and some kinds as inappropriate and help to achieve and maintain social order. Although the precise emergence and role of norms and deviance has been subject to debate in sociology, I think it is important to note that most sociological theories explain what deviance is by referring to the social institutions of a society.[34] Biological studies that

[34] Parsons (1939) for example, argues that people internalise norms through socialisation which in turn determine their perceptions, their reasoning amongst alternative course of action, and their choices. Garfinkel (1967) on the other hand argues that norms are not only regulative, but also constitutive of behaviour. It is by means of norms that people can make sense of other people's actions. These different interpretations of norms also have consequences for the notion of deviance. A 'deviant' person in Parsons' theory is someone who has not internalised the norms and is likely to be punished by his/her environment. According to Garfinkel, people interpret other people's actions regardless of their intentions, which means that behaviour is always meaningful. Whether behaviour is regarded as deviant therefore depends on how other actor's interpret the behaviour. Merton claimed that the scientific community works according to a 'scientific ethos', a set of prescribed norms that consist of: universalism, communality/communism, organised scepticism, and

explain deviance by pointing to for example peculiarities in brains of criminals, psychological studies that associate deviant behaviour with particular types of personality, and more traditional political science studies that explain deviance by referring to intentions of policy makers, seem to adopt a relatively unproblematic and stable concept of deviance (Giddens, 1989: 123-127). Some sociological studies on the other hand see the notion of deviance as something that needs to be explained. Since norms vary between different cultures, and between differing sub-cultures within the same society, what is normal in one cultural setting is deviant in another. One of the, according to Giddens (ibid.), most important sociological theories, the so-called labelling theory, interprets deviance therefore not as a set of characteristics of individuals or groups, but as a process of interaction between deviants and non-deviants. This notion of deviance as interaction between deviants and non-deviants in which notions of deviance can vary between different groups can be a useful device to avoid having to regard deviance only with respect to the intention of policy-makers and I will return to it in the methodology section. Yet, according to Giddens (ibid.), different notions of deviance of various social groups do not all have the same influence. Often one notion of deviance becomes dominant due to political and legal power:

> Those who represent the forces of law and order, or are able to impose definitions of conventional morality upon others, provide the main sources of labelling. (ibid.: 129)[35]

The studies mentioned above remind us that implementation is not a straightforward matter. Instead, regulations are often renegotiated during implementation. Studies in STS have demonstrated similar processes with regard to the implementation of artefacts, facts, and technical and scientific standards.[36] In these studies the meaning of an artefact, fact, or standard does not (solely) lie in the intention of the maker of

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disinterestedness. However, Mulkay (1979) argued that it was more plausible to interpret norms as a repertoire of claims that scientists use quite variably, as contexts change, in order to justify their particular behaviour.

[35] It has to be noted that, although I will not be able to pay explicit attention to informal norms and sanctions in the water industry, these may nevertheless play part in maintaining social order and water quality: 'Although formal sanctions are usually more dramatic and visible than informal ones, informal sanctions are of fundamental importance in ensuring conformity to norms. Wanting to secure the approval of family, friends and colleagues, or wishing to avoid being ridiculed, shamed or rejected, often influences people's behaviour more than formal rewards or punishments' (Giddens, 1989: 121).

the 'product', even though the product was produced for what the maker thought of as the ideal user and it may be accompanied by manuals that try to enforce this 'script'. Instead, they acquire their meanings in the heterogeneity of social interactions. In the words of Akrich (1994: 222):

> It is only when the script set out by the designer is acted out – whether in conformity with the intentions of the designer or not – that an integrated network of technical objects and (human and nonhuman) actors is stabilized.

Berg and Timmermans (2000) describe medical protocols as technoscientific scripts. They ask what ideal practice the tool presupposes and the authors of the protocols had in mind. These protocols, which contain instructions that should be followed step-by-step and are also decision-making tools ('in situation X, do A') aim, as we have seen in a previous section, at creating uniformity and standardisation to ensure that patients are judged in similar ways regardless of the local context. However, the order the protocol desires, becomes a clearly visible disorder when the instructions are disobeyed or a prescribed sequence is disturbed.

The notion of script can be a useful device for studying standards and protocols, that is, if the intentions of the policy makers or technology designers can be known. However, like the other studies above, it also implies the notion of deviance. Deviance is, as we have seen, not a straightforward concept. Yet, by stressing (the negative) deviance as opposed to (positive) compliance, it limits an understanding of the multiplicity of ways in which people can deal with standards. They do not either deviate or comply; instead standards are mobilised for a wide variety of purposes. I would therefore like to add the notion of mobilisation to prevent getting caught up in an interpretation of a practice around standards as either deviance or compliance. This is however not to say that we have to get rid of the notion of deviance. Deviance can be a useful device for indeed determining when people regard other people (or material, as we will see in the next section) as non-compliant and believe (formal or informal) sanctioning is in place. I will further discuss the concept of deviance in relation to power structures in *Methodology or How Water Quality can be of Help*.

[36] See for example Lie and Sørensen (1996).

Standards at Work or Dealing with the Specific

Just as the world has to be turned into a laboratory in order for standards to become universal, standards have to become universalised locals in order to function in specific situations. It has been widely recognised that standards differ between policy cultures and that 'local variations in politics and practice can bring contingency back into the implementation of standards' (Jasanoff, 1998: 180). Variations may exist in knowledge, training, resources, technical skills, and supervision of implementing bodies. This causes standards 'to wear increasingly thin as they are stretched to cover worlds of perceptual divergence' (ibid.: 190). Others acknowledge this as well. Repussard (1995: 63) therefore argues that standards have to be adjusted to their local or national environments:

> Standardization has to be looked at as a reflection of the organization of society in a given country. In this light, we must consider whether the status of standardization is coherent with the overall organization of a society at a given moment in time. This is why, for example, it can be dangerous to promote in eastern European countries a particular model which has proven successful in a different kind of society. Standards are best set and used in the context of a national system that is well integrated into the mainstream organization of a society and economy.

Berg and Timmermans (2000) would regard this perhaps as the creation of different or multiple universalities for different parts of Europe. Repussard is not alone in wanting to change some of the attempts to achieve standardisation. Salter (1988) reviews the debate in which it is argued that regulatory standards should be replaced by guidelines set by voluntary or consensus bodies or by codes of good practice. One of the arguments is that voluntary standards as opposed to regulatory standards can be enforced because no one would set standards they were not willing to comply with. Majone (1984) is an active proponent of this proposal and argues that standard setters deal with highly heterogeneous and uncertain situations in which standards should be revised as soon as new scientific information becomes available. He argues in addition that guidelines could focus only on safety, health, and environmental quality, whereas legally enforceable standards are policy tools and must therefore include considerations of costs and benefits. Jordan (2003) picks up on this discussion and investigates whether there really is a shift from government to governance as many people claim.[37] This discussion is interesting, but not relevant for my purposes here.

In this section I will discuss what happens to standards once they have been set. Above I suggested the notion of mobilisation to help us make sense of the adjustments of standards to their local situations. Also Timmermans and Berg (2003) argue that standards should not solely be studied in the regulatory-political environment from which they emerge. They (ibid.: 22) state that:

> Standards are inherently political because their construction and application transform the practices in which they become embedded. They change positions of actors: altering relations of accountability, emphasizing or deemphasizing pre-existing hierarchies, changing expectations of patients.[38]

If we focus on standards without explicitly taking into account how they came into existence, but drawing on the notion that standards are inherently political because of the process of standard setting, the notions of script, discretion, and deviance are not of much value. Instead, we can concentrate on the ways in which these standards are mobilised and therefore transform practices. Schmidt and Werle (1998: 41-41) noted how standards 'influence technology by coordinating its production, its operation, and its use, and they are themselves shaped by technology'. As we have seen in previous sections, standards can be mobilised and thus allow for being mobilised in many different ways (we will come back to the issue of resistance to mobilisation later). I have provided a number of them in Table 2.2.

Table 2.2: Possible mobilisations of standards

Reduce	Costs	Negative externalities	Uncertainties	Complexity
Reduce/Increase		Competition		
Increase	Objectivity	Trust	Efficiency	Discipline
	Coordination	Order	Legitimacy	Compatibility

Timmermans and Berg (1997) mention a few of the ways in which a resuscitation protocol can be 'mobilised', some of which have already been mentioned in a

[37] For more information on this and alternative policy instruments, see special issue of Jordan (2003).

previous section. This protocol sets out what needs to be done, when, by whom, and in what order. Like other protocols it standardises a set of practices, actors, and situations. They argue that only by looking at how these protocols are used, can one analyse how they change pre-existing practices. In principle, nurses should always start a resuscitative effort until an emergency physician arrives and takes over the decision making. However, nurses admit that in hopeless cases they may ignore the protocol, although this also depends on the physician on duty. Here the protocol is simply disregarded or resisted. The choice of whether or not to resuscitate depends however not only on whether the person still has a chance or not, but also on the emergency physician on duty. We can start to see that the interpretation of a protocol can become complicated and is context-bound. One physician mentioned how she switches between protocols when the situation of the patient gets worse or better.[39] We have already seen that standards always operate in a specific situation. In addition, it is important to note that standards often, if not always, operate in a context of other standards. In the words of Bowker and Star (2000: 38):

> Although it is possible to pull out a single classification scheme or standard for reference purposes, in reality none of them stand alone.

I will come back to this in *Methodology or How Water Quality can be of Help.*

Another example Timmermans and Berg mention is that nurses often take more control than they would have according to the protocol: they can hint that resuscitation will not help in a particular case or that alternative treatments are needed, for instance when the person is a drug addict. Although the protocol should work for every person, the individual always has to be taken into consideration. A third example is that often a drug is given in resuscitation efforts of which the effects cannot be explained and which is not mentioned in the protocols. So far, the examples have illustrated that people indeed do deviate from the protocol: not using it, adding to it, adjusting it. However, it can also be mobilised, that is used as a resource in very specific ways. A protocol can, for instance, be a means to obtain drugs free of charge. It can also be used to create a place where someone who cannot be helped can be sent in order to delay the final verdict. In a similar fashion it can

[38] See Winner (1996) [1985] on the politics of artefacts.

[39] Lock (2002) illustrates that also people working in intensive care units switch between protocols to deal with practical situations.

delay death to give family members a chance to say goodbye, whereas the protocol was originally meant to save lives.

To conclude, there are many other ways in which protocols and standards can be mobilised, depending on the standard and the situation in which it is used. However, it is often assumed that the mobilisation of standards, just as their interpretative flexibility, is unlimited. However, in the previous sections one important aspect of standards has been overlooked, an aspect that may hint at possibilities to talk about resistance and the way in which mobilisations and interpretative flexibility are restricted.

2.2.7 Materiality debated

The sociological studies mentioned in the previous section remind us that the regulations and norms do not operate in a vacuum. However, they do not only operate in environments of various social norms and local cultures, but also in material and built environments. Neither do they always regulate people's behaviour. In some cases, standards have been set to regulate material. Compatibility standards regulate how different materials interact and many regulatory standards regulate the quality of material (food, air, water). This can have consequences for the notion of deviation, since it may not be deviating action that is sanctioned as it is in social norms, but action that has not been undertaken to prevent deviation of the material (deviation by omission). It is important to note that in these cases there is no direct relationship between the material being regulated and the regulation. Instead, there often is an in-between agency that will have to act in order to make the material comply. The material cannot be expected to comply by itself. In making the material comply, the material environment plays a significant role since often much of the work is delegated to measurement instruments, purification instruments and so on.

Only a limited number of cases mentioned in this literature review have paid attention to the role of materiality with regard to standards and standardisation. Yearley (1995) talks about interactive physical phenomena and quantities that are difficult to measure and Bowker and Star (2000: 39) speak about how standards are both symbolic and material and therefore also have a material force in the world:

> All classification and standardization schemes are a mixture of physical entities, such as paper forms, plugs, or software instructions encoded in

silicon, and conventional arrangements such as speed and rhythm, dimension, and how specifications are implemented.

Yet, neither of these studies has addressed the role of materiality in detail and discussed the way in which this can be studied. If standards are material and/or govern materiality as in the case of quality standards, what is this something we call materiality? Does this something have an essence or essential properties? Does concentrating on materiality presuppose a realist basis, a world out there? Or should we regard materiality as a social construct? The debate about these epistemological and/or ontological questions originated over 2000 years ago. These questions are still discussed within STS –sociological, political science, and economic literature rarely address the question of materiality– but it has become a debate between different versions of social constructivism rather than a debate between realism and constructivism. Social constructivism, a sort of container concept for different approaches to science and technology with a similar theoretical basis, is widely accepted as the (only) starting point for all studies within this field. Social constructivism has been a very fruitful approach for studying science and technology and offered important insights. However, I agree with Ian Hacking (1999: vii) who says after recognising that social construction has in many contexts been a truly liberating idea and has liberated some, that it 'has made all too many others smug, comfortable, and trendy in ways that have become merely orthodox. The phrase has become code.' In addition, Hacking (ibid.) argues the debate has led to what he calls a 'a painful schism': the situation in which historians, philosophers and sociologists are divided about this question and won't talk to each other because one side 'is so contentiously "constructionist" while the other is so dismissive of the idea'. Hacking (ibid.) proceeds: 'You almost forget that there are issues to discuss'. But there are issues to discuss, important and interesting issues about, amongst others, the role of materiality with regard to standards and the (non)mobilisation of standards. Discussions take place in language and although language is not the main focal point of this dissertation, it requires some attention, attention that is exactly focussed on this realist-constructivist debate. A short overview of the debate in which different people with different opinions and worldviews talk with each other is necessary before proceeding to distil a theoretical toolkit that will help me to gather and analyse my data.[40]

Realists, although very few people call themselves realists these days, claim that science can and sometimes does deliver true explanations of inquiry-independent phenomena.[41] Constructivists, on the other hand, suggest that we can never know the world 'out there' as it is, because it is always mediated by perceptions, instruments, and language: 'Facts neither speak for themselves nor exist independently of some agency which constructs them' (Grint and Woolgar, 1997: 10). This has led to a debate about the very existence of the world out there. Klee (1997: 168) for instance would consider Grint and Woolgar's statement absurd because that would 'imply that the *existence* of viruses *depends* on such artificial equipment and such elaborate detection procedures. If such procedures and equipment did not exist, *then viruses would not exist*'. Radder (1992: 156) responds in a similar way to constructivism. He argues that if constructivism is taken seriously, it would mean that if the discourse about the hole in the ozone layer ceased, then 'the hole would simply disappear at the very moment we stopped discoursing about it'. Searle (1995: 190-191) attempts to demonstrate that a reality exists independently from social constructions by arguing that the construction has to be constructed out of something:

> To construct money, property, and language, for example, there have to be the raw materials of bits of metals, paper, land, sounds, and marks. And the raw materials cannot in turn be socially constructed without presupposing

[40] I would like to add a (methodological) comment here. Originally this section of materiality was written in the form of a dialogue or theatre play between the different players in the field of epistemology and ontology. The active dialogue would help me not only to explore what people have said, but also where they stop responding to each other. Some liked the format of the text, whereas others strongly disliked it. In the end I decided to follow the advice to write a more 'conventional' text, because of the expectations associated with this sort of chapter. I am afraid this is exactly what Hacking criticises about the phrase social constructivism. I now follow the 'standard' format, because it may give me more chance to pass the PhD and stay in academia, but at the same time, standards like this may prevent innovative or just different and alternative formats. This is not (just) meant as some clever, reflexive remark, but expresses a real concern, a concern that also Weingart has expressed. Weingart explores how the norms and standards that count in publishing prevent innovative research. For instance, people have to publish as much as they can (or more than others) in order to be able to stay within academia. They are therefore more likely to present articles that fit in exactly with the existing format, their ideas will be phrased in terms that are widely accepted (like social constructivism), and they are likely to make changes to the texts as the editors require, even if this means adding (unnecessary) references to articles from previous issues of the same journal to raise this journal's status.

[41] Of course, the term realism, like constructivism, has many different varieties. I am generalising here.

some even rawer materials out of which they are constructed, until eventually we reach a bedrock of brute physical phenomena independent of all representations. The ontological subjectivity of the socially constructed reality requires an ontologically objective reality out of which it is constructed.

However, most –if not all– constructivists do not deny that there is an outside world; they are, what Knorr Cetina (in Callebaut, 1993: 183) calls, ontological realists. When Latour (1999: 1) was asked whether he believed in reality, he answered: 'But of course! What a question! Is reality something we have to believe in?' Some are also teleological realists, that is, they believe that the purpose of science is to get a better picture of nature. They only dispute that it is possible to know (epistemological realism) 'the' practice- and theory-independent world, because this material world is filtered through with 'socially sanctioned metaphors' (Bloor in Klee, 1997: 159).[42] They can therefore not be considered as anti-realists, in Wynne's (2002: 462) words:

> Physical reality still courses through these contending and overtly less determinate representations and meanings, but different versions of reality are not only competing in the sense of claiming or denying the reality of an element of nature. They may also be making conflicting claims that a real element is more salient once one gives the issue a particular meaning. The same natural reality thus shows up differently, depending on the intersections it is given with human questions and commitments.

The world as we know it is therefore a consequence rather than a cause of what goes on in science (Knorr Cetina, in Callebaut, 1993: 180). Knorr Cetina then argues that it is exactly what goes on in science and the accounts that science produces that should be (and for many people is) the focus of interest, rather than the relationship between science and the world out there. Also Grint and Woolgar (1997: 145-146) try to get away from the ontological question of what is true or not true and ask instead the epistemological question of how we know that something is true. This is why Hacking (1999: 61) claims that constructivism is a metaphysical position, which

[42] Bloor, D. (1991). *Knowledge and social imagery*. [2nd edn]. Chicago: University of Chicago Press.

is not related to either realism or anti-realism, because it is indifferent to ontological questions.

So far, the debate and the different positions seem relatively clear. However, there are two issues I will explore in more detail below. The first one deals with the question of whether 'being shot' can be seen as a social construction and shows how significant the debate can be in political terms since each position taken will lead to different possible actions. Secondly, I will look more closely at the role of the material in the debate by discussing whether material can resist certain scientific practices.

Grint and Woolgar (1997) argue that 'being shot' is a social construction. This has led to quite a heated debate in the STS field about whether objects or artefacts have (known) essential properties. Kling (1992) was Grint and Woolgar's main opponent in the debate. He argues that one cannot simply list the fixed capacities of a gun and the styles of use that accompany the capacities (it can be a trophy, a totem, a shooting weapon, a hitting weapon, etc.). Yet, one can say that it has capacities that other weapons (knives, hands) do not have. A gun can tear flesh and splinter bone from a distance, which would probably be impossible with the other mentioned weapons. Again, Grint and Woolgar (1992: 376) do not deny that a bullet can tear flesh. They argue however that we can only know that the bullet made the hole through a series of social (re)constructions. When the construction is successful, it seems as if the construction stems from the event, rather than vice versa. Technology thus does not have objective effects. They use another example to clarify their position. In this case some experts (representing the inhabitants) claimed that a town's water supply was poisoned with aluminium. Water authority experts contested this. I will leave it to Grint and Woolgar (1997: 33) to tell how the dispute ended:

> In this case, the 'truth' is the upshot of a judge's assessment of the relative merits of the competing accounts. Whether the judge was an 'expert' in water pollution is both doubtful and probably irrelevant. The court pronounced in favour of the water authority. So the 'truth' became the version advanced by the winning experts; the 'truth' did not leap out of the water and cry 'foul'.

Kling notes that both parties in the debate agree about the importance of social mediation between technologies and effects. Yet, he comments that Grint and

Woolgar's approach makes it impossible 'to make strong claims about the consequences of using specific technologies in specific social worlds' (Kling, 1992: 382). In his eyes, they seem to deny that physical objects like guns and roses have some capabilities that are not arbitrarily derived from the talk about them. He argues that it should be possible to say that 'it is much harder to kill a platoon of soldiers with a dozen roses than with well-placed high-speed bullets' (Kling, 1992: 362). Grint and Woolgar then seem to regard Kling as an essentialist who believes that artefacts have technical cores with specific properties that are independent from the social. Searle (1995: 164) provides a good example of this:

> Take a corner of the world, say, the Himalayas, and think of it as it was prior to the existence of any human beings. Now imagine that humans come along and represent the facts in various different ways. They have different vocabularies, different systems for making maps, different ways of counting one mountain, two mountains, the same mountain, etc. Next, imagine that eventually the humans all cease to exist. Now what happens to the existence of the Himalayas and all the facts about the Himalayas in the course of these vicissitudes? Absolutely nothing. Different descriptions of facts, objects, etc. came and went, but the facts, objects, etc., remained unaffected.

Grint and Woolgar however argue that the social and technical (or natural as in the above example) can never be separated. They would not talk about the Himalayas before humans existed, because we can only know about the Himalayas when humans are around and when they are around there cannot be a separation between the social and the natural. They (1997: 161) argue that even if the gun goes off and the bullet hits someone, its precise effects are still subject to interpretation: was it one bullet or two, can we save the victim or not? So, the bullet cannot be said to have an effect that is objective or on which everyone agrees. Therefore they deny the existence of a technical core of a gun.

This debate can be extended endlessly which I do not intend to do. However, I do think it might be important to add that for instance Bijker (1995) would argue that social groups will reach some form of closure and thus agreement at some moment and assume that there is a technological core, that is, they agree on the impact of the bullet. This may be contested again, but it means that he would not agree that every case would have to be investigated totally anew, because at some point in time ideas about technological cores may be more open or closed. Callon (1991) and Latour (1987) may add that actants operate in a network which defines who they are and what they do and whether they are categorised as social or technical. These networks may stabilise and become inscribed in material forms which may make it difficult to reopen them.

This example has made the debate more complicated. Both parties would consider themselves constructivists and yet one seems to take a more realist position. Table 2.3 is an attempt to illustrate the ideal-type positions of both realists and constructivists. It cannot take the more complicated picture into account.

Table 2.3: Constructivists and realists between epistemology and ontology

	Ontologically Subjective		**Ontologically Objective (Ontological Rawness)**	
	Constructivists	*Realists*	*Constructivists*	*Realists*
Epistemologically Subjective	Crime	X	Mount Everest	Disease
Epistemologically Objective	Marriage Money	Nutrition	X	Mount Everest DNA Being shot

The debate has not only become more complicated, it has also become clear that the different positions in the debate point to different ideas about what we can say about reality. Rosen (1998: 214) argues that Grint and Woolgar's work 'offers no way beyond a solely analytical engagement with political issues':

> Grint and Woolgar's problem is that they apparently believe their intellectual position would be compromised were they to take a definite stand on an issue such as gun control. Rather than adopt, for example, a precautionary position that sees gun control (...) as a good idea despite the uncertainty of scientific and technical knowledge, they prefer merely to deconstruct that knowledge – being careful, of course, to deconstruct the knowledge of both pro- and anti-gun control camps.[43]

[43] Jasanoff (1998: 183-184) argues that the slogan 'guns don't kill people, people kill people' is successful because of the assumption that risk originates in the inanimate world. 'Both regulators and the public know, of course, that this is only a simplifying assumption; yet it is an acceptable simplification because it serves modern society's need for control and social order. It is, after all, easier to manage inanimate things (and the impersonal corporations that produce them) than animate people, even when people are known to be part of the problem one wishes to control.'

We have just seen that the 'material' is debated and cannot simply be ascribed certain essential properties without taking part in this debate. I would now like to talk a bit more about the (contested) role of the material, more specifically about the material as agency.

From the above it may have become clear that Grint and Woolgar would not talk about a kind of material agency because that would imply the essentialist –or technological determinist– assumption of a technological core in which the intrinsic properties of the technology can be found.[44] They do not deny that for instance material artefacts can have constraining influences upon actors, but they contest that these constraints can be known without human interpretation: 'there can be no *self-evident* or *transparent* account of such 'material constraints' (Grint and Woolgar, 1997: 23-24). When they treat technologies as text they argue that constraints have to do with the organisation of the text: not all readings are possible. However, unfortunately, they do not further clarify their view of constraining influences to interpretation. Instead, they mention once again that we have to look at accounts of technological capacity and explore why some are more convincing than others.

Their position makes it clear that it is important to review the different possible positions on materiality, because they all have different implications. I find Grint and Woolgar's a very coherent perspective and therefore straightforward to defend, but believe it fails to take materiality –as we encounter it– into consideration. Reducing materiality to accounts does not do justice to the role of materiality: it is after all not an account, but 'nature' which Klee (1997: 77) sees as 'push[ing] back against our theorizing'. He argues that 'if a hypothesis fails to do the work for us that we want it to do, that is a rational ground for becoming suspicious that the hypothesis might be barking up the wrong tree, ontologically speaking' (Klee, 1997: 77). A discussion between Knorr Cetina and Giere clarifies the point. Giere (in Callebaut, 1993: 182) would agree with Klee that the work in laboratories consists of a process of '*active interaction*' with the world. Knorr Cetina then explains that laboratory studies have shown that there is no nature in the laboratory. One can only find

[44] Hacking (1999: 17) warns that essentialism is not a purely descriptive notion: 'most people who use it use it as a slur word, intended to put down the opposition. I cannot recall anyone standing up and saying, "I am an essentialist". He applies this to race in the quote, but it is just as valid for technological determinism.

'highly *preconstructed* products' like substances which have been purified, animals which have been specially bred, instruments, etc. (Knorr Cetina in Callebaut, 1993: 182). Scientists therefore do not interact with the world directly but with what other scientists have said about the world. Giere (in Callebaut, 1993: 184) responds to Knorr Cetina by asking what the purpose is of all instruments in a laboratory if it is not to interact with nature:

> On the constructivist view it *seems* as if maybe one could just get rid of all this machinery and just have the scientists in the laboratory interacting and talking with one another and writing articles for one another, and reading other people's articles and thereby constructing science. I mean, they could do it without machinery. One could wonder, why do they need all this machinery? What is it doing there if it is not serving as what they would call their "probe of reality", to put it in those slightly grandiose terms?

Knorr Cetina (in Callebaut, 1993: 184) acknowledges that the material world 'out there' offers resistance when humans act on it: 'we can't just do everything with it'. However, these resistances have to be interpreted and 'at the very moment you interpret them, you enter the realm of the social world, you enter the thoughts of previous scientists, of your colleagues in the field, of what you think yourself' (Knorr Cetina in Callebaut, 1993: 185). Whereas Giere wants to believe there is a point at which one can say that scientists now have a part of reality right, that is in some respects and to some degrees, Knorr Cetina argues that one can have technological success without assuming that you have a true picture of the world. It has been shown that what has been seen as 'real' or 'true' can be overturned years later.[45]

Both Giere and Knorr Cetina believe in material resistances; it is the way one can talk about them that is contested. In Grint and Woolgar's approach they can only be debated in terms of human accounts. However, as I said before, this does not do justice to the role of materiality in my eyes. Yet, I also realise that I may find myself in a difficult position by moving away from this strong constructivist and post-

[45] An example of how material resistance can be interpreted is the 'discovery' of the hole in the ozone layer. Joseph Farman et al. (1985) made the 'discovery', but was at first not heard since for example NASA questioned whether Farman's elderly equipment was accurate. NASA's own sophisticated technology showed nothing unusual. It turned out that NASA had decided to ignore the very high and very low values for the moment. Yet, by trying to obtain accurate results they had stopped themselves from finding it, because it was in these very high and low values that Farman found evidence for a 'hole' in the ozone layer.

essentialist approach, because it assumes a tendency to the realist side of the debate or at least a combination of realist and constructivist approaches. In the words of Rappert (2003: 571): 'Trying to adopt a middle ground between relativist and realist positions (...) is tension-ridden because one must struggle against making definitive statements while taking certain things for granted'. This is problematic for two reasons. First, I do not think I am a pure 'realist'. I have been educated in and part of 'constructivist environments' for about ten years now and have acquired a constructivist view in the sense that the world to me *is* constructed. Secondly and most importantly, both constructivist and realist approaches are defendable on their own, but once one tries to combine the approaches, chances are that the 'middle way' is not coherent and logical. Latour and other ANT proponents have tried to find a way out of this by dissolving the distinction between realism and constructivism.

Latour argues that approaches like Grint and Woolgar's actually do make a distinction between the technical and the social. In these approaches it is possible to talk about the social, but not about the technical without the social: 'it does not give the non-human's action, it only defines the rhetoric of humans about non-humans' (Latour in Callebaut, 1993: 116). And, he argues, 'to explain science without taking into account the nonhumans is a complete absurdity' (Latour in Callebaut, 1993: 124-125). However, he does not take the side of the nonhumans over the humans. Rather, he argues that what counts as material and social, human and nonhuman, is itself a social construction. Both humans and non-humans are defined relationally in the network in which they operate: their identities and qualities are only defined in relation to and in negotiations with other humans and non-humans in the network. Collins and Yearley (1992) worry that when one does not focus on the accounts scientists provide of material agency and that should be analysed sociologically as the products of human agents, but instead takes material agency seriously, STS scholars lose their authority to the scientists. Callon and Latour (1992) then respond that they use symmetry between humans and nonhumans as a methodological heuristic. They regard the agencies they talk about as semiotic ones, that is that agents in texts can easily transfer between being real entities and social constructs and back again.

Like Pickering, I value ANT over the post-essentialist approach of Grint and Woolgar because 'its acknowledgement of material agency can help us to escape from the spell of representation' (Pickering, 1995: 13). Humans and nonhuman agency are not reduced to each other, but associated with each other in a network in which both are constitutive of science. Pickering therefore criticises Callon and Latour's appeal to semiotics as looking 'like a kind of retreat, a return to the world of texts and representations that one does not wish to make' (Pickering, 1995: 13). He proposes instead to take material agency seriously, because things like winds, storms, and floods are agencies that come at us from outside the human realm and cannot be reduced to anything within this realm.[46] Just as humans are *coping* with material agency in their everyday life, so are science and technology. This is not to say that material agency cannot be interpreted in different ways or that we can know it as it is. Instead, Pickering argues that the contours of material agency are never decisively known in advance; scientists have a continuous job to try 'tuning' into the material agency. Material agency can then be *temporally emergent* in practice. In this process of 'tuning', both the material contours of new machines and human skills and gestures have to be found out in the real time of practice. Whereas ANT sees humans and nonhumans as symmetric and interchangeable, Pickering argues that humans cannot be substituted for machines, especially since humans have intentions, goals, and plans that have to be taken into account. These intentions and possible futures are intertwined with existing ideas and scientific results and can also be changed by tuning. Therefore, 'the world of intentionality is (...) constitutively engaged with the world of material agency, even if the one cannot be substituted for the other' (Pickering, 1995: 20). Material agency comes to the fore as resistances that are relative to the material-conceptual alignments needed to produce facts. Pickering (ibid.: xi) explains that success and failure can be seen as *accommodations* of resistance and that 'this temporal structuring of practice as a dialectic of resistance and accommodation' is what he calls the mangle of practice in which the focus lies on the intertwinement and recriprocal interdefinition of human and material agency. This means that Pickering's approach allows for exploring how connections between knowledge and the world are made in practice, not by focusing on correspondence between knowledge and the world, but in terms of performativity.

In conclusion, I will shortly summarise the different positions in this materiality debate in Table 2.4.

[46] Michael (2000) takes in some ways a position on materiality similar to Pickering's. He focuses on how culture, technology, and nature interweave and create new hybrids. According to him, it is these hybrids that need to be studied.

Table 2.4: Different Positions in the Materiality Debate

Correspondence theory	The world is out there and our science reflects that. This is often defined as *realism*. Science is trying to and will come closer to the truth in time. No one will take it as unproblematic as this, but Klee and Giere are people that represent this position.
Sociology of Scientific Knowledge (SSK)	The world is out there, but is so filtered through "socially sanctioned metaphors" that it is unknowable as it is. Scientific theories are therefore not significantly affected by the reality out there. Bloor and Yearley represent this position.
Anti-essentialism or *post-essentialism*	Technical artefacts are fruitfully understood as texts that are embedded in, and at the same time constitute, their interpretative contexts. Hence, what a machine is, what it will do, what its effects will be, are the upshot of specific readings of the text rather than arising directly from the essence of an unmediated or self-explanatory technology. Grint and Woolgar represent anti-essentialism.
Social Construction of Technology (SCOT)	Different social groups have competing versions of an artefact. This interpretative flexibility often decreases when the technology is further developed and one version will stabilise. We should really talk about socio-technical ensembles, because the technical and the social cannot be distinguished. This view is represented by Bijker.
Actor-Network Theory (ANT)	Rather than saying that all we can say about science and technology is how we know them, ANT claims that how we define the social and the technical, objective and subjective, human and nonhuman, are consequences of negotiations processes that take place in networks. Humans and nonhumans should be treated the same. Callon and Latour represent this approach.
The Mangle of Practice	Human and nonhuman (material) agency, cannot be reduced to each other as in ANT, but operate together in a network where both material and human agency can become temporally emergent in a 'dance of agency'. The dialectic between resistance to material-conceptual alignments and accommodation of certain alignments is central. Pickering represents the Mangle of Practice.

We have seen that the discussion about materiality is complex. Every position in the debate allows for certain interpretations and makes others impossible. It is therefore important to consider the different positions in light of what it is one wants to explore.

2.3 *Methodology or How Water Quality can be of Help*

The literature review has identified a number of areas that are problematic, heavily contested, or need further exploration. In the research design I will discuss these areas further in light of the field in which this dissertation takes place: water quality. This will lead to the formulation of the (sometimes overlapping) research questions that will be addressed. From this, a theoretical toolkit that can be used to explore the research questions will follow.

2.3.1 Research design

The field of drinking water quality, which forms the empirical field for this dissertation, is a site *par excellence* to address a number of the issues mentioned above.

Drinking water quality is heavily regulated. Standards developed by the European Commission and implemented by national governments govern the quality of drinking water. I will explain these regulations in detail in chapter 5, but for now it is important to note that these 'regulatory' or 'social' standards are the main focus of the thesis, although, as we have seen, they operate in an environment of other standards: design standards (or technical standards, ISO), terminological standards (what does it mean to provide water 'unfit for human consumption'), procedural standards, and customer service standards.

The standards shape and are shaped by notions of good water quality, good analysis, and valuable treatment technologies. They operate not only in an environment of other standards, but also in an environment where regulators, water consumers, chemists, microbiologists, pipelines, treatment plants, measurement instruments, alarms, and laboratories have to work together to make the mobilisation and functioning of the standards possible. Since ANT has mainly (though not solely) focused on the construction of networks as if they originated in a new space without pre-existing infrastructures, it has left out important questions about negotiations with existing infrastructure. In the words of Kleinman (2003: 59-60): 'emphasis on construction turns our gaze away from the effects of the already existing attributes of the world in which science is produced'. Standards, according to Timmermans and Berg (1997), operate in settings that are pre-structured by other standards, practices and infrastructures. They argue that standards may attempt to change and replace these practices, but will also need to incorporate and extend the existing routines.

Both the social and material environment in which standards are put to use are therefore important to understand how standards work. Water quality standards operate in a socio-material environment *and* govern materiality. This allows me to explore the relationship between standards, standardisation processes and materiality, an issue that, surprisingly, has hardly been addressed by STS scholars. However, this relationship can be investigated in very different ways. I will not take a position in the materiality debate in advance. Instead, I regard the literature review above as informative and would like to probe the field in light of the whole discussion rather than in light of one particular position. I will *track* the role of materiality with regard to standards and standardisation empirically. My first and main research question is therefore:

> *What is the relationship (are the relationships) between standards, standardisation processes and materiality and how can this (best) be addressed?*

Yet, I have to acknowledge, as is clear from the literature review, that I value approaches like ANT and Pickering's 'Mangle' over Grint and Woolgar's post-essentialism, mainly because they allow me to deal with materiality in a way that is impossible under post-essentialism. They also allow me to ask a question that has come to the surface a few times in the review, namely that of resistance. ANT does not talk about resistance; it seems that everything that resists being enrolled in the network simply does not exist. It has been unproblematically accepted that standards and artefacts are mobilised. According to Berg and Timmermans (1997, 2000) resistance is necessary for standards to work and it is therefore not regarded as resistance. Surprisingly Callon (1991), one of the ANT proponents, is one of the few who mentions resistance. However, this is not resistance against standardisation, but resistance of an already standardised and tight network towards new transformations. Bowker and Star (2000) and Star (1991) mention resistance to classification and standardisation, but do not explore what this resistance is and how it can be theorised. Also Knorr Cetina (in Callebaut, 1993) touches on material resistance, but comes close to arguing that by interpreting resistance it immediately becomes social. This is something that Grint and Woolgar would agree with. However, as I argued before, this approach does not do justice to the material in my eyes. On the other hand, a (perhaps ideal type) realist view on resistance (of materiality) suggests that we can know the resistance as it is, which I find unrealistic. Therefore: although I do want to consider the whole materiality debate when going to and analysing the empirical field, I have a bias towards Pickering's approach, which allows me to formulate a second research question:

> *What resistances (to standardisation, mobilisation, interpretative flexibility, and enrolment in networks), if any, can be identified and how can these be theoretically explained?*

Resistance may emerge from local cultures, other standards, or institutional settings. Yet, I will mainly focus on material resistance. Whereas most social-constructivist studies have stressed our socially constructed realities, I will focus on how materiality can be addressed theoretically and be regarded to set limits to the seemingly unlimited social constructions. Also here I will track empirically to what constructions the material world lends itself and whether cases can be identified where these constructions are constrained. However, I would like to underline that in accentuating materiality, I do not deny that this materiality has to be interpreted and is –at least partly– (socially) constructed.

Resistance will take place when standards are at work. Unlike ANT and many other approaches, I will therefore concentrate on standards at work rather than on the construction of standards. We have already seen that this will allow me to focus on negotiations of standards with pre-existing worlds. However, it has another important consequence. In existing environments, power relations may already be in place. They may have originated as the outcome of a network, but at a certain point in time they exist. In the words of Kleinman (2003: 62):

> Structures, interests, actors, and identities are constructed historically, but at any given time, these phenomena have an established character, and this configuration has effects. In the case of structures, human and organizational actors are likely to confront them as "external" and sometimes "constraining".

This is not to say that these structures have stopped evolving. Kleinman argues that a continuous focus on construction and on the assumption that context and content, the micro and the macro cannot be distinguished but are always co-constructed make it impossible to explore how one might shape the other. In the field of drinking water quality, the quality standards can be legally enforced. A water company can be taken to court for not complying with the standards. This is an existing power structure I will take into account in my analysis. Yet, it is important to note that this power structure does not determine how standards are dealt with. As we have seen, standards and regulations can be mobilised in various ways; according to some discretion and disorder are even necessary components of the environment in which standards can work. This is a crucial issue that needs to be explored in a bit more detail.

According to some (see *Complicating standards*) mandated standards should not be regarded as standards, because they have the force of law behind them. The implementation of mandated standards is not voluntary and in a definition of standards that stresses the voluntary aspect, mandated or regulatory standards do not qualify as standards. If I would accept this definition of standards and the question would be raised whether a water quality standard is a standard, the literature review above would have been unnecessary and would not stand in any relation to the empirical work and the rest of the thesis. Needless to say that I do consider regulatory standards as standards; standards that orchestrate action, techniques, and material bodies in rule-governed ways, that regulate, authorise, and standardise. We have seen that the distinction between voluntary and regulatory standards is more complicated than that and that they, in practice, can resemble or even seem to interchange at moments: 'standards are often just guidelines, and even regulatory standards are not always enforced' (Salter, 1988: 25-26). Timmermans and Berg (2003: 224, note 6) explain why they do not distinguish guidelines and protocols whereas the latter are often considered as stricter than the former. They argue that the actors studied sometimes use the terms interchangeable and that the use of the terms (and probably of the protocols and guidelines themselves) differs per professional group and per time period. Hawkins (1984: 26-27), like Lipsky earlier, gives an example with which he demonstrates that there is still a level of flexibility in the enforcement of standards:

> Standards are by no means treated as absolute proscriptions inexorably enforced. The agencies display a sometimes considerable flexibility both in the standards set and in the enforcement policy adopted, in recognition of the

> technical difficulties and costs of complying, the potential for error, and the stigmatizing effect of strict legal enforcement.

He talks here about water pollution standards, in his case, licences to discharge polluting matters. The regulatory agencies are legislative authorities and can sanction non-compliance with the standards. In his fieldwork standards were treated more as guidelines than strictly enforced standards, in fact he argues that 'pollution control standards are flexible markers of rule-breaking' (ibid.: 35). He (ibid.: 27) is one of the few people who touches on the role of (material) constraints on the enforcement and discretion of standards:

> The processes giving rise to pollution sometimes produce erratic discharges in which effluents may become heavily polluting, and river water is also inherently variable in quality. The result is that a degree of leeway is normally granted to dischargers, and a certain amount of pollution allowed to occur with impunity. Such leeway is the means by which the enforcement agency adapts to uncertainty.

It seems from this that materiality is a worthwhile issue to discuss in relation to standards and standardisation. Hawkins also argues, like Salter, that it is only in practice that one can distinguish which standards are legally enforced and which mobilised voluntarily. Relations between what is considered micro and macro, context and content, can therefore also be tracked empirically instead of taking an *a priori* position on this structure-agency debate. Drinking water quality standards can therefore be especially interesting in light of this debate and analysis of the fieldwork will clarify how water quality standards are dealt with. This leads to a third research question:

> *How are distinctions between notions like 'macro' and 'micro', 'context' and 'content', 'voluntary' and 'enforced' established in practice and how are they consequently dealt with?*

There is another reason why drinking water quality forms an interesting field: it does not only incorporate regulatory standards, but also regulatory science. Under *Standards and Regulatory Science* we have see that regulatory science is regarded by many as an under-researched field and that few people have focused on the detailed organisation of regulatory science. Complying with water quality standards requires an organisation that is geared to these regulatory requirements, and what is more, is subject to regulatory standards itself. Water companies do a great deal of what Irwin et al. (1997) call regulatory compliance testing. In addition, the water industry has not been a topic of research either on regulatory science or in wider STS and standardisation studies. As mentioned in the *Introduction* to the thesis, it is a relative invisible field, but one every person deals with and is dependent on in everyday life. From seeing the water that comes from the tap one cannot conclude what the quality of the water is. One therefore needs to trust the system that consists of all the socio-material elements mentioned before (including standards). Getting an understanding of how the water industry works in routine everyday situations is therefore in itself a significant project.

In order to explore regulatory compliance testing further in the under-researched field of regulatory science I focus on routines and everyday practices. STS often studies issues related to science and technology in the form of controversies. Halffman (2003) argues that there are good methodological reasons for studying controversies; they can help to study a wide range of actors and can help to explore what is otherwise black-boxed. However, he states that controversies as methodological tools also have disadvantages. The study of controversies assumes that the underlying structure of regulatory science that becomes visible was already there, whereas the number of actors during a controversy is not the number of actors involved in routine regulatory decision making and the 'institutional locus of debate' is different. A focus on controversies can therefore not help to understand routine regulatory activity. I concentrate therefore on standards-at-work (rather than standards-in-the-making) in a similar fashion as Berg and Timmermans have done and use ethnographic fieldwork to understand standards-at-work. This will be further discussed in the next chapter. The issue of regulatory science that will specifically be explored in relation to standards and materiality leads me to the last research question:

> *What (specific) roles do standards and materiality play and how are they mobilised in a field of regulatory science?*

To be able to explore standards at work in their specific socio-material environment, I decided to focus in depth on the water industry in the UK. A comparative study between different countries would have been valuable, but was not feasible within the time available for this project and would have remained more superficial. The UK water industry is relatively small which makes it possible to get a fairly good idea of how the industry works. At times I hint at differences between the water companies (organisation and size for instance) which, if I would have had time, would allow for an exploration of different mobilisations of standards.

2.3.2 Conceptual Toolkit

Black box, immutable mobiles, translation, implementation, discretion, materiality, regulatory science, compliance, closure, and local universalities are just a few of the concepts we saw in the literature review. Most of these will occasionally come to the surface in the thesis. However, I do not think they need to be explained in detail here. The literature review has taken care of that. In this section I want to review briefly a few concepts that may particularly be able to help address the research questions when I enter and analyse the empirical field.

In the thesis I will regard water quality standards as *scripts*. They incorporate specific notions of good water quality and expect the water to behave in certain ways. Regulatory standards can be enforced with reference to the script (to the meaning or intention of the policy makers); claims are made that the intention of policy makers is known. However, there is an *interpretative flexibility* to the script which may overlap with the claims made about the script in cases where the intentions of the policy makers cannot be known. Like interpretative flexibility, also the concept of *deviance* often rests on claims about the intentions of the policy makers. However, in the thesis I will use the notion of deviance to describe people who regard other people (or material) as non-compliant. This can be with or without reference to the intentions of policy makers. *Mobilisation* will refer to the ways in which standards are mobilised without reference to deviance or compliance. In order to address materiality and possible constraints to standardisation, I use the notions of *resistance* and *accommodation*. By following Pickering (1995) we have seen that the notions of resistance and accommodation concentrate on material agency. These notions have been explained above, but it is important to note that they are important for understanding material-conceptual alignments. It then seems necessary to discuss another, and heavily contested, concept that refers to materiality in a slightly different way: the notion of *affordances*. It is a contested concept because it has been placed in the centre of the realism-constructivism debate. To understand the various meanings ascribed to the concept and its place in the debate, it is important to look at it in a bit more detail.

The notion of affordances was coined by Gibson (1979) in the psychology of perception and has been taken up by a number of scholars from other fields amongst which sociology. Recently Hutchby (2001) discussed the notion in an attempt to talk about the way in which material enables and constrains human action. Hutchby explains how Gibson understood the notion of affordances:

> For Gibson, humans, along with animals, insects, birds, and fishes, orient to objects in their world (rocks, trees, rivers, etc.) in terms of what he called their affordances: the possibilities that they offer for action. (Gibson, 1979, in Hutchby, 2001: 447)

According to Aristotle a sculptor can make a sculpture from marble, but not from water or air. This is exactly what Gibson meant by 'possibilities for action': a river may have the affordance for a buffalo of providing a place to drink whereas it might provide a hippopotamus a place to wallow. Affordances might thus differ per species and context. However, they cannot be seen as freely variable: 'While a tree offers an enormous range of affordances for a vast variety of species, there are things a river can afford which the tree cannot, and vice versa' (Hutchby, 2001: 447). Hutchby (ibid.) then applied the concept to the sociology of technology where he elaborates on the concept. He argues for instance that there are many types of affordances (of artefacts, or natural environments) which interact with each other. In this interaction they can be enabling or constraining. Affordances of an object, as Gibson already said, may be different for different species: 'Water surfaces do not have the affordance of walk-on ability for a lion or a crocodile, but they do for an insect waterboatman' (ibid.: 448). Affordances can also be subject to social rules. For example, if a child finds a camera in the house, it might think that the hinged door of the camera affords opening. However, if a film is inside it will be destroyed if the door is opened. The child has to learn that one does not open the camera while a film is inside unless one wants to destroy the film. Finally, affordances of artefacts do not necessarily derive from natural features of the artefact's materiality; they can also be designed into the artefact. This last point can be regarded as closely related to the notion of script. According to Hutchby (ibid.: 444) affordances can thus offer possibilities for action but also constrain action: 'they frame, but not determine, the possibilities for agentic action in relation to an object'.

Hutchby has been heavily criticised for his use of the notion of affordances. Rappert (2003) argues, in defence of Grint and Woolgar, that nobody denies that the materiality of artefacts can enable and constrain action: this is encountered in everyday experiences. As we have seen above Grint and Woolgar can only explain the enabling and constraining in terms of (winning) accounts since artefacts are always interpreted. Rappert may prefer Grint and Woolgar's approach, but I think he has to acknowledge that Grint and Woolgar do not offer a solution to the questions Hutchby is interested in. Rappert (2003: 575) also criticises the notion of affordances in a different way:

> The notion of affordance in itself does not help out with the hard work of elaborating the relation between the technical and the social when that is the matter that actors and analysts are struggling with.

However, Hutchby (2003: 582) replies to Rappert indeed by saying that he is not so much interested in 'questions of representation and negotiation in understanding the relation between 'the social' and 'the technical''. Rather, he focuses on 'the use-in-situated-social-interaction of technological devices' (ibid.: 582). Rappert (2003: 577) makes another comment:

> In treating affordances as factors to be evoked as explanations rather than topics of analysis, there appears to be little scope for critical reflexive examination about their status.

Yet, also this can be brought back to the difference in questions they are interested in. This quite extensive discussion on the concept of affordances was necessary because of its contested 'nature'. It has been accused of being related more to the realist side of the debate than to the constructivist side of the debate.[47] Although I agree with a number of the criticisms made by Rappert –the notion is explanatory and does not explain how affordances come into being and how relations between the technical and social are maintained– I do think it can be a device with which *perceived* properties of material and artefacts (and their constraints) can be described. These perceived properties and constraints can be regarded as either social or material, but nothing has to be said about their ontological status. Affordances in this sense can be seen as a subdivision of interpretative flexibility. In order to examine the perceived affordances, I will draw on Pickering's notions of resistance and accommodation.

2.4 Conclusion

In this chapter I have reviewed a wide range of literature on standards and standardisation processes. In the literature review I have tried to complicate rather than simplify issues around standardisation in order to show the complexity of standards that work in different socio-material environments and about which various and contrasting claims are made. It was demonstrated that many of the (simple) modernist claims do not hold. Rather than talking about the specific and characteristic inherent functions of standards, I showed that standards can be mobilised in various ways. By posing the question of the relation between standards and materiality, I raised the question of (material) constraints to the ways in which standards can be mobilised. In the research design I further elaborated on the research questions and argued that the UK water industry is a field *par excellence* for studying relations between standards and materiality in an area of regulatory science. The theoretical toolkit then identified a number of 'tools' that will help me to explore the empirical field.

I also identified some respects in which the thesis is limited, one of which is the restriction to the UK. Other limits are the many interesting questions that can be (partly) distilled from the literature review, but cannot be answered here. Just to give

[47] In writing the thesis and at conferences I have been caught up in the debate myself and found that not clarifying exactly how one uses the notion of affordances can lead to unpleasant situations. A more detailed discussion of this concept as opposed to others therefore seemed in place. It has crossed my mind to leave the concept out of the thesis, but since it is one of the relatively few concepts that deals with the material-social relationships (Rappert (2003) mentions a few more) I decided to leave it in. However, in the thesis it has a narrower meaning than in Hutchby's article.

an idea I will mention a few of them. What happens with networks when standards change and vice versa? This was a question I intended to answer when I started the thesis. One of the ways in which I wanted to address this question was by asking what happened before and after privatisation. As will be explained in chapter 5, privatisation and the introduction of European regulation cannot be distinguished from each other and it was therefore impossible to relate certain developments specifically to privatisation. Other questions are whether different types of materiality and different standards can be distinguished and whether these allow for different standards and networks to be shaped. We can also ask how standards operate in different networks at the same time and how networks interact with each other. What happens when different standards, networks, and elements in a network do not work together? How do different mobilisations of standards or standards in different networks change or shape notions of water quality? Interesting would also be to focus explicitly on the interaction between different (types of) standards and to ask how different mobilisations of standards or constraints to mobilisations relate to distributions of risks and responsibilities in the area of quality standards.

There are thus many research questions that cannot be addressed in this dissertation. However, I may come back to some of them in the conclusion of the thesis where I will address some topics for further research. In the next chapter a few further limits of the thesis will be addressed.

3 Methods

3.1 Introduction

Chapter 2 presented an overview of the literature on standards and standardisation processes. I identified a number of issues that had not received much attention, in particular the relation between standards and materiality. It became clear that materiality can be dealt with in a number of (incommensurable) ways. At the end of the chapter I formulated a number of research questions and conceptual tools. This chapter explores the ways in which the questions raised in chapter 2 can be investigated. It operationalises the conceptual research programme into a more empirical research programme by concentrating on three main questions. Firstly, what constructions does the material world lend itself to and how did water quality come to be defined in terms of standards? Secondly, how were the specific standards current today established and how are they mobilised, translated and negotiated within the institutional waterworld? Thirdly, how do these current standards relate to the material waterworld? These three questions are subsequently dealt with in the next three chapters. In order to explore these questions a variety of data and sources were needed. Although there is some overlap between the chapters, the types of data used can roughly be split according to the chapters. Hence, I will now address the issues I explore in the following chapters, the methods of data collection I have used, and the problems I encountered along the way.

3.2 Constructions of the material world (secondary literature)

The first research question is explored in chapter 4. This is a historical and cultural analysis of 'water'. It studies in what ways 'water' can be regarded as a construction. The chapter gives a first, fairly fluid idea about relations between water(s), construction and materiality; a theme that is further explored in later chapters, in particular in chapter 6. To touch on these issues –the chapter is not meant to provide a full history of water– mainly secondary sources have been used. A problem with both secondary and primary sources on this subject is however that some practices related to water (drinking and bathing for example) have often been considered as trivial and normal and therefore not worth writing about. I have noted the occasions when this applies in the chapter.

3.3 *Regulations in the institutional waterworld (documents and interviews)*

Chapters 5 and 6 together are a sociological study of the relations between regulatory processes and water quality. Chapter 5 focuses on the role and negotiations around regulations and standards in institutional/organisational settings (the second empirical research question), whereas chapter 6 locates the regulations explicitly in their material/physical environment and in day-to-day work. In chapter 5 I concentrate on the question of how standards are constructed and consequently implemented and mobilised? I have used several types of data for this chapter. Documents are the first type of data. Many, if not all, organisations produce and consume a lot of documents and the water industry is no exception. Documents play an important role in mobilising and distributing water quality standards. However, documents cannot be considered as representations of what is really going on in the water industry. They are not simply secondary data which provide a descriptive and historical context and against which other types of data can be checked. As Atkinson and Coffey (1997: 47) noted, documents 'are 'social facts', in that they are produced, shared and used in socially organised ways,' and have to be studied as such. The Table in Appendix 1 can be regarded as an example. It was published by the Drinking Water Inspectorate (DWI), the institute that calls itself 'guardians of drinking water quality' and is responsible for assuring that water companies supply water that is safe to drink and meets the standards set out in legislation. It would be easy to take the Table for granted and assume that it represents the facts of the waterworld: the number of samples taken, the number of failures for specific parameters, etc. However, one can also say that it gives a version of events that demonstrates the credibility of the DWI by showing that they do their work and control the water companies. The relations between standards and materiality may be mobilised for certain purposes. When looking at a Table like this one, one can ask what it says about standards and their relation to materiality and how it represents or constructs these relations? The Table is not just a Table that represents the world 'out there', but it is produced in a certain context, form and with a certain purpose. This is not to say that it is meant to mislead us; rather that we need to pay attention to the way in which documents are produced, distributed, read, etc.

Within my study of the 'waterworld' two types of documents have been key. Firstly, the water quality regulations themselves. These consist of a variety of documents, amongst which are two European directives and a number of national regulations and guidelines. These can partly be subdivided according to what aspect of water quality they refer to. The UK water quality regulations will help to understand how the EU directive is mobilised and adjusted to a more local context: one particular country. The second set of key documents consists of 'information letters', which are produced by the DWI. These letters provide guidance for companies on how to implement the regulations. For the purpose of this thesis, they provide further insights in the mobilisation of standards and processes of translation. Other documents I analysed were annual reports, fact sheets, information booklets, and websites. These are documents 'concerned with self-representation' (ibid.: 46). They play a more implicit role in the thesis.

Documents could however not be the only source of information in my dissertation, because there are a few issues they cannot cover. Most of the current regulations, guidelines, and information letters can be found on the website of the DWI. However, when I was looking for regulation that preceded the current regulation, it turned out that old regulations and information letters often disappear as soon as new regulations and information letters come into force. Neither the DWI nor the Department for Environment, Food & Rural Affairs (DEFRA) archives previous regulations. The Public Records Office did not have many of the older regulations either. A short historical comparison between current and preceding regulations became therefore a very difficult task. Perhaps individual persons who work or have worked in the waterworld still have a few of the old documents, but that would be hard to track down. A second problem was that I am interested in the mobilisations, negotiations, and translations of and around drinking water quality standards. This is information that is not available in formal regulation. Regulation is the end and start product of these processes; it does not provide information about the routes that were followed before and after the regulations have been agreed on. It is information that is often not available in documents, because after such a process has been completed the 'working documents' are not any longer regarded as important and thus often thrown away. This is something that was recognised by my respondents.

> But a lot of this stuff isn't dealt with in the normal published literature. (...) I guess that is quite difficult for you, a lot is done through regulatory processes. (Thomas, HQD/181102/WaterCo)

Another said:

> There is no easy way to track changes [in regulations]. It is difficult, I accept that. How things have changed, you are the first one to ask about that from an academic perspective. The information we have is up here [points to his head], a collective sort of knowledge. But you might be in a hurry, because people retire and disappear. That is just the way things are. (Charlie, IDWI/050603)

Even if the documents were kept, they may be regarded as confidential by the different institutions and it would have been hard to negotiate access to these documents. Participant observation would have been a very valuable source of information on regulatory processes in action. However, I was interested in differences in negotiations, translations, and mobilisations of standards between various institutions. Unfortunately, participant observation in a number of different organisations during the period of my PhD was inconceivable due to the large number of settings of water companies and regulatory agencies, the difficulties in gaining access to the companies and time constraints. In the next section of this chapter, I will write about the one setting for which I did use participant observation.

To be able to study a number of different settings and to overcome the problems with documentary analysis, I decided to supplement the documents with interviews. I conducted a total of forty interviews. As shown in the Table in Appendix 1, England has twenty-six water companies. Seventeen interviews were held with sixteen different water companies in England and four interviews focused on regulatory agencies in England. These are the key interviews for chapter 5. The other interviews – fifteen during ethnographic fieldwork (see next section) and four with water companies and a research institute in the Netherlands that give a small comparative perspective – provide more implicit information for this chapter. Fourteen interviews I conducted with water companies and regulatory institutions like the Ministry of Health, Food Control Agency, Institute of Public Health and

Environment in Norway and the Netherlands for my MA dissertation do not figure explicitly in this dissertation, but have also played a role in the background.

The interviews have been conducted in roughly four periods: February-April 2001, May 2002, November 2002, and June 2003. Fifteen interviews were conducted by phone and twenty-five face-to-face. All interviews were arranged in advance. This meant that, if the interview was conducted by phone, I had time to install the recording equipment, prepare the interview schedule and assure that I would not be disturbed while doing the interview. Often I had the website of the organisation on my computer screen, so that I could quickly look something up if that was needed. Similarly, the respondent also had time to prepare for the interview. Thirty interviews have been audio-recorded and during the remaining ten I made notes. Twenty-eight lasted for about one and a half hour, five for about three hours, and for seven the time varies (these were mainly conducted during the fieldwork). Twenty recorded interviews have been fully transcribed, the other ten selectively. There is no base data set from which one might derive a 'representative sample' of how standards are being or not being mobilised. Instead purposive sampling was used to generate data, as I now explain.

In selecting the water companies in England for the interviews, I mainly paid attention to the size of the company. Originally, I also wanted to distinguish companies by whether they operated in a rural or densely populated area and whether they were old or new. However, these features are difficult to separate per company. Many companies supply a few cities and parts of rural areas at the same time. Only one company can be said to be truly new, because it was established after privatisation. Others have existed longer, often since around 1900, and may have replaced their distribution network and treatment plants at different times. It would therefore be difficult to draw conclusions about the relations between certain developments in the company, the ways in which standards are mobilised, and the type of area they supply or the age of their networks and treatment plants. Although these aspects do not appear in the Table below, I have taken them into account in the sense that some companies I interviewed are more orientated to the city and others more to the countryside. Some have relatively newer distribution systems and/or treatment plants than others.

Table 3.1: Number of companies interviewed related to size

	Large (>100 zones)	Medium (50-100 zones)	Small (<50 zones)
Total	4	6	6

To identify the water companies I was interested in, I investigated their websites and annual reports. At the start of my PhD, the interviewees were mainly identified via the website –usually through a central office. This often required a few e-mails to be sent and phone calls to be made. A few companies did not respond, but many did. As my research progressed I was more able to explain the research and to interest possible interviewees. An important part of this was my ability to use their discourse. The first round of interviews (February-April 2001) consisted of pilot interviews which were used to gather basic information about the field and, in the words of Fielding and Thomas (2001: 125), to 'get acquainted with the phrasing and concepts used by a population of respondents'. Interviews I had done in the past, documents I had read and theoretical considerations helped to identify issues for the first few interviews. However, I still often asked for further explanations about things that now seem evident to me during the interviews. Sometimes I also asked a few naive questions on purpose, for instance to compare this with answers of other respondents. I believe that my position as a student and a foreigner made this easier to do. If my position as interviewer would have been different, the respondent could have become impatient or even irritated. Newby (1977: 119) had a similar experience during his fieldwork on Suffolk Farm Workers: 'I discovered that a mixture of naivety and willingness to learn was a not altogether inappropriate fieldwork technique – provided I had either the knowledge or reliable informants to ensure that I was not being fooled'. After each round of interviews, I had time to do preliminary analysis and adjust the interview schedule for the next interviews. I would transcribe as many of the conducted interviews as possible. Fielding and Thomas (2001: 135) advise to transcribe interviews because 'these will help guide your analysis and probably reveal lines of analysis you had not thought of. You may even be able to adjust your guide for subsequent interviews to pick up on things your transcription reveals as unexpectedly important.' I transcribed 20 interviews verbatim. Especially at the beginning this was important, because I did not know what would turn out to be the most important points of the analysis. Transcribing was a time-consuming and not always exciting task. At first I did not always write my analytical thoughts down when I transcribed an interview. I assumed the thoughts would return when I would read the transcript afterwards, but they did not. I therefore made a habit of writing analytical thoughts down immediately. This made the transcription process more interesting. Sometimes, especially while listening to tapes from the beginning stage of my research, I wonder why I did not ask something or probe further. When I knew what the most significant points of analysis were and time was running out, I transcribed the rest of the tapes selectively. During the intervals between interview rounds, I started the process of coding (using paper, Atlas Ti and Word). Also this became much easier as the research progressed. This helped as well with adjusting the interview schedule. If a large number of answers to one question were the same, I would not spend so much time on this question in the next interviews or leave it out altogether. If a respondent had answered a question with 'that is a good question, I have to think about that', I would usually follow that up in other interviews. The interview schedules were always specific to the organisation for which the respondent worked. I studied the website of the organisation and, in the case of water companies, read reports of the DWI on the problems the company had that were reported.

After a few interviews, I started to get used to talking about chemical substances and treatment processes and could often come up with my own examples or analogies. Although I never became a chemist, microbiologist, or engineer, I was no longer someone from the social sciences who, for some inexplicable reason, studies a world she does not know much about. A better mutual understanding developed and I had the feeling I was taken more seriously. I did not ask many naive questions anymore, because my position had slightly changed and so had the detail and issues during the interviews. The basic questions did not have to be covered anymore and the interviews were conducted at a different level. I was still the one asking for information and wanting to learn, but the 'knowledge' gap between me and the respondent was not that big anymore. Apart from a better understanding of the discourse of the respondents and the smaller knowledge gap, I also gained more contacts. And the more contacts I gained, the more I was regarded as an insider. I had built up some trust with interviewees and all had agreed to be contacted in the future for further questions.

Sometimes I followed interviews up by e-mail. Some respondents suggested other people to me whom I could interview and a sort of snowball effect started. I read more documents on specific topics and sometimes the names of the authors or people involved were mentioned. Even if I had to contact a company without having a contact person as I did at the beginning, I could now mention the name of the person I wanted to speak with. This made access to the company easier and also the interview itself. The interview could be based on a specific document which served as a mediator between me and the respondent: I had read it, he/she had written it; we could use it as a starting point, because it was something we had in common. I assured respondents that they and the organisation for which they worked would remain anonymous.

The respondents are marked in the text with fictional names. The first time a respondent is mentioned in a chapter, his or her function and the date of the interview will be added to the fictional name. Appendix 2 gives a more detailed picture of the process of anonymisation. A list of respondents in the Appendix will, later in a chapter, facilitate connecting a name to the function of the person. Despite my attempt at anonymity and confidentiality, I cannot exclude the possibility that insiders may recognise themselves or others. The waterworld is a relatively small 'social world'. Regulators and companies may be familiar with specific incidents of non-compliance for instance and recognise a company that way.

I started to have a number of interviews with people working for water companies. However, the DWI, the Office of Water Services (Ofwat), and Water UK (representative of the water industry) had not responded. I was surprised about this. Water companies are private companies, whereas the DWI and Ofwat are public regulatory institutions that might be expected to be, at least formally, available to public inquiry. I had some contact with Water UK trying to negotiate access to a "network practitioners group", a group of people from different companies and regulatory agencies who discuss day-to-day implications of the new regulations with each other. This would have been a very useful source of information that would provide data on interaction between different companies, companies and regulatory agencies, and of course the day-to-day practices related to the regulations, even if I would not have been allowed to use it explicitly in my dissertation. Unfortunately I was denied access to this and have also never managed to set up an interview with someone from Water UK. The DWI responded that they did not have time for an interview and that all their information could be found on the website. The problem was that the information I was interested in, their day-to-day work, is not accessible on the website. When I sent another e-mail a few months later, they referred back to my former e-mail (which, apparently, they had kept) and responded in the same way.

I began to give up hope, even though the Drinking Water Inspectorate would be an important source for my dissertation.

However, in addition to documents and interviews, I also attended two conferences organised by the waterworld. The first conference was called 'Water contamination emergencies: can we cope?' and took place from 16-19 March 2003. The organisers, one of whom works for the DWI, were very friendly and let me attend two days of the three-day conference for a reduced price. The conference provided not only interesting information about various topics, but also gave me a chance to see how people from different companies and regulatory agencies interacted, and –perhaps most importantly– to set up new contacts. Two contacts I made at this conference have become very important, one of whom is a DWI Inspector. Via this last contact I was finally able to go down to London and speak with a DWI Inspector for over three hours. The water contamination emergency conference has also been very helpful in speaking to other people in the waterworld. Having been there, met people, and knowing more about the subject has again made me more of an insider. If people themselves did not go to the conference, they would know someone who went there. The second conference I attended was on Sustainable Water Management on the 25th of June 2003. I made a few new contacts, but the conference did not play the key role the first conference played.

I have described how I set up contacts with respondents and how my interviews developed throughout time. When I talked about documentary analysis I showed that documents should be analysed as social facts instead of taken at face value. This refers back to the realism-constructivism debate of chapter 3. The debate is intrinsically linked with ways of analysing data (documents, interviews, and ethnographic fieldnotes). Also with regard to interviews, it is important to think about the question whether an interview can provide information about the world 'out there' or whether it is (just) an interaction between interviewer and interviewee who both construct narrative versions of the social world. Silverman (2001) sketches three main positions. Firstly, in the positivist or realist position, interview data are believed to give access to facts about the world. If one adopts this position, the interviews have to be highly structured, standardised and always conducted in the same order. Secondly, in what Silverman calls emotionalism, the interview data give access to 'authentic accounts of subjective experience' (ibid.: 90). Researchers who use interviews in this way criticise the positivist position, because that would not take into account the social nature of the interview situation. The second position stresses access to what respondents *really* think and standardised interviews are not thought suitable for this. Interviews should be unstructured and leave respondents to talk freely. The third position is constructionism: 'accounts are not simply representations on the world; they are part of the world they describe' (Hammersley and Atkinson, 1983: 107; in Silverman, 2001: 95). Holstein and Gubrium (1997: 114) suggest therefore: that researchers take a more 'active' perspective, begin to acknowledge, and capitalize upon, interviewers' and respondents' constitutive contributions to the production of interview data. This means consciously and conscientiously attending to the interview process and its product in ways that are more sensitive to the social construction of knowledge'. Other people have focused mainly on the role language plays in both interviews and documents. According to Wooffitt (2001: 326) language cannot describe a world 'out there': 'It is (...) untenable to retain conceptions of language as a merely neutral medium for the transmission of information, values and beliefs about a world 'out there'.' He studies language use as a form of social action.

I will first comment on a few difficulties I had in conducting and analysing my interviews before taking a position in the debate. Respondents often differed in the way they answered questions. Some showed a very strong engagement with issues and were forthcoming in providing information and insights, whereas others were much more reluctant in providing information. This meant that I had to respond to interviewees in different ways. Sometimes the information came almost 'too easy' and I probed for further information. Other times a respondent would mainly answer 'yes' or 'no' and I would follow-up the questioning to get a fuller response. The interviews therefore did not lead to a systematic approach. This would be a problem if I adopted the positivist approach, because I cannot compare the data. They have been retrieved in different ways. However, I am aware that one cannot (fully) control the type of exchange and the sort of data that will occur during an interview. One of my worries was that sometimes an answer was given to a question which the respondent anticipated I wanted to hear. Fielding and Thomas acknowledge that this may be the case. Like many other textbooks, or 'cookbooks' as Newby (1977) calls them, they give some solutions to this problem. However, these solutions always remain very abstract. To me, only the experience of 'doing sociology' can teach one to deal with these issues. The position one takes during the interviews (or ethnographic fieldwork for that matter) may help to reduce that risk. Newby (1977) remarks that, as a student, one is not likely to be a threat to the respondents. He also remarks on his own fieldwork: 'there remained, of course, the danger that farm workers, in their eagerness to help, would feed me answers to my questions which they believed I wanted to hear. However, the role of student offered fewer risks of this than any other. I hoped that as an objective seeker-after-truth I would be perceived as having no particular axe to grind' (ibid.: 115). Whether this would be an issue of concern depends on the position one takes in the realism-constructivism debate. Gilbert and Mulkay (1984: 10) argue that we, as sociologists, are not equipped to make judgements about good or bad accounts:

> Once we begin to conceive of the social world in terms of an indefinite series of linguistic potentialities which can be realised in a wide variety of different ways and which are continually reformulated in the course of an ongoing interpretative process, the simple procedure of sifting good from bad accounts becomes entirely inappropriate.

Thinking that we can distinguish good and bad accounts, means often that a link to the world 'out there' is presumed. Gilbert and Mulkay argue that sociologists do not take into account the many different stories that different and sometimes the same actors tell: 'sociologists' attempts to tell *the* story of a particular social setting or to formulate *the* way in which social life operates are fundamentally unsatisfactory' (ibid.: 2). Sociologists too often look for similarities in their data and if they find them they take the result at face value. They do not take into account that language may function differently in different contexts and that the similarities may be a consequence of the way the data were collected. This means that:

> if there *is* a strong connection between the form and substance of discourse, on the one hand, and the social situation in which discourse is produced, on the other hand, it follows that discourse can never be taken as simply descriptive of the social action to which it ostensibly refers, no matter how uniform particular segments of that discourse appear to be.' (ibid.: 7)

They argue that what needs to be researched is why so many different versions of events can be produced. Participants' discourse should be the topic of analysis instead of the resource. They acknowledge this does not address questions about the nature of scientific actions which other types of analyses seek to address, but hold that these questions cannot be answered by sociology, at least not until we 'improve our understanding of how social actors construct the data which constitute the raw material for our own interpretative efforts' (ibid.: 15).

Although I find Gilbert and Mulkay's approach, like Wooffitt's approach, very valuable and consistent, their approaches would not help me to answer the questions I have asked. As mentioned in chapter 2, the study of language and discourse is important. However, if I would just study the role of materiality through discourses of people, I believe I would miss out something important. The world consists of more than discourse. Nevertheless, I do not want to adopt a realist position either, because I do not think that does justice to the variety of answers one can get to the same question. As we have seen this is an ongoing debate. Fielding and Thomas (2001: 143) state that 'we cannot authoritatively conclude that one is 'better' than the other, but what we must acknowledge is that, in pure form, they are tied to very different theories of the social world.' As I do not want to occupy too strong a position in the debate as yet, I will choose a method that I think will help me best with answering my questions. I therefore treat the interviews as narratives in which inconsistencies can result from the way people interpret and make sense of particular situations. My interview data do not give access to facts about the world as such, but are part of the world they describe. The context in which they occur is an important element in the generation of data. The interviews have been shaped by the contexts in which they occur, but this does not necessarily mean that the narratives cannot provide any information about the issues they refer to. They may not be 'false' or 'true', but show how people position themselves in a certain situation. They represent social actors in the process of what Pickering (1995) called, as we saw earlier, 'tuning in' to the world. One of the reasons I used interviews was to get more information about regulations preceding the current regulations. Many people who worked with older regulations of guidelines are retired, but I have met a number who have worked in the water industry for twenty-five years or longer. If I took a realist approach, I would have to say that their memories tell us either 'what it was like' or that they are false. If I analysed the memories from a discourse analysis or conversation analysis perspective, I would probably talk about the way they organise the talk. When I study this as a narrative, I can say something about how people position themselves to the past and the future and perhaps why they do it that way. Why people are saying something is in itself a source of information. Respondents could sometimes be very defensive. Mary (WQM/010202) opened the interview for example by saying: 'I am the water quality manager for the company and I am sure that we are following the drinking water quality regulations'. I have treated this as a source of information about the way this company positions itself and wants to position itself in relation to outsiders and the quality regulators. I have used the different types of responses to produce a more nuanced reading of the material, instead of taking them at face value. This means that I do acknowledge and keep in mind that 'there are a variety of philosophical and sociological arguments which suggest that descriptions are designed not merely to *represent* the world, but to do specific tasks *in* the world. [And] that any actual description, however sensible or accurate it may appear, has been assembled from a range of possible words and phrases.' (Wooffitt, 2001: 333)

In line with this my interviews were all semi-structured and contained open-ended questions to be able to cover the core issues and, at the same time, provide the respondent and researcher with the opportunity to explore some issues in more depth than others and to raise issues that were not part of the initial interview schedule. The interview schedules were partly based on information about the particular company or regulatory institute, but all had a number of core questions which were addressed in various orders. Three examples of interview schedules can be found in Appendix 3.

3.4 Regulations in the material waterworld (ethnography)

The third operationalised research question is investigated in chapter 6. In that chapter the relation between standards and materiality is explored in the context of the practices performed in a water company. It investigates how standards work, are made to work and are met in their social and material environment. The ethnographic fieldwork I did to obtain this information consisted of spending two and a half weeks in different periods (14-18 April 2003; 12-16 May 2003; 2-3 July 2003) in one of the bigger water companies which I will refer to as WaterCo. Ethnography is a well-established method to study science and technology and thus to include the material environment. Gilbert and Mulkay (1984: 8) claim that, because 'social action is not 'directly observable'' and which action is performed in a particular situation can only be established by reference to the statements of participants, accounts of participants should be the primary focus of analysis. However, no one in science studies has made the claim that a researcher could, through ethnography, observe social action as it is. In the words of Knorr Cetina (1995: 141): 'Ethnography furnished the optics for viewing the process of knowledge production as "constructive" rather than descriptive; in other words, for viewing it as constitutive of the reality knowledge was said to "represent"'. An ethnographic study does not exclude texts and spoken word; it adds something to this. Latour (1987: 63) remarks that 'scientists and engineers invariably argue that there is something behind the technical texts which is much more important than anything they write'.

In a study that investigates materiality, it is, if nothing else, important for the researcher to observe the material and the setting in which this 'acts'. The account I will give of materiality is not the same as that of the interview respondents who have already formulated a narrative about this. Ethnographic fieldwork has allowed me to observe the everyday practices and their relations with regulations and materiality without the intervention of language and pre-constructed narratives. In Hawkins' words (1993: 228): 'Observation provides the raw material which permits the activities of enforcement agents and their discretionary behaviour to be understood in the context of their routine work'. Hawkins carried out his study of regulatory processes of water pollution control in the period 1976-1979 and his work was first published in 1984. Chapter 5 will show how the organisation of the waterworld in England today differs from the waterworld in the period Hawkins studied it. Despite the fact that Hawkins' waterworld differed substantially from the one I studied and that he focused more on the people controlling the pollution than the people, organisations, and technologies trying to keep the water clean, I have learned much from his study. Many of the insights he gained with regard to regulatory behaviour and water pollution, will apply to a more or less extent also to the setting I explored.

His study was based on 'extensive participant observation of field staff in their routine work' (ibid.: 226). However, he also used taped conversations and both published and unpublished materials. My study partly focused on many different institutions and could therefore not concentrate on participant observation in one setting. Although my study would have benefited from a longer period of fieldwork, there were difficulties with gaining access to a company to which I will come back later. The ethnographic fieldwork allowed me to study one water company in much more detail. However, it has not given me access to the world 'as it is'. The result of fieldwork is, as Gilbert and Mulkay (1984) argued, never a description of how the world *really* is and I will now say something about how my fieldwork was shaped by my own interests and broader circumstances.

I had tried to gain access to a water company during the second year of my research. Unfortunately, the company I had approached was not prepared to let me conduct fieldwork in their departments. One of my interview respondents had suggested me to approach a senior member of another water company, WaterCo, for an interview. This person turned out to be someone well respected not only with regard to WaterCo, but also in the broader water industry in the UK and internationally. Amongst other things, he is involved in discussions about the assurance of future drinking water quality. During the interview it became clear that he was interested in sociological issues as well. WaterCo is a large company in which many translations of regulations would have to be made. It would therefore be a good case study. I decided to ask him whether he would be prepared to help me by letting me conduct fieldwork in WaterCo. He agreed and both he and his secretary were very helpful. However, this resulted in the fact that I conducted the fieldwork only in a later stage of my research and for a short period of time. The fact that the period during which I could conduct fieldwork was short had both advantages and disadvantages. I gained a good understanding of the daily practices in WaterCo and the work of and relations between the different departments – some respondents or actors I followed admitted that they wished they had experienced so many departments in the company; they did not always know what happened in other departments than their own. However, it was not long enough to build up trust or an emotional bond with the members of the company and I could not negotiate unrestricted access to meetings and documents.

Because of the short period available, I made the most of the time I had. I made long days. Often I had to get up early to travel to the place I had to be that day. At times during the day when one normally relaxes like lunch or tea breaks, I concentrated hard to remember the interesting things that were discussed, so I could write them down as soon as we came back. Hawkins (1993: 228) describes a similar experience: 'the pub at lunchtime, and sometimes in the evening as well, was also a place in which the field men would relax and reflect at length on their activities. I spent the whole of the time during the fieldwork watching, listening, and talking. Where and when I could I scribbled brief notes which I later amplified and wrote up.' The evenings were reserved for writing fieldnotes. I will return to this later. Another result of the short time frame within which I had to do my work was that I focussed on particular examples, interests, and questions I wanted to try to answer during my period in the company. These examples, questions and interests were carefully selected on the basis of documents, other literature, and interviews that I had already done. They are thus an outcome of previous research and interpretations and my account of relations between material and standards.

One of the decisions I made was to focus exclusively on the 'clean water' side of the company, even though this had several relations with the 'dirty water' side of the company. I do not consider this as a hindrance for my fieldwork; instead it has helped me to collect, sift, and analyse the data in the short period that was available. My own view of what was important and worth following up also changed as a result of the fieldwork. Every night I wrote my fieldnotes, made the first ordering, and reflected on connections between various issues. This then helped me the next day to focus on issues I found interesting the previous day. The fieldnotes often consisted of twenty to thirty pages a day. The possibility of taking notes during the day was of great help because 'erosion of memory is not related to time so strongly as it is to new input; that is, the more stimuli to which you are subjected during a day the more detail is forced out' (Fielding, 2001: 152). It also helped in the sense that I have full quotations of some conversations and notes on personal feelings at the time. Like the interview rounds, also the periods between the different stages of my fieldwork were used to start the process of analysis and coding.

However, despite my focused fieldwork and thus the list of issues I wanted to explore, I tried to avoid premature categorisations of which 'variables' were important and definitions of certain processes. Instead, I explored how in different contexts 'water quality' and 'standards' came to be defined. Hawkins' observation was devoted to 'learning what officers define as relevant in their everyday environment of sampling, monitoring, and routine encounters with dischargers and polluters' (Hawkins, 1993: 229). This was true for my study as well, except that encounters with dischargers and polluters did not figure in my case. Hawkins also did not study the pollution legislation before he started his fieldwork in order to be able to learn the law as the officers knew it. He wanted 'to avoid the distortion arising from a particular sense of relevance which thorough prior knowledge of the formal structure of rules may have conferred on what I was actually observing' (ibid.: 229). I had seen the water quality regulations before I started the fieldwork, because they had been a subject of conversation with interview respondents. However, they had not been studied in detail and the different narratives of the respondents about the regulations had partly prevented me from determining what was relevant and what was not. On the other hand, what I had seen of the regulations did provide me with a framework within which I could study when standards were considered to be met and what issues, technologies, etc. were regarded as relevant in this context.

During the fieldwork I made notes of everything related to my research questions, because within that domain I still could not be sure what were going to be valuable data. The document and interview analysis had shown some points of significance, but the water company was a different setting and fieldnote realities may be different from documentary and interview realities. My role as a visitor and student who had come to the water company to learn, made it possible to make notes during the day. Several people working for WaterCo mentioned that students or people who start working in the company often visit a few departments to get a feeling for what is going on. I did therefore not have problems other ethnographers have encountered. Kleinman for example notes that there were tensions between him and members of the laboratory he studied:

> I entered the Handelsman lab with expectations; likewise, lab members made assumptions about what a sociologist might think and do in their work environment. Furthermore, we all have self-images – senses of who we are and what we do. The self-images of lab members and my understanding of my objectives for this project at times conflicted. (Kleinman, 2003: 18)

The presence of students in the various departments of WaterCo was however not unusual and my period of study was too short to experience similar problems. In my case the employees often took time to explain things to me and gave me the opportunity to ask them about the company, the various departments and their experiences with and views of the regulatory processes with regard to water quality. Some issues I wanted to explore came up accidentally during the fieldwork, others were discussed during more formal interviews where I would sit down with someone and have a shorter or longer talk. I mentioned in the previous section that a number of these interviews were audio-recorded. The purpose of these interviews was to discuss some of the key issues that were emerging from the fieldwork and to place the day-to-day work of various departments in context. I took notes during other interviews, most of the time because that seemed more practical in the particular setting or because I did not want to give the interview a more formal character. Two respondents were very unclear about answering my question of whether I could tape the interview or not and I decided not to. My previous research had helped me to understand the discourse used in the company, but there were still occasions where I had to keep asking questions until I understood how processes worked or things were done. One person remarked that she had never been asked so many and detailed (common/tacit knowledge) questions, not even during an audit of the DWI. The questioning was however mostly interpreted as a sign of interest, which many respondents appreciated and saw as a sign of encouragement to keep talking and explaining things enthusiastically. People were very friendly and helpful. The knowledge that the company and respondents would be anonymised and that everything I would write about the company would be read by the senior member who also provided me access to the company may have helped the employees to give more detailed and rich information. It would assure them that I did not use any confidential information. However, like Newby I found that people were sometimes trying to find out who else I had interviewed, what their answers had been and in which company I did my fieldwork. Newby (1977: 118):

> One assurance I readily made and was determined to keep (...) was a guarantee of total confidentiality. This seems to me to be the right of every respondent, and it had to be firmly adhered to despite occasional nudges and winks over cups of tea to pass on the replies of others to certain questions.

The assurances of confidentiality and anonymity made interactions easier and I did not feel restrained in what I could ask. People also seemed to think it was their duty to provide me with the information I asked for and wanted to impress the senior member. One respondent even reminded me explicitly of how helpful he had been and whether I could pass that on to the senior member. Three members of staff have read parts of the chapter I wrote to ensure that I understood the more technical issues correctly (also a DWI Inspector read part of my work). This gives information about hierarchies (who is important, who gets access to what) and the working of the organisation. In Newby's words: 'the methods of obtaining the data is often valid sociological data in its own right' (ibid.: 115). Another impression I had was that people were proud of the company and its achievements and results. Many had been working there for a long period of time and were provided with the opportunities to do what they were interested in within the company. Sometimes people told me that they enjoyed having me around, because it broke their routine. A quality inspector who would usually be on her own the whole day to take the samples, did like some company for a change.

The fieldwork, although short, was of crucial value to the thesis. As mentioned above, it gave me a chance to go beyond the question and answer sessions of the interviews. It helped me to get hold of information in informal ways and contexts, information that I could not have collected in other ways. I attended formal and informal meetings[1], spent lunch breaks with employees, visited several sites (head office, treatment works, microbiology laboratory, chemistry laboratory, Cryptosporidium laboratory, the department responsible for the distribution network, etc.), and followed people in their day-to-day work (a quality inspector collecting samples, people auditing a burst main, microbiologists, etc.). This is very similar to the fieldwork Hawkins (1993: 228) did in his study about water pollution: 'a lot is to be learned from travelling around with research subjects and hanging about in their offices. In my case I spent a good part of each day in the field men's cars, talking to them at length on the road between visits or at sampling stops'. I was taught to take samples and do chlorine analysis on the site and to filter a microbiology sample and put it on the media from where it was analysed further in the microbiology laboratory. This was something they assumed I could do, like the trainees they sometimes have. At the end of the day, my task in the microbiology laboratory was just emptying bottles and throwing them in a bin. People were talking and joking and I was included in this. I had to dress like the people working there as well and perform the same actions, like washing hands with antibacterial soap before entering the laboratory. Through these experiences and talk about what it was like to do this work and why people had chosen to do what they did, I could imagine what it would be like to do this work. It is important to notice that I could only participate in certain settings. These were settings where participation did not require too much background knowledge (like how to deal with instruments in a chemistry laboratory) or it was essential that no mistakes were made (as in the *Cryptosporidium*

[1] Amongst which a meeting on section 19, a program to replace pipelines, to which I will return in chapter 5 and a meeting where general things were discussed: money, what everyone was working on and how this related to the planning of the work, what problems had been encountered and how these could be or had been solved. I received minutes or other documents of some of these meetings. For reasons of anonymity, these cannot be explicitly referenced.

laboratory). This in itself provides information about the company and the importance of certain departments and settings compared to others.

The possibility of collecting a lot of fieldnotes through my fieldwork gave me the opportunity to use 'thick description' in the thesis. In using thick description I treat some observational data as raw ethnographical and thus pre-analytical data. As mentioned before, the data depend on my selection of what I observed, how I wrote the fieldnotes, and which fieldnotes I have used for chapter 6. I could give a summary of the fieldnotes. However, instead, I wanted to give an impression of the materiality and the setting which readers of the thesis have not experienced. For the same reason I also use pictorial representations. Like texts, visual images do not speak for themselves. In the words of Alexander (2001: 354): 'they can carry multiple meanings and are therefore called 'polysemic' or 'multivocal'.' The photos I took are as selective of my view of the world as are the interviews I conducted. When I took the photos I decided what was materially important. Nonetheless, visual sociology in the form of photos can bring materiality to life in another, non text-based form. Like documents, interviews and fieldnotes, visual images have their own reality and the relation between text and images can be regarded as problematic. For that reason, I will not write a lot of text about the photos, but instead leave people to make sense of the materiality of and in the photos themselves.

3.5 Conclusion

To answer the research questions I have used a number of methods: analysis of paper and web-based documents, interviews, conference papers and settings, and ethnographic fieldnotes; thick description and the use of visual images. I have argued that none of the sources can be taken as representations of the world 'as it is' and that by studying discourse and language –although it is a valuable and consistent approach- one does miss out on other aspects of the world. Since the material world is an important aspect of this dissertation, I have looked for methods that could provide insights in the relations between standards and materiality with help of both written and spoken language as well as observations and visual images. I acknowledge that all different sources have their own realities and that they cannot simply be combined to present one single reality. The attempt to combine different methods is often used to validate the analysis. However, as Miller (1997: 25) points out: 'a major assumption of triangulation is that sociological research is a discovery process designed to get at an objective truth that may be systematized as a formal theory of social structure and process.' Miller therefore uses a bridging metaphor for finding a way in which different methods can be used in one study:

> Bridges link distinctive land formations, making it possible for people to traverse between them. While opening new opportunities for residents on each side, bridges do not blend the formations or otherwise make them indistinguishable. (ibid.: 24)

In this way different perspectives can be mutually informative, without forgetting and blackboxing the context of production of the various sources. Interviews and documents have allowed me to look through other people's eyes at the relations between materiality and standards, whereas observation has allowed me to use my own eyes.

If I had not had a limited period of time and limited resources to write this dissertation, I would have started with further ethnographic fieldwork, both in WaterCo and other companies. Especially a comparison with fieldwork in a small water company might have provided interesting data. Fieldwork in a regulatory agency would also have been fascinating. In that case I would also have organised a (video) conference with all my respondents to discuss certain issues that occurred from the fieldwork. This would have provided data on interactions between the different participants and would be an effective check on earlier research (keeping in mind that this would –yet again– be a different means of data collection). I would certainly negotiate access to the network practitioners group. I would also study a number of water-related journals over a long period of time. Unfortunately this is not the case. I have often wished that I could start my research project anew, but now with the contacts I have established and insights gained so far. If I would go back to WaterCo or would interview my respondents once again today, I could ask different questions and would observe different things. There is so much more to learn. But, as Latour (1999: 74) says: 'To know is not simply to explore, but rather is to be able to make your way back over your own footsteps, following the path you have just marked out.' This is what I have tried to do in this chapter. And like in Latour's article, the outcomes of this research are new questions, ones that require yet another expedition.

4 Into the water

4.1 Water as construct

> Water remains a chaos until a creative story interprets its seeming equivocation as being the quivering ambiguity of life. It is the deep ambiguity of the water that makes it elusive for us. (Illich, 1986: 25)

In his book *H_2O - A Biography of Water* (2002a), Phillip Ball recognises that our beliefs about what water is have been continuously modified and dramatically changed throughout history. However, he then argues that despite changes in our perception of water over time, 'water has throughout this time been just what it is today: H_2O, a remarkable chemical compound with a private history' (ibid.: x). Illich, on the other hand, argues that from the start of his book he 'shall refuse to assume that all waters may be reduced to H_2O' (Illich, 1986: 4). The problem with reducing water, or 'stuff' as he calls it, to H_2O is that the stuff is then a-historical. Instead Illich wants to explore the 'historicity of matter', because 'the very substances that are shaped by the imagination –and thereby given explicit meanings– are themselves social creations to some degree' (ibid.). To (social) constructivists it may not come as a surprise that 'water' has been defined in different ways and used for different purposes throughout different periods and cultures. However, very little has been written about constructions of 'water' and 'water quality'. In this chapter I will explore how water has been regarded as constructed and how these constructions are produced, especially in the light of notions of purity and quality. I argue, following Hamlin (2000) in this, that over time a singularisation of notions of water and water quality and purity has taken place. The broad variety of water (quality) definitions and with that affordances have decreased because of processes of governance, globalisation and standardisation. However, this is not to say that all diversity in concepts has disappeared.

It is often assumed that scientific progress leads to disenchantment of the world (see for example Weber, 1999 [1930]). In this vision science is both regarded as a blessing and as something that would deprive our world of all the magic at the same time. The underlying assumption is that notions of water purity in a scientific sense would have an impact on ideas of symbolic purity or perhaps, would even replace them. Emmanuel Le Roy Ladurie (1986) seems to argue that scientific notions of water purity would, if not replace, at least disenchant cultural or symbolic or metaphorical notions of water purity:

> Water retained its sacred, purifying role for a long time, whether this was reflected in the mineral springs honoured even in protohistorical times by *ex-votos* which had nothing Christian about them (...), or quite simply in the holy water at the entrance to our churches. Was it really Lavoisier who, in the eighteenth century, gave a decisive push to the secularization and demystification of water by analysing it and showing that it could be broken down into hydrogen and oxygen, thus disproving the notion that it was an element like air, earth and fire...? In any case, mystery gave way to science, religion to technology and salvation to health.[2]

So, was it science and technology that took away the symbolic powers of water? Have the different 'waters' been reduced to one single 'water'? In this chapter I will argue that, although a singularisation of notions of water has taken place, not all of the symbolic powers of water disappeared. They may still exist independently or perhaps are even incorporated in modern notions of water purity. The material properties of water have been defined, interpreted, responded to and dealt with in a variety of ways throughout history and there is no way of objectively knowing these material properties or – as Ball believes is possible – to make a clear distinction between attitudes and facts. Ball argues that: 'With water, we have at least the good fortune that our impersonal subject permits us an unusually clear distinction between attitudes and facts' (Ball, 2002a: x). Squatriti (1998: 4), in his book on early medieval Italy, states:

> An analysis of human adjustments to water in the evolving postclassical Italy is (...) both an analysis of a sometimes neutral, almost inert thing, an element with stable characteristics such as chemical composition, boiling and freezing temperature, or susceptibility to gravity, and an analysis of people's imaginative reactions to it. This study demonstrates one thing above all

others: water was indissolubly both matter and custom, both nature and culture in the diverse landscapes of Italy during the early Middle Ages.

This goes back to the discussion between proponents of a more realist and the proponents of a more constructivist view outlined in chapter 2. Can we distinguish between the raw material and people's attitudes towards and actions around it? I draw on the view that, as Squatriti wrote, water is both matter and custom. These two can however not be distinguished from each other because they develop together and also together, defined perhaps by their actions, they may determine the affordances of water.[3] Affordances in this sense are determined by whether matter is perceived as in or out of place, and thus by social, cultural, economical, political and scientific beliefs and contexts. Water, as Illich (1986: 25) argues and I would like to agree with, 'reflects the fashions of the age; what it seems to reveal and betray hides the stuff that lies beneath'. Water and water purity can therefore not be interpreted straightforwardly and objectively as concepts that are evident and stable over time and context.

The notion of things 'in' and 'out' of place, can help me to concentrate on the context and environments in which water was considered pure and impure or used for purifying or polluting purposes. Both Mullin (1996) and Douglas (1966) argue that purity is often concerned with control of boundaries, both social and bodily.[4] Pollution or impurity, the opposite of purity, can threaten certain orders. That what is impure does not fit accepted social, cultural or political systems of classification and is, according to Mary Douglas, 'out of place'. What is out of place can thus differ in different cultures or time periods or even within the same culture.[5] It is a useful tool to remember and show the construction of water and purity.

In this chapter I will by means of a few examples – water and ritual purity, bathing and purity, water and physical purity, and purity of drinking water – explore how water and water purity have reached their current meaning or meanings and

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[2] Le Roy Ladurie, E., *Introduction*, In: Goubert 1986, p. 2.

[3] As a response to Rappert, Hutchby (2003) stresses that he focuses on actions rather than the nature of technology (or matter if you like) and that affordances of technologies can be observed in the actions in which they play a role. He looks, in other words, at the performativity of matter.

[4] Mullin agrees with Douglas that concerns over purity are often about social order and is associated with sharp boundaries, but she argues that this concern often arises in periods of social disorder.

[5] Unsurprisingly, the term 'culture' is a contested term that can have a wide variety of meanings. I will not explore these meanings here.

which ones have been lost or retained. These examples are by no means exhaustive, but will give an indication for answering the question how different notions of purity have contrasted over time or cultures and whether they have shown similarities as well. The information comes from secondary sources. A problem is that attitudes toward and uses of water have rarely been written down. Squatriti studied different uses of water in early medieval Italy and was surprised at the very few sources he found on this subject: 'The scarcity of such evidence even over the course of the six hundred years this study addresses is most striking' (Squatriti, 1998: 8). Water was often so much part of daily life, taken for granted and therefore invisible, that it was probably not regarded as interesting or important enough to keep a record of activities around water. Squatriti indeed argues that 'the reason for the relative invisibility of these natural sources of water for domestic use is probably their banality' (ibid.: 11). What is known about the uses of water, often relates to the upper class; the relationship of the ordinary man or woman to water is not readily available. However, the secondary sources in this chapter should provide us with enough material to distil a few different notions of purity regarding water.

The chapter will end with some observations on the effects of standardisation on definitions and concepts of water quality. This will then lead us to chapter 5 in which the current drinking water quality standards will be investigated in close detail.

4.2 Waters and water purities

In every culture water has or has had a strong symbolic power. In many cultures all over the world water has been connected with purity: purity in a religious sense or purity in a physical sense of ensuring hygiene of the body. In this section I will give a few examples of relationships between water and purity. Later on in the chapter I will argue that these metaphors and purities matter and that matter performs metaphorically.

4.2.1 Affordances of use 1: Water and ritual purity

The video *A Journey in the History of Water* shows an interesting image:

> Rain is pouring down in Bergen, Norway, which is, I believe, the rainiest and wettest city in Europe. The streets and drains can't handle the amount of water and the water flows through the streets. People wade through the water with high boots on and umbrellas in their hands. They go to church. In the church they can fold in their umbrellas. In the church a baby is baptised. (Tvedt, 2001)

Baptism is a very important ritual in Christian religion. If a person is not baptised, he or she cannot enter the kingdom of God. It is water that unites the child with God. The Bible describes how John baptised Christ in the river Jordan. Jesus is standing in the waters while John performs the ceremony on the bank of the river. After the baptism the Heaven opens and the Holy Spirit descends in the shape of a dove hovering over Christ's head, while God's voice resounds from heaven. Originally babies were baptised in running water like Christ was. Nowadays the water used for the ceremony might just be tapped rainwater. However, the water cannot just be any water: muddy water or bottled water would probably not be regarded appropriate for the ceremony. The image described above shows that, even though the water outside and in the church may have the same origin, the water in the church is of an entirely different order than the water outside. The people going to church can complain about the rain, that is the water they try to wade through, but see the water used for the baptism as holy water that purifies the baby and the relationship between the baby and God. According to Peter Brown, early Christians, such as Paul, regarded purity as something that would ensure a unified community. 'Paul saw baptism as a Christian purification.'[6] It is thus holy water that sets up a boundary between people belonging to a certain community and outsiders. It brings people to the right place, or perhaps 'in place'. Douglas' notion of matter out of place may be relevant here in a way that is closer to the original meaning of the phrase. The water in the church is considered as water in place whereas the water outside may be considered as water out of place. According to Ivan Illich, purification processes do not always need water, but 'the purity that water restores or confers has a special connotation of freshness and transparency that transforms the innermost being and so it is often associated with re-birth' (Illich, 1986: 59). The purity here described is ceremonial

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[6] Brown, P. (1987). "Person and Group Judaism and Early Christianity". In *A History of Private Life*. Cambridge, p. 254. In: Mullin 1996: 516.

purity rather than physical purity or cleanliness. It is the soul that is rinsed. The water touches the body of the baby, but does not wash it.

Norwegian professor Terje Tvedt in the video mentioned above suggests that the holiness of water originated in desert religions before it came to the west. In some tribes in the deserts the word for water and rain is the same word as the word for life. Water was and still is regarded as life in the deserts. Therefore water is a gift of God.[7] The control of fresh water was seen as a visible manifestation of God's omnipotence. When the Jews had to flee Egypt and leave the fertile Nile Valley behind, they only saw sand and rocks, got thirsty and threatened to leave. God told Moses to 'ask' a rock in Petra, an ancient trading centre, for water but Moses struck it with his stick. The water was a sign of the almighty and the people could build canals with it. Since Moses did not trust God to provide water when He said He would, Moses was not allowed to enter the land of Israel when they reached it. He died on Mount Nebo from where he could see the Promised Land and Jericho, an oasis with running water. After Joshua had taken over the city Jericho from the original inhabitants, some of the inhabitants were not happy with the water. It was too bitter.

> And the men of the city said unto Elisha, Behold, I pray thee, the situation of this city *is* pleasant, as my lord seeth: but the water *is* naught, and the ground barren. And he said, Bring me a new cruse, and put salt therein. And they brought *it* to him. And he went forth unto the spring of the waters, and cast the salt in there, and said, Thus saith the Lord, I have healed these waters; there shall not be from thence any more death of barren *land.* So the waters were healed unto this day, according to the saying of Elisha which he spake. (Bible: 413; 2 Kings 19-22; italics were present in the original)

Enough water and clean water is here clearly a blessing of God. Also the Koran stresses the importance of water and states that all living things arise from water. In water one is able to see the will of God. The Hindus in India have a similar idea of holy water. It is believed that a drop of the holy river Ganges will wash away sins and impurities. It is the purest water for the believer. Any water that is mixed with

[7] Absence of water or destructive floods can then be regarded as God's punishment. It can cause chaos. In these cases religious leaders may ask God for more or less water. At the day I am writing this, the 10th of August 2003, the pope is praying for rain when fires destroy the forests of Italy, Spain, France and Portugal.

Ganges water becomes Ganges water with its healing powers and holy properties. One can say that by mixing water with Ganges water, one puts the water 'in place' and it becomes pure. Holy men may dedicate years of their life following the river from the mouth to the source and back. The city of Varanasi is built at the place where the Ganges turns north and where according to legends four underground streams come together. The city's 70,000 temples and the river itself attract many pilgrims and visitors. Numerous people walk around with small vessels with Ganges water. Some staircases into "mother Ganges" are reserved for the people who bring water to the temples.[8] Varanasi is also the place where Mahatma Gandhi, like thousands of others, was cremated. Sick and old people come to Varanasi to wait there until they die. Their family members will take the dead person into the river for a last holy bath before they carry the deceased to the open fires.[9] No one who is cremated in Varanasi will have to go through the endless cycle of reincarnation; the sacred river will make sure that their soul will go to heaven.[10] Water here both cleanses and purifies the body, or perhaps it cleanses the body at the same time as it purifies the soul. 'What for the dead man or woman is "ablution," "absolution," delivery from burdensome soil and dirt is, for the living, a purification of their

[8] The river here is female as it is in most Asian countries: life giving, fertility. In the West rivers are often male: it is old father Thames, the Mississippi is called 'old man river' and around the many fountains half naked and bearded old men are shown.

[9] Since wood has become more expensive, the poor cannot afford to be cremated on open fires, so there are electric places for them.

[10] Not everyone is cremated on the fires. Holy men, infants, people bitten by snakes, pregnant women and animals are sunk into the river. The river washes the ashes to heaven. The legend goes that a long time ago the proud and arrogant King Sagara had two wives. The first wife gave him sixty thousand sons, whereas the second wife only gave him one, Asamanjas. The sixty thousand sons became great warriors, but Asamanjas treated the population very badly and was expelled by Sagara, leaving a grandson, Ansuman, behind. One day King Sagara decided to let a horse loose and made the warriors follow it wherever it would go. If someone would stop the horse, it would mean war, not stopping it meant that the land belonged to King Sagara. The horse was lost and the warriors started searching everywhere for it. When they found it, they disturbed the sage Kapila (Vasudeva), who sat nearby, in his meditation and he burnt them to ash. King Sagara heard of his sons' fate and sent his grandson Ansuman to undo the harm. Kapila enjoyed Ansuman's company and revealed to him that the waters of Ganga, then resident in heaven, could release the souls of Sagara's sons. Ganga was one of the daughters of Meru (the Himalayas) and was given to heaven to soothe the Gods with its cool waters. Both Sagara and Ansuman and later his son Dilipa tried to convince Ganga to come to earth. Eventually it was Dilipa's son Bhagiratha who succeeded. However, the impact of Ganga's fall would be so severe that they needed Shiva's help to reduce the impact. Bhagirathi went into meditation and did get Shiva's consent. The river came down, through Shiva's hair, and reached the earth. The town Allahabad is the place where the river came down from heaven. People now come here to bathe in the river; it is the greatest gathering of people in the world. Bathing here has a more purifying than cleansing role. Bhagiratha led the way and the river followed. When the river

dwelling space corrupted by death.' (Illich, 1986: 30) The dead, corrupt materiality of the body is overcome by the metonymic power of water as both spiritual and physical purifier.

Holy waters exist also in Europe. Earlier I referred to water that is used to baptise children and that becomes holy because of the place and ceremony in which it is used. Here I refer, like the river Ganges, to the water of a certain source that has a special religious meaning. Lourdes in France is perhaps the most famous example. Every year three to five million disabled, sick and healthy people from all over the world visit Lourdes. Many of them hope that the water of the spring will heal them and wash away their sins. Lourdes became seen as a place of miraculous healing in 1858. In that year the Virgin Mary appeared eighteen times before Marie Bernard Soubirous, the 14-year old daughter of a local miller. The girl later said that the Virgin Mary had commanded her to go and drink at the spring and wash herself with the water. At first she couldn't see any water, but even so she made her way into the grotto. There she found only a trickle. When she dug a hole, a spring began to flow. Mary promised that the spring would heal those who used its water. Immediately the news spread that people were being cured of great illnesses at the spring. Marie Bernard was later canonised as St. Bernadette. Also here water is seen as a medium through which divine power can flow, a 'stuff' that can heal and wash away sins.

As shown above, water has a special purifying role in Christianity, Islam, Buddhism and Hinduism. Perhaps this originated indeed, as Tvedt suggests, from the desert religions. These cleansing rituals have, up until this day, figured prominently in art, especially paintings. In the mentioned rituals the source of the water is very important (river Ganges, spring in Lourdes, and even water for baptism cannot be any water); it is a blessing from God and can purify the soul, heal the body, and make people part of one community rather than another. The water from these specific sources can make a difference between living in sin and living in grace, living in illness and in health, going straight to heaven or having to go through (other) reincarnations after one has died, and belonging to one part of society rather than another.[11]

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touched the ashes of the sons, they were liberated and an ocean formed from the waters there. Since then the river washes away sins and washes ashes to heaven.

[11] Chang (1997 [1991]: 212) mentions yet another 'power' ascribed to water. In the 1950s, the communists in the Chinese city of Yibin were attacked by an army of soldiers, landowners, and unarmed farmers, the latter of whom had drunk 'holy water' which made them invulnerable.

Unlike the important role of water as a sign of God's goodness in the religions just mentioned, in Norse religion no aura of holiness surrounded water. For the Vikings water was more a curse than a blessing. It was not water that gave life as in the Bible or the Koran, but warmth. Without warmth, water would turn into ice immediately.

> In the south is a realm called Muspell. That region flickers with dancing flames. (...) In the north is a realm called Niflheim. It is packed with ice and covered with vast sweeps of snow. In the heart of the region lies the spring Hvergelmir and that is the source of eleven rivers. (...) Between these realms there once stretched a huge and seeming emptiness; this was Ginnungagap. The rivers that sprang from Hvergelmir streamed into the void. The yeasty venom in them thickened and congealed like slag, and the rivers turned into ice. (...) Just as the northern part was frozen, the southern was molten and glowing, but the middle of Ginnungagap was as mild as hanging air on a summer evening. There, the warm breath drifting north from Muspell met the rime from Niflheim; it touched it and played over it, and the ice began to thaw and drip. Life quickened in those drops, and they took the form of a giant. (Crossley-Holland, 1993: 3)

Myths such as the ones in Buddhist, Christian, Hindu and Islamic religion simply did not exist in Norse religion. In the Edda the end of the world is not described as 40 days and nights of rain as in Buddhism and Christianity, because that is, according Tvedt, normal Scandinavian autumn weather. Different religions thus ascribe different roles to water, many positive, a few perhaps more negative. As Douglas argues, this in part may be anchored in different risk cultures that inscribe water with powers to either manage or increase such risks. Affordances in this regard relate to wider risk cultures expressed as salvation beliefs.

4.2.2 Affordances of use 2: Bathing and purity

In the last section we have seen how water can play different purifying roles in ritual ceremonies and beliefs. Water can purify the soul and bring someone into a community; it can wash away sins, sometimes while it washes the body at the same time; it can heal illnesses of the body or the soul. Illich makes a distinction between the acts of cleansing and purifying. 'Water communicates its purity by touching or waking the substance of a thing and it cleans by washing dirt from its surface.' (Illich, 1986: 27)[12] He regards purity as referring to a quality of being while cleansing literally has to do with washing dirt off a surface and argues that purity and cleanliness are two totally different things with different histories. He suspects that 'senses of purity and cleanliness can change historically with considerable independence from one another' (ibid.: 35). However, he acknowledges that making a distinction between the two is not easy. In one and the same ceremony both activities can take place, as in the washing of the dead. As we will see, the notions of purity and cleanliness can be so closely connected, that it becomes very difficult and perhaps even unnecessary to distinguish them. In washing the dead in India, both purifying the soul and cleansing the body need water. Illich argues that purification does not necessarily require water; it can also be performed by dancing, meditation, and so on. In some periods water was even purposefully abandoned in order to maintain purity. Scientific arguments would often be included in and support the overall notions of purity and cleanliness in a certain period and place.

In this section I will give a taste of different attitudes towards bathing, cleanliness and water. As much of the literature acknowledges, a scarcity of sources on bathing behaviour exists (Squatriti 1998; Perrot 1987). And as mentioned in the introduction to this chapter, most of the information deals with the bathing habits of the privileged classes and leaves the lower classes out of consideration (Squatriti 1998).

Bathing as pleasurable social event: Ancient Rome

In ancient Rome bathing was an important aspect of social life. Squatriti writes: 'Among ancient societies, the Roman one was most noted for its willingness to allocate huge hydraulic resources to such unnecessary things as baths and bathing' (Squatriti, 1998: 5). The therms of Caracalla in Rome could host 2000 to 3000

[12] Goubert (1989: 51) makes another distinction: 'The rules of cleanliness are not necessarily the same as the rules of hygiene; the criteria for cleanliness are essentially cultural, whereas the basis of hygiene is purely scientific. If there is a difference between the social rituals of cleanliness and those created by the diffusion of hygiene, there is no need to cry shame or to parade outraged virtue. Each set of rituals belongs to a different system, even if they sometimes coincide.'

people at the time and around 100.000 a day (Tvedt 2001).[13] The therms were temples that celebrated the delights and blessings of water. Bathing in Roman times had a variety of functions. Going to the baths gave the opportunity to show one's status by taking a great number of people to accompany you to the baths. In the baths, beauty, especially for women, could impress the others as well. Bathing was also very much a social event where people could meet each other and discuss things. The amount of water brought to Rome by aqueducts was enormous (A.D. 97, 100 gallons of water per capita per day), especially compared to water that other cities had available centuries later (London, Frankfurt, and Paris 0.8 gallon per capita in 1823 and 10 gallons per capita in 1936) (Illich, 1986: 36-37). Sextus Julius Frontius who was in charge of Rome's water system in A.D. 100 was proud of it: 'With such an array of indispensable structures carrying so many waters, compare, if you will, the idle pyramids or the useless, though famous works of the Greeks' (ibid.: 37).

From recreational to cleansing baths: Middle Ages

During the Middle Ages the attitude towards bathing slowly changed. In the beginning bathing was principally seen as a continuation from the Roman times. Either secular or religious rulers built baths to show their richness. The elites wanted to visit the baths that were built by the ruler they supported. Baths continued to have a role as a meeting place. This was usually a meeting place for people from similar social statuses. Also the men and women were not mixed. 'Only outside the rigid atmosphere of the cities, in springs and natural pools, was mixed bathing sometimes attempted; but even then the very waters were liable to heat up and froth with rage to repulse the shameless attempt, as Cassiodorus related.'[14] For the women this was the only time and place they could be without supervision of men.

Next to being important meeting places, baths also had functions in terms of ritual and bodily purity. Examples of ritual purity are the 9th and 10th century baths for the Jewish population in Apulia. According to Squatriti these were maintained to 'facilitate ritual observances'.[15] At least in the higher classes bodily cleanliness was

[13] Squatriti (1998: 46) however states: 'The baths of Caracalla, most monumental of bathing complexes left by the pagan emperors, were themselves used as a *diaconia*, though not, it seems, for bathing'. This does not deny the existence of large public baths.
[14] Cassiodorus, *Variarum Libri Duodecim*, ed. T. Mommsen (Berlin, 1894), 2.38, p. 68. In: Squatriti 1998: 49.
[15] *The Chronicle of Ahimaaz*, tr. M. Salzman (New York, 1924), pp. 75-6. In: Squatriti 1998: 47.

valued. The bodily cleanliness one could get in the baths was different from what other water could do: '"Bright and delicate limbs," polished hands and face, free of the "impure water" one was liable to be splashed with in Lombard city streets, were marks of distinction' (Squatriti, 1998: 52). Baths can perhaps be regarded as sacred spaces where the water was purer, either because of the source or because of the bath itself, than the water outside the baths.

Bathing practices slowly changed. Whereas in Roman times servants washed the people who could afford that, from the 6th century on people started washing themselves. In monasteries monks washed each other's hands and feet only for ritual purposes, but they should never wash others in everyday circumstances.[16] Apart from cleansing and ritual purity, water had another purifying role: it was believed to restore or maintain health. Water from springs was believed to be most suited for this, since these were most therapeutic. Cassiodorus admired the gout-curing powers of the waters of Bormio and Isidore of Seville believed that the depressed would be relaxed and cured when they would visit the baths (ibid.: 55).[17] However, after the seventh century the springs' popularity and belief in their curative powers declined.

Despite the joys, or perhaps I should say because of the joys, of the baths, they had not been popular with everyone. Tacitus saw baths as bad for 'moral excellence' and others saw them as instruments of social corruption.[18] The Christian clergy continued this line of thinking. Public baths would lead to disorder and sexual excess. Bathing could also be unhealthy because the body got waterlogged. In the medieval literature baths were portrayed as places where murders and seduction took place and although people valued cleanliness, Squatriti states that public baths gained a reputation as fearsome places (ibid.: 59). Within walls of the monasteries semi-collective baths were built. In these baths the primary goal was cleanliness. Relaxation and recreation were no longer functions of these baths. Between 800 and 900 A.D. private domestic baths had also become more prominent. Not everyone could afford this and being able to wash oneself at home became a sign of prestige and of being a better Christian than the people who had to go to public baths (ibid.:

[16] *Smaragdi Abbatis Expositio in Regulam S. Benedicti*, ed. A. Spannagel and P. Engelbert (Siegburg, 1974), p. 247. In: Squatriti 1998: 53.
[17] Flavius Magnus Aurelius Cassiodorus Senator (490-585) was by turn statesman and monk and left behind a substantial body of literary work on politics, public affairs, and religion.
[18] J. Leclercq and F. Chabrol, "Bains" in *Dictionnaire d'archéologie chrétienne et de liturgie* (Paris, 1925), pp. 73-4. Tacitus *Agricola*, ed. E. De Saint-Denis (Paris, 1956), 21.3, p. 18. In: Squatriti 1998: 56. Also Perrot (1987: 13) mentions how bathing could give pleasures, something Christianity tried to ban.

62). People without baths found other ways to cleanse themselves. Wash basins in front of churches were often used to wash, both for bodily and ritual purity: 'The *labrum* in front of postclassical churches often had an inscription inviting the pious to wash their hands before entering, so that their prayers might be more acceptable'.[19]

Purity in place, water out of place: Sixteenth and seventeenth century

Perrot sketches a very different attitude towards water and cleanliness in the sixteenth and seventeenth century in France.[20] As in the later Middle Ages, nudity was something to be ashamed of and public baths were seen as places where diseases could spread or originate. If people took a bath, it was in private and often covered up. Being unwashed and dirty became a symbol of sanctity (Tvedt, 2001). In 1885 Freud writes: 'Dirty knees are a sign of a girl's virtue'.[21] A clean body was not considered morally right, because it wants to please. Bodily cleanliness is bad for the soul, whereas dirt is something innocent. In order to be 'pure' one had to be 'unclean'. In Japan, whorehouses were euphemistically called 'water houses'. The distinction between pure and unclean became more important as nudity became less acceptable and the smell that came with not washing was regarded as normal. Water was not only immoral, after the French Revolution it also explicitly stood for the distribution of wealth. Sweat was seen as a symbol for people who have to work hard.[22] In addition, water was considered unhealthy for the skin (Illich, 1986: 65). Illich (ibid.: 59) clarifies the relation of people to water:

> Until the 1930s, in many areas of France and England most infants' skins were carefully shielded from water and wiped only with a handkerchief moistened with their mothers' spittle. In many areas, more than half of the

[19] E. Diehl (ed.), *Inscriptiones Latinae Christianae Veteres* (Berlin, 1924), pp. 289, 298. In: Squatriti 1998: 63.
[20] Although the source focuses on France, there is reason to believe that this was the case in other countries as well. In any case, the source does help to show the variety in attitudes towards water and purity.
[21] Freud in preface to German translation of J. G. Bourke (1913). *Scatologic rites of all nations*. In: Perrot 1997: 28. This is my translation from Dutch.
[22] Chang (1997) describes a similar attitude to water in China in 1950. It was an unusual hot summer and farmers seldom washed themselves due to the lack of water. During the guerrilla war men and women had competed to see who had most 'revolutionary louses'. Cleanliness was regarded as non-proletarian.

> population had never taken a bath at the time they died. They were washed when they were born and again after death.

In some places there was a lack of water, but other places (the palaces of Fontainebleau, Saint-Cloud and Versailles) had an abundance of water which was only used for the king to show off. The water was for the eye and not for the skin. Louis XIV would usually have someone clean his face with a cloth with spirits. In 1671 a book was published in which instructions were given for how to wash children and why to wash them this way:

> [the children] have to rinse their face and eyes with a white cloth; the cloth removes the dirt while complexion and colour remain in their natural condition. Washing with water is harmful for the eyesight, causes toothache and inflammation of the mucous membrane, makes the face pale and more susceptible to cold in winter and sunburn in summer.[23]

In contrast with the earlier period, the materiality of water was regarded as harmful and as contrary to health, here defined not in spiritual but in hygienic terms. However, in an age where water was regarded as bad for the skin, Louis the XIV had, for health reasons, taken a bath once, in 1665. Apparently water was not entirely banned.

Washing as class distinction: Eighteenth century

In the eighteenth century the elite slowly started to use water for washing again. In 1816 Paris had 500 public bathtubs, in 1832 almost 4000, and in 1851 more than 2 million bathtubs existed in bath-houses, equivalent to two baths a year per person.[24] The baths were mainly reserved for the richer strata of society. The bourgeoisie became more and more sensitive towards the dirt of the lower classes; dirt and smell were no longer acceptable and washing and perfumes were used to keep the smell down. However, water was expensive and lower classes could not afford much. The aristocracy was much less interested in water than the bourgeoisie; for them water

[23] L. Bâle, J. Bertsche (1671). *Civilité Nouvelle*, p. 69. In: Perrot 1987: 16. This is my translation from Dutch.
[24] P. S. Girard (1832). *Recherches sur les établissements de bains publics*, p. 56 and A. Debay (1850). *Hygiène des baigneurs*, pp. 165-174. In: Perrot 1987: 118.

was not a means with which they needed to distinguish themselves. According to Illich smell became class-specific and social advance became connected with cleanliness. The only way to move into the better classes was by getting rid of body smell. The function of water was not (yet) the cleaning of the body inside out, as we will see in a moment, but served very much as a way to distinguish oneself by smell.[25] Illich (1986: 59): 'Water became a detergent of smell'.[26]

However, it was also still believed that washing was immoral and the trend towards water use as a sign of social status was very slow. People were still warned not to take too many baths. Some said no more than once a month, some once every two weeks where caution was given to weaker women who should not have a bath more than once a month (Perrot, 1987: 116). Taking a bath was subject to many precautions. After taking the bath one had to sit down and rub oneself dry with warm towels. If a sense of shame would prevent this, one had to put on a dressing gown and could close the eyes until this is done.[27] Another advice was to lie on bed for at least an hour and only slowly expose the body to the air, to prevent the open pores from contracting suddenly.[28] The cleanliness remained superficial, not every part of the body was being washed. The hands and feet were washed quite often (once a week), but the hair on the head was never washed. The hair could be massaged with egg-yolk in a bit of lukewarm water once every two months.[29]

Due to resistance towards washing and to the fact that part of the population could not afford taking baths, the majority of women still died without having taken a bath once in their lives in 1896. This would have been the same for men if they were not obliged to take a bath in the army.[30] This situation persisted until halfway through the twentieth century, both in the countryside and in the cities.[31] Especially religious schools did not manage pupils' hygiene through water, and indeed the notion of bodily hygiene was itself excluded from social disciplining. Even just

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[25] Chang (1997: 210) describes how water was used to distinguish high-ranked communists from other communists and ordinary people in China in the mid-twentieth century. To save water, only the high-ranked communists were allowed to use water. Water became therefore a status symbol.

[26] This is part of a broader development that Elias (2000: 421, 424) describes: 'This repulsion of the vulgar, this increasing sensitivity to anything corresponding to the lesser sensibility or lower-ranking classes, permeates all spheres of social conduct in the courtly upper class. (...) Over and again customs that were once "refined" become "vulgar"'.

[27] Madame Celnart (1833). *Manuel des dames*, p. 36-37. In Perrot 1987: 117.

[28] H. Raisson (1828). *Code de la toilette*, p. 201-202. In Perrot 1987: 117.

[29] Omnibus de la toilette (1828-1829), p. 5. In: Perrot 1987: 121.

[30] Vacher de Lapouge (1896). *Les sélections sociales*, p. 316. In Perrot 1987: 128.

[31] G. Thuillier. *Pour une histoire du quotidien*, 'L'hygiène corporelle'. In Perrot 1987: 128.

mentioning the parts of the body was a sign of loose morals. Nuns regarded washing a sin.[32] However, in Protestantism this was different. Here piety and cleanliness were one.

Slowly bodily cleanliness became an equivalent to morality and being a good person. This development falls together with the emerging movement of hygienists and scientific discoveries like Pasteur's about which we will read more in the next section. The first thesis on the need to wash dirt off children was published in 1843 (in France). It was however still only a question of washing the 'decent' parts of the body.[33] Only between 1910 and 1920, did the last connotations that relate washing with immorality disappear according to Perrot (1987: 137).

Cleanliness as lifestyle and accessibility

After the First World War there seems to be a more universal trend towards cleanliness. Washing with water became a virtue and a sign of modern living. In Aurora, Illinois, people could even be arrested if they didn't take a bath at least once a week (Tvedt, 2001). According to Hassan (1998: 54) rising standards of hygiene and cleanliness were made possible because of the water fittings that were installed in many houses: 'After 1919, the vast majority of new London houses were fitted with a heated water system operated by a back boiler in the living-room fireplace, or a slow combustion stove or gas circulator in the kitchen'. Both easy access to water and to warm water led to a much higher consumption in the 1930s and 1940s.

Conclusion

Washing and bathing are, like other activities around water, always embedded in social and political circumstances. In some contexts water afforded social status, in others it could work against this as we saw in late 18th century France. The material properties of the water do not define this relationship but are configured, intersect and help confirm diverse hierarchies, risk cultures and regimes of social control (as in schools and monasteries). Apart from, or perhaps better, implicated in such relationships, water may play a powerful symbolic role as purifier and healer, in some contexts (as in Lourdes) taking on spiritual, other worldly potency. In the next

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[32] Mr. E. Prévost (1903). *Le procès du 'Bon-Pasteur'*, p. 83. Perrot 1987: 129.
[33] E. Le Roy Ladurie, in: Goubert 1989: 5.

section I discuss the framing of water as an element that had/has specific material or physical properties, from pre-modern to modernist social context.

4.2.3 Affordances of use 3: Water and physical purity

Attention towards the physicality of water has always existed.[34] As the quote from the Bible shows in the first section of this chapter, it was perhaps believed that God took care of water quality in early times. In other societies this was certainly the case. In Nigeria, the gods and spirits of the Yoruba religion helped the local people in their search for 'good' and 'safe' water.[35] The inhabitants of Jericho complained about the taste of the water. Taste, smell and sight of water have for a long time guided people in finding drinking water sources (Goubert, 1989: 37). These physical and material properties of water and what has been regarded as good water quality are neither universal nor self-evident. They often depend on localised knowledge of water from a certain source and on (localised) theories about water and can become a matter of debate in cases where people try to convince each other of their being in the right. The concentration on physical aspects of water increased largely during the Industrial Revolution.

Taste, smell, sight: medicinal properties and class distinctions in Roman and medieval times

Squatriti shows that water quality was not always defined in the contemporary sense of the word, which will be discussed later in this chapter. Water purity and impurity were classified in terms of the use (for drinking, cooking, washing) and the source of the water. In this hierarchy, drinking water was highest. The classification was not universal; people had their own preferences:

> For the senior Pliny no water was better than that drawn up from a well; but Columella observed that spring water was best, well water second, and cistern water least acceptable. According to Macrobius the problems were greatest

[34] Although physicality of water is often intimately connected to for instance moral and symbolic purity, for analytical purposes I concentrate solely on physicality in this section.
[35] Awolalu, J. O. (1981) [1979]. *Yoruba Beliefs and Sacrificial Rites*. Essex: Longman Group Limited. Simpson, G. E., (1994) [1980]. *Yoruba religion & medicine in Ibadan*. Ibadan: Ibadan University Press. Both in: Rinne 2001, p. 1.

> for those who drank melted snow, for this type of water had lost its health-giving vapor and contained a predominance of solid, earthy elements.[36]

However, it is evident that some waters were seen as purer and healthier than others. Early medieval people judged the water quality or purity on appearance, feeling, taste, and smell; photo 4.1 (p. 131) shows that smell is still important in defining water quality. When discussing the contents of Ravenna's aqueduct in the fifth century,

> Cassiodorus distinguished between sweet-tasting water and tainted water which robbed the drinker of all appetite. He believed that clear water was pure and likely to make bodies limber, while opaque water was of lesser quality and was likely to congest the body and make its consumers sluggish. Dank and verminous water from wells horrified Tuscans at the turn of the tenth century and 'brackish' water appalled tenthcentury diplomats during their travels. (Squatriti, 1998: 36-37)

And Pliny the Elder himself wrote (1991: 276):

> I am surprised that Homer did not mention hot springs, although in other contexts he speaks of hot baths. The reason is that in his time medicine did not use hydrotherapy as we do today. Sulphur-impregnated waters, however, are good for muscles, and waters with an alum content for paralysis and similar cases of collapse; waters with bitumen and soda, such as those of Cutilia, are good for drinking and for internal irrigation.

That optical purity mattered can be gathered from the fact that in the eighth and ninth century local wells in Bavaria were often re-lined with wood to prevent the clay soil infiltrating the water (Squatriti, 1998: 36).

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[36] Pliny *Naturales Quaestiones*, ed. G. Serbat (Paris, 1972), 31.23, p. 42; Columella *Res Rustica*, ed. H. Boyd Ash and E. Foster (London, 1941), 1.5.1-2, p. 58; Macrobius *Saturnalia*, 7.12.25-6, pp. 452-3. In: Squatriti 1998: 37.

Original in colour

Photo 4.1: The smell-bell: also today relatively low-tech methods are crucial ways of informing people about the quality of water

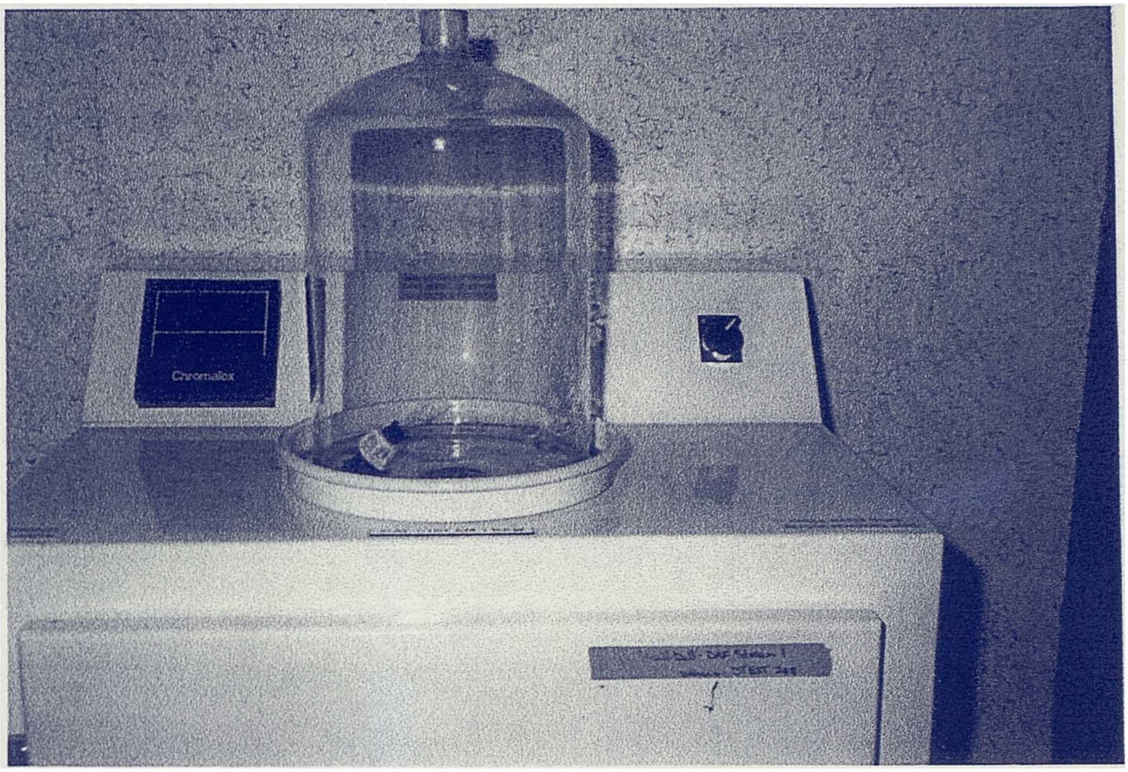
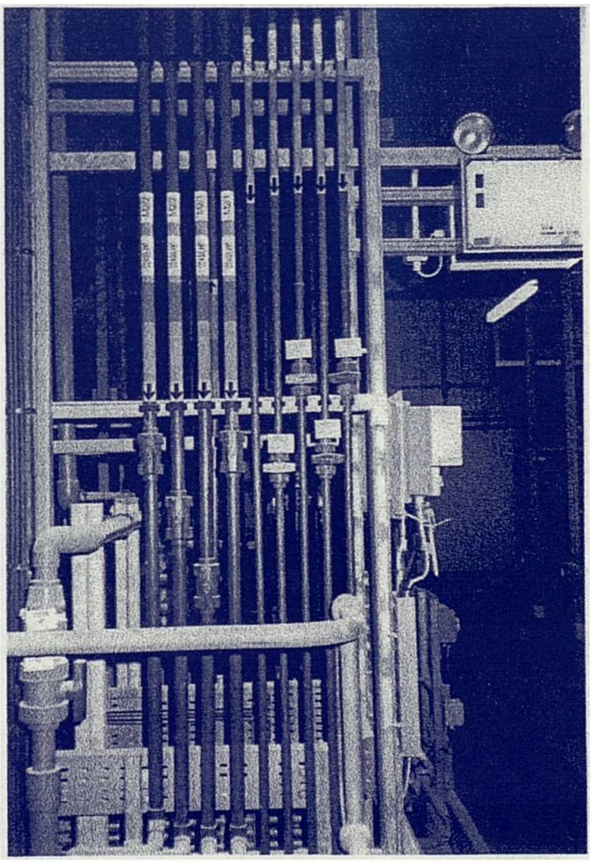


Photo 4.2: Automatic coagulant dosing: the low-tech (and mundane) co-exist with the high-tech (and perhaps exotic) to create quality assurance



If the water was clear, odourless and cold it was thought suitable for drinking. Its qualities were well known and some writers in antiquity did explicitly mention the (liquid) pleasures of the drinking of a glass of water:

> For Paulinus to drink cold water when he was thirsty was the perfect image of satisfaction, and for Sidonius the water of his special spring, so cold that on warm days it clouded with condensation the glass that held it, was unsurpassed delight, while for the sainted bishop of Ravenna the thirsty ought always to be refreshed with this precious liquid. (ibid.: 38)

Also in the middle of the tenth century some people praised the drinking of water: 'For Liutprand (...) nothing conveyed the sense of deep longing better than the human desire for a drink of cold water, a desire not everyone could fulfil'.[37] Despite these celebrations of water, available sources suggest it was not a very popular drink in either ancient times or the early Middle Ages. In the middle of the ninth century Lupus, abbot of Ferrières, said that he only drank water in emergencies when no wine or other alcoholic beverages were available. This water was then clear, 'drawn from a well or sparkling stream, not murky water from a cistern'.[38] In other sources Squatriti consulted, military elites could be humiliated by having to drink water and rulers would drink wine instead of water. Water was only acceptable if it was cold, because cold water was different from normal water and showed men's powers over nature and the rulers' power over their subordinates. Pliny already noted that 'people ascribe class connotations to water, in itself a neutral liquid, by consuming 'improved' or unusual waters for which they have paid'.[39] Improved here means either chilled or mixed with wine, parsley seeds or vinegar. Hippocrates had announced that 'the very finest water' could not be drunk unless a little wine was added.[40] Water also had some medical connotations. In monasteries water was believed to cause wild dreams and fits: 'a rush in the veins, vertigo, sleepiness, cold in the marrow, headaches, and sneezing assail the water drinker'.[41] However, if water

[37] Liutprand of Cremona, *Antapodosis* 5.23, p. 144. In: Squatriti 1998: 38.
[38] *Epistolae*, ed. E. Dümmler, *MGHEpistulae* V.1 (Berlin 1902), 109, p. 94. In: Squatriti 1998: 36.
[39] Pliny, *Naturalis Historia* 19.19.55. In: Squatriti 1998: 38.
[40] Hippocrates, *Airs, Waters, Places*, tr. G. Lloyd, in: *Hippocratic Writings* (Harmondsworth, 1978), p. 152. In: Squatriti 1998: 42.
[41] *Regula Magistri* 27, p. 144. In: Squatriti 1998: 39. Squatriti suggests that this might have been influenced by the ancient medical notions that related the production of sperm with 'wet' substances.

was drunk in moderation or mixed with other drinks, it was believed to be less dangerous. Squatriti, at this point, states again that water was quite invisible and that if we knew more about the daily life of even these higher classes, we might well find out that they did drink the water anyway.

The physical characteristics of water and therefore of water purity was clearly appreciated in various ways: some water was believed to be more healthy and tasty than other water. The need to focus attention to *physical* purity of water became unavoidable during the Industrial Revolution.

Industrial Revolution

> It was a town of red brick, or of brick that would have been red if the smoke and ashes had allowed it; but as matters stood it was a town of unnatural red and black like the painted face of a savage. It was a town of machinery and tall chimneys, out of which interminable serpents of smoke trailed themselves for ever and ever, and never got uncoiled. It had a black canal in it, and a river that ran purple with ill-smelling dye. (Dickens, 1995 [1854]: 28)

This quote comes from the novel *Hard Times* by Charles Dickens in which he describes Coketown, an industrial city situated in the north of England.[42] Many historical sources portray the physical purity of water as deteriorating very quickly during the Industrial Revolution. The Industrial Revolution that took place in nineteenth century Britain had a huge impact on water sources, supply and demand. For the first time a large number of people lived in cities whose population grew rapidly. Domestic and industrial waste was deposited in rivers which would conveniently take it away from the cities. There were other descriptions of rivers. The Mersey, near Warrington, was described as 'black as ink at most times, and most offensive in smell'; the Wear at Durham was 'simply a gigantic cesspool...emitting a stench vile enough to generate a pestilence'; and Bourne, where it emptied into the Wear, was 'at times... as yellow as ochre and as thick as glue...' (Wohl, 1983: 235-236). In London, the stench was so bad that, during the summer of 1859, the courts could not sit and sheets soaked in chloride of lime had to be hung from the windows of the committee rooms in the Houses of Parliament. In 1868, a committee studying

[42] It is believed that Coketown stands for either Manchester or Preston.

river pollution 'received a letter, the writer of which considered it useful to point out that he had written it not with ink but with water from a river in Yorkshire!'[43]

Some artists sought to reflect these circumstances in their work, as Dickens did, and as this poem, read before the Leeds Philosophical and Literary Society in 1857 shows:

> The AIRE below is doubly dyed and damned;
> The AIR above, with lurid smoke is crammed;
> The ONE flows steaming foul as Charon's Styx,
> Its poisonous vapours in the other mix.
> These sables twins the murky towns invest.
> By them the skin's begrimed, the lungs oppressed.
> How dear the penalty thus paid for wealth;
> Obtained through wasted life and broken health.
> (Poem by William Osburn, in: Briggs, 1965 [1963]: 137)

Not surprisingly perhaps, many artists kept referring back to better waters. They retreated from confronting the issues of the day, taking refuge in beautiful realms of their own creation, filled with nostalgia for the past. In the words of Bendiner (1985: 2):

> The modern social issues of industrial Britain had a profound influence on Victorian painting, motivating not only artists who depicted the problems of the age directly, but also those who sought to escape through the dreamworlds of classicism, medievalism, or orientalism.

Even in times when the physical purity of water seemed to have deteriorated, symbolic purity kept its place. The idea of naturalness might even have been enhanced by the increasing sense of pollution of the waters: we have lost the innocence of nature and now need to recapture that. Notions of naturalness and purity were not reconfigured because of pollution. In fact, rivers were seen as being naturally pure, thus sewage polluted them (Porter, 1998: 19). The works of art that address these issues can thus be seen to be addressing polluted rivers as 'matter out

[43] Pierre Boutin (1984) 'Points de repère pour une histoire de l'assainissement', CEMAGREF, BI, 314-15. In: Goubert 1986: 59.

of place' to use Douglas' notions of purity and pollution once again. Polluted rivers were not seen as pure or natural.

Before it became routine to deposit domestic waste in rivers, people had left the domestic waste in the city. However, according to Wohl, immorality became linked to physical impurity. One could not pretend to be clean and pure if the physical surroundings were not clean and pure:

> Before a man could become 'a good son, husband, or citizen, I almost dare say, or Christian, his home must be made clean, the impurities by which he is surrounded, removed.'[44]

If the diagnosis was that immorality was rooted in a proximate physical impurity, then, according to Wohl (1983: 7), 'the remedy, the preventive medicine, called for the abolition of evil through abolition of dirt and disease':

> To Charles Kingsley, who encouraged men and especially women to equate cleanliness with godliness, the formula for social progress was obvious. The social state of a city depended on its moral state and 'the moral state of a city depends...on the physical state of the city; on the food, water, air and lodgings of the inhabitants'.[45]

Thus, the waste had to be removed from the city and the most convenient way was dropping it in the river which would take it away. Given the moral framework of Victorian discourse, it was perhaps inevitable that 'an intemperate and ill-disciplined way of life' became seen as one of the factors disposing individuals to cholera, and 'personal moral strength and resilience in adversity' were regarded as the key determinants of who would survive an cholera epidemic (Luckin, 1986: 64-65). It was however not only moral purity that made pollution of the rivers acceptable and favourable over keeping the waste in the cities. The scientific theory at the time, the miasmatic theory, had the same consequence. The miasmatic theory was the scientific explanation for the spreading of diseases at that time. Bad vapours which could arise from, among others, heaps of waste were sources of disease. These

[44] H. Gavin (1847). *The Unhealthiness of London and the Necessity of Remedial Measures*, pp. 65-66. In: Wohl 1983: 8.
[45] C. Kingsley (1860). "Great Cities and their Influence for Good and Evil", *Miscellanies*, II, pp. 321, 328. In: Wohl 1983: 7.

vapours distribute themselves through the air. It was thus important to get rid of the waste as soon as possible. In 1842 Sir Edwin Chadwick had presented his *Sanitary Report* on the sanitary conditions of the working classes in Great Britain. It was only after that report that people started to fully recognise the problems of supplying water to cities. Chadwick propagated the view that water had to circulate through the city and leave it as dirty sewage.[46] The main objective was to get rid of the waste in the city since that caused illness in densely populated areas. The miasmatic theory had a strong appeal to people: 'Despite the work of Snow on water-borne cholera (...) the fact remained that death rates *were* declining and so polluted water did not appear to be particularly hazardous' (Wohl, 1983: 239). Even after Koch had identified the cholera bacteria, many stuck to the miasmatic theory.

The water that had supplied the cities thus far became insufficient in terms of both quantity and quality. Since industrialisation the demands for water had increased. Local supplies were not sufficient and they were polluted as well. Often river water was regarded as so polluted as to become 'utterly unsuitable' for manufacturing purposes (Hassan, 1998: 20). Domestic consumers in London complained about 'finding 'leeches' in their water, as well as 'small jumping animals that looked like shrimps', 'an oily cream', a 'fetid black deposit', etc.' (Goubert, 1986: 42).

According to Sheail (1997) the industrialised parts of Britain were among the earliest to experience large-scale water pollution.[47]

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[46] Illich 1986: 45; Goubert 1986: 42; Wohl 1983: 239. Illich (1986: 39-40) argues that the whole idea 'of a 'stuff' that follows its destined path, streaming forever back to its source, remained foreign even to Renaissance thought. Harvey's concept of 'circulation' represents a profound break with the past.' The connection between water and circulation had not been made before. Before Harvey the 'circulation' of a liquid meant what we call 'evaporation': the separation of a 'spirit' from a 'water'. The idea of a material that flows forever back to its own source constitutes a major innovation in the perception of water, a transubstantiation of its 'stuff'. But 'neither the radical newness of the idea of circulating "stuff" nor its impact on the constitution of modern space has been studied with the same attention that was given to Kepler's laws or to the ideas of Newton, Helmholz, Darwin, or Freud'.

[47] The rest of Western Europe followed later and encountered the same problems as the following poem about the Rhine in 1828 by the poet Coleridge illustrates. In: Goubert 1986: 42-43.

In Köln, a town of monks and bones
I counted two and seventy stenches,
All well defined, and several stinks!
Ye Nymphs that reign o'er sewers and sinks,
The river Rhine, it is well known,
Doth wash your city of Cologne;
But tell me, Nymphs, what power divine
Shall henceforth wash the River Rhine?

The supply of water to manufacturing industry was often extremely poor, only one-fifth of all commercial and industrial enterprises in Manchester, for example, being customers of the local company in 1845 (Hassan, 1998: 20). For the local population the water supply was bad as well. In most cities the piped supplies were restricted to one part of the town: in 1837 only about one-third of Bradford's 35,000 population was receiving regular supplies, and water carts still provided a door-to-door service in the less fortunate areas (Smith, 1972). However both the demand from industry and a growing awareness of the importance of a wholesome water supply in relation to public hygiene and sanitation demanded a solution to the problem. Perhaps for the first time, the physical properties and supply of water became a matter of both government and governance: the industrial and urban development required state intervention to manage and discipline the provision and use of water.

Before the industrial revolution very few towns received piped supplies at all. Most communities relied on rough and ready means of obtaining water from local streams or wells, supplemented perhaps by a public fountain or conduit (Hassan, 1998: 16). Now the water was regarded as so polluted that the water supplies for the cities had to come from elsewhere. As a result of reports as made by Chadwick and others, the public health movement became strongly identified with the search for new sources of potable water in the moorland valleys which surrounded many of the industrial towns. Manchester Corporation was greatly influenced by the Chadwick report and initiated the first of the large upland impounding schemes. Confidence in the purity of upland sources was reflected in Manchester's decision to send Longdendale water, arriving from the Pennines from 1851, unfiltered into the city (Hassan, 1998: 22; Porter, 1978: chapter 3). The only precautions initially taken were the building of deep reservoirs to inhibit the growth of vegetation and the straining of water through fine wire gauze before admitting it into inhabitants' houses. In similar circumstances, water authorities strove to protect gathering grounds from contamination by sheep, and to generally restrict human activity there. Slow sand filters had already been used since the 1820s when water was abstracted from rivers.[48] The Pennines were also exploited by Lancashire and Yorkshire. In the 1880s Liverpool Corporation obtained a large supply from the Vyrnwy valley in North Wales. The trend towards long-distance piped supplies is well illustrated by Manchester Corporation. Around 1875 the growing demand threatened to overtake the available supply from the Longdendale works in the Etherow valley and, in 1879, Parliament authorised the use of the natural storage afforded by Lake Thirlmere at around 161 km (100 miles) distance in the Lake District. In 1923 Manchester took over Haweswater some 129 km (80 miles) from the city, and so became the largest undertaking dependent on surface supplies in the country. To safeguard the purity of the water, most authorities purchased the gathering grounds around the reservoirs and prohibited public access to large areas of upland Britain.

Roberts (2001) shows that these large engineering projects were not necessarily logical solutions to the problem of water supply. Instead they were the outcomes of intense political debates. He argues, with Hassan, that there were arguments in favour of upland water that had little to do with public health, one of them the need to have soft water for industry. However, most of the debates centred on water purity and public health. Some people in Liverpool and Birmingham claimed that 'Welsh water generally tended to be peatier and dirtier than that which came from England' (ibid.: 5). Water with a high peat content could lead to diarrhoea. The purest water could be retrieved from deep under the city or from local wells. Their opponents promoted other notions of water purity: the minerals in the well water filled the pores of people's skin with 'insoluble greasy and curdy salts'.[49]

The Victorian notion of purity was linked to a nearness to God and to a notion of being morally good as we have seen before. The technical achievements to provide clean water to the cities were part of this. Religious leaders would bless the new water systems and the way in which these systems could deliver the water in its pure state. A nice example of this is a painting of the Archbishop of Canterbury blessing the new water system in Croydon, in South London. So, although cleanliness of the city was considered very important and pollution of the rivers was a consequence of this, the Victorians also thought that a supply of clean pure water was the cornerstone of a civilised society.

Despite the admirable technical achievements, there were debates about pollution. Not everyone could agree about the extent to which the rivers were polluted. As late as the beginning of the new century the Clerk of the West Riding of Yorkshire Rivers Board sadly reflected that among the public there remained 'the still lingering belief born of long usage that the flowing streams are the natural

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[48] See Luckin (1986) for a historical overview of the discussion about the use of sandfilters.
[49] *Liverpool Mercury*, 14/8/1878. In: Roberts 2001: 5.

means for carrying away the off-scourings of the population'.[50] The Metropolitan Water Supply Act of 1852 is an example of this. Despite the Sanitary Report of 1842 and a survey carried out by the General Board of Health in 1848, the Metropolitan Water Supply Act did not follow the recommendations issued by the General Board of Health to extend the London water supply. Three chemistry experts who were consulted about this in 1851 thought the measure unnecessary: 'The river may reasonably be supposed to possess, in its self-purifying power, the means of recovery from amount of contaminating injury equal to what is present exposed to its higher section'. They were positive that the oxidation would lead to disappearance of the contamination.[51]

One very prominent cause for the growing awareness of both the inadequacy of existing laws and the increased pollution was the mounting concern for the industry and sport of fishing (Wohl, 1983: 246). However, there was a lot of disagreement concerning the effects of industrial and human waste upon fish. In 1864 the Royal Commission on the Pollution of Rivers had been founded. The Commission expressed great concern for the future supply of water for drinking and industrial purposes (ibid.: 236). Untreated sewage was dumped into the rivers and 'the great irony of the Chadwickian revolution was that as they became 'more fully sewered and drained [they] pour out continuously a much larger proportionate volume of sewage'' (ibid.: 233). The commission did not focus specifically on industrial pollution. The textile industry, the mines and the leather industry were seen as heavy polluters, but 'compared with all the ebb and flow of human excrement, dead cats, and flotsam and jetsam of discarded objects, the industrial pollution of rivers was understandably not seen as a major problem. It was after all, just one of many polluting agents' (ibid.: 234).[52] They tried to promote sewer farms, but these required money and advanced technologies.[53] The miasma theory demanded a quick removal of filth, 'common sense' dictated it, and countless reformers and public

[50] *Interim Report of the Commission appointed in 1898 to Inquire into Treating and Disposing of Sewage II. Minutes of Evidence* (1901), p. 62. In: Wohl 1983: 239. Also Goubert states that 'it was not until the end of the nineteenth century that the measures implemented brought about a significant improvement in the quality of the water supplied and that the complete reliance ceased to be placed in the self-purifying capacity of rivers' Goubert 1986: 46. See also Hamlin (1990: 78) on self-purification abilities of water.
[51] *Report on the chemical quality of the Supply of Water to the Metropolis,* B.P.P. (1851), XXIII, pp. 9-10. In: Goubert 1986: 46.
[52] The importance of domestic and industrial waste was heavily debated. Also Smith (1972) and Hamlin (1990) disagree about the significance of domestic and industrial waste.
[53] According to Hamlin (1990) some people argue it was the political will that was lacking whereas others suggest that the proper technology was lacking.

servants enthusiastically advocated it. It seemed clear that on balance dumping sewage into the rivers saved far more lives than it took in the occasional outbreak of typhoid or even the rarer cases of cholera. Only very rarely did fatalities stimulate a debate on river pollution and expedite sanitary reform. Wohl (ibid.: 240):

> Although the general attitude that utilization of the rivers for industrial and human waste removal prevented far more deaths and illnesses than it could possibly cause was a powerful deterrent to reform, an even stronger deterrent lay in the cost to the ratepayer and to industrialists of the improvements called for by environmentalists.

The arguments of the Commission did not gain much support. There did not seem to be any immediate benefits from the control of river pollution, but people could loose their jobs and the industrialists argued that there was no other way to get rid of their waste products and that control of river pollution would be bad for the economy. Throughout the last quarter of the century, the slowly developing legislation to control river pollution reflected sensitivity to manufacturing interests (ibid.: 242). Other laws would cause irreparable damage to the economy (Luckin, 1986). Another problem for the Commission was that in 1864 the pollution of rivers was considered to affect only private rights and so only individuals could sue and that was expensive. Proving who caused the nuisance was difficult.

When the Commission wanted to set some chemical standards for purity and pollution levels, this was ridiculed in Parliament (Wohl, 1983: 248). Different sets of experts would usually come to opposite conclusions. Distrust of 'expert' scientific advisers dominated the legislative mind. In parliament many people believed that one could decide by common sense how bad the pollution of a river was. Salisbury agreed with the commission that they could not do completely without experts but he hoped to have as little as possible to do with them. Instead of definite standards, the phrase: 'best practicable and available means' was again introduced.

Conclusion

In the preceding discussion, I have illustrated the ways in which the physicality of water became, in different circumstances, a focus for societal regulation. It is clear however that, as in the brief commentary in regard to the Royal Commission, competing (economic and political) interests determined how such physicality performed to shape water regulation itself. In the next section, I shall consider the affordances of use provided by water, but here in regard to conceptions of water purity for drinking.

4.2.4 Affordances of use 4: Drinking of water/drinking water purity

The section on taste, smell and sight showed that the physicality of especially drinking water has always played a role in people's day-to-day life. Developments during the Industrial Revolution reinforced this and urged people like Edwin Chadwick to seek attention for the quality of water: 'At the end of the eighteenth and the beginning of the nineteenth centuries, the theory that 'miasmas' caused serious illness hastened the construction and even the completion of some water supply systems' (Goubert, 1986: 45). However, whereas the quality of drinking water had long been determined by pointing to the source where the water came from and the medicinal properties of the water, slowly drinking water quality started to be dictated by a focus on the chemical and bacteriological composition of the water. Illich describes how bacteriology changed both scientific theories and people's expectations of drinking water. Koch's theories of bacteriology 'tended to replace the old filth-theory of corrupting emanations with a new germ-theory that seemed to explain the appearance of specific diseases. Instead of contact with foul airs, bodily invasion by microbes was the thing to be avoided. Citizens demanded, above all, to be supplied with 'germless drinking water' when they opened their taps. During the first half of the twentieth century, several generations of Americans learned to abstain from drinking water unless it came from an approved faucet or bottle' (Illich, 1986: 74-75).

The practices of drinking water were not only determined by (scientific) judgements of the quality of the water. As with bathing, other social and political values played a role as well. As Hamlin argued: 'there was no clear relationship between scientific discovery and political and technical action' (in: Burnett, 1999: 23). The scientific evidence itself was sometimes conflicting and could be manipulated by resisters to change, especially by those who represented the interests of invested capital. But before I focus on the practices around drinking water, I will first give a summary of various attempts to develop a science of water. This science of water parallels and contrasts with religious notions of purity.

Water as material object in ancient Greece

We have seen a historical account of symbolic and physical contexts of water, but the question of what water *is* has not been addressed. Not surprisingly, history shows us a variety of waters. Water has not always been (seen as) H_2O (and indeed such a scientific reductionism does not encompass contemporary notions of water). In ancient Greece water was considered as one of the essential elements of which the world was built up. Thales of Miletus (c.620-c.555 B.C.) believed that the physical world was constituted of only one fundamental substance: water (Ball, 2002b: 7).[54] He argued that the nutriment of all things is moist. Aristotle later suggested that Thales might have been influenced by older theologies wherein water was the object of adjuration among the gods. But despite that, evaporation suggests that water may become mist or air whereas with freezing water may become earth.[55] Therefore water was a likely candidate for being the primal substance. However, others at the time argued that the primary substances were air or fire. Anaximenes believed it was air, and air can turn into fire. Anaximander argued that 'water or the moist was itself one of the 'opposites', the conflicts and encroachments of which had to be explained.[56] If change, birth and death, growth and decay, are due to conflict, to the encroachment

[54] Also in the seventeenth century similar views were held. John Baptist from Helmont (1580-1644) believed for example that 'water must be the primary matter, since the waters were mentioned in the Bible as the primeval chaos antecedent to the rest of the Creation. Such a view he thought confirmed by an ingenious experiment. He planted a willow cutting, weighing five pounds, in a tub containing two hundred pounds of earth and watered the cutting for five years after which it had become a tree weighing one hundred and sixty-nine pounds, the weight of the earth in the tub remaining unchanged. Helmont argued that as water only had been added to the tree, its increase in weight must be due to assimilated water which had become transformed into wood.' (Mason, 1960: 234-235). Brock (1992: 50) adds: 'Additional supporting evidence came from the fact that fish were nourished 'solely' by water, that seashells were found on dry land, and that solid bodies could be transformed into 'savoury waters', that is, into solution.'

[55] Metaphysics, Aristotle, in: Copleston, 1993: 22-23. Also others argue that Thales of Miletus may have been influenced by older theologies. Mason (1962: 25-26): [on his travels he] 'doubtless came across the creation stories of the Babylonians and the Egyptians, in both of which water featured as the primeval chaos, for he supposed that all things came from water in the beginning. The earth, he supposed, was a cylinder or a disc with waters below, on which it floated, and with waters above, from which the rains came.'

[56] Others state that Anaximander believed that water was the origin of life: [mit] 'der weit vorausschauenden Einsicht, dass sich Lebem in Wasser entwickelt hat' (Pleger, 1991: 62). Because of this he is by some regarded as a precursor of evolution theory. Mason (1962: 26-27): 'Anaximander believed that living organisms had arisen from elemental water and that the higher animals had developed from the lower: 'Living creatures rose from the moist element as it was evaporated by the sun'.' Ricken (1988: 22): 'Die Lebewesen sind, hier kann Anaximander am Thales anknüpfen, im Feuchte entstanden (...). Im weiteren Verlauf

of one element at the expense of another, then –on the supposition that everything is in reality water – it is hard to see why the other elements have not long ago been absorbed in water' (Copleston, 1993 [1962]: 24). According to him the primary element is indeterminate. According to Toulmin and Goodfield (1982: 48-49) it was the materiality of the water that turned Anaximander against Thales:

> It was in many ways indeterminate: colourless, tasteless, transparent and without any shape of its own. Yet it could easily be given both a colour and a taste, and it would take the shape of any vessel into which it was poured. At this point the difficulties began. Any unique 'basic stuff' must have the powers both of a chameleon and of a magician. The trouble was that even water could not be sufficiently versatile. As Werner Heisenberg still points out, a 'universal stuff' can be satisfying to the intellect only if it is entirely devoid of *all* individual properties of its own. And in that case (as Anaximander retorted) it could not even be 'water'.

There was a debate or at least a variety of beliefs about the origin and changeableness of matter. Thales and also Anaximenes, as stated above, believed that one kind of matter (water) could become another kind of matter (ice and thus earth). Parmenides on the other hand, believed that 'Being, the One, *is*, and that Becoming, change, is illusion. For if anything comes to be, then it comes either out of being or out of not-being. If the former, then it already is – in which case it does not come to be; if the latter, then it is nothing, since out of nothing comes nothing' (Copleston, 1993: 48). So, change is impossible. It was Empedocles (c.490-c.430 B.C.) who postulated the four elements, earth, air, fire, and water that were to become so important in Western natural philosophy and later also in art and literature.[57] Like Parmenides, he held that one kind of matter cannot become another

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der Entwicklung siedeln sie auf das Festland über (...). Wir finden bei Anaximander die erste Ansätze einer Evolutionstheorie'.

57 In China, the primary 'elements' or principles which produced all things by their interaction were what were termed the Yin and the Yang. 'The Yin was the passive, dark, and female force, while the Yang was the active, light, and male force. These two principles came from a primordial mixture of matter and energy in the form of a fluid in gyratory motion. Such a kind of motion separated out that which was dark and heavy from that which was light and fine, the former giving rise to the earth and the Yin principle, while the latter became the heavens and the Yang principle. The interaction between the two principles then produced the five elements, water, fire, wood, metal, and earth. First came water and fire which were largely Yin and Yang respectively in composition, then came wood in which Yin was slightly predominant and metal containing a small excess of Yang, while finally came

kind of matter. There are eternal and fundamental kinds of matter or elements: earth, air, fire and water:

> Earth cannot become water, nor water, earth: the four kinds of matter are unchangeable and ultimate particles, which form the concrete objects of the world by their mingling. So objects come into being through the mingling of the elements, and they cease to be through the separation of the elements: but the elements themselves neither come into being nor pass away, but remain ever unchanged. (ibid.: 62)

Both Plato and Aristotle believed that elements could change. However, they had very different concepts of the elements. Plato (c.428- c.348 B.C.) did not believe an exact scientific account of the world was possible, but his geometrical inclinations led him to propose that the elements had regular, mathematical shapes, triangles: the polyhedra called regular Platonic solids. Earth was a cube, air an octahedron, fire a tetrahedron (pyramid) and water an icosahedron. These bodies are so small that no single one of them is perceptible by us, though an aggregate mass is perceptible. The elementary solids or particles may be, and are, transformed into one another, since water may be broken down into its constituent triangles under the action of fire, and these triangles may recombine in space into the same figure or into different figures (Copleston, 1993: 250, Toulmin and Goodfield, 1982: 76). Since the four elements are constantly changing, they cannot be said to be substances. Plato preferred to call them qualities.[58] It is important to remember that the ancients saw elements as types that cannot be too closely identified with particular substances. When Plato speaks of water the element, he does not mean the same thing as the water that flows in rivers. River water is a manifestation of elementary water, but so is molten lead. Elementary water is 'that which flows' (Ball, 2002b: 15).

Aristotle's (c.384–c.322 B.C.) natural philosophy did not use geometrical shapes. His ideas followed from the earlier Greek philosophers, in particular those of

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earth in which the two principles were balanced. The continued interaction of the two principles produced a further differentiation into all the objects of nature, the 'ten thousand things' of the world.' (Mason, 1962: 76)

[58] This is slightly confusing since the four elements (fire, earth, air, and water) are usually characterised through combinations of two of the four qualities (warm, dry, cold, moist):

Fire	Warm	Air
Dry		Moist
Earth	Cold	Water

Anaximander. Like Anaximander, Aristotle believed that there was only one primal substance, but it was too remote, too unknowable to serve as the basis for a philosophy of matter. So he accepted Empedocles' elements as a kind of intermediary between this imponderable stuff and the tangible world. Aristotle shared Anamixander's view that the qualities heat, cold, wetness, and dryness are the keys to transformation, and also to our experience of the elements. It is because water is wet and cold that we can experience it (ibid.: 9).

> 'Air, for instance, *is* air, but *can become* fire. It has the form or *actuality* of air, but has also the *potentiality* of becoming fire. But it is logically necessary to presuppose, prior to the potentiality of becoming fire or any other particular and definite kind of thing, a potentiality of becoming at all, i.e. a bare potentiality.' (Copleston, 1993: 307-308)

The four elements have played and do still play a big role in western culture. The Canadian writer Northrop Frye writes: 'The four elements are not a conception of much use to modern chemistry-that is, they are not the elements of nature. But... earth, air, water and fire are still the four elements of imaginative experience, and always will be' (Ball, 2002b: 13).[59] The elements have persisted throughout time also in science, at least until the end of the 17th century. Around that time 'modern' analytical chemistry was born. Water analysis started in the seventeenth century with analysing spas, and the perspectives developed there carried over into the potable water analysis of the second half of the nineteenth century. As often in science, the road towards water analysis was a bit bumpy.

Water and chemical science

In 1774 oxygen had been discovered by Joseph Priestley. However 'Priestley is perhaps best regarded as the *last* person to discover oxygen, for others had reported its preparation but had not realized that it was an element. The Swedish chemist Karl

[59] Ball (2002b: 24-25) makes an interesting comment about this: 'Until the twentieth century, scientists had no idea why there should be so many, nor indeed why there should not be thousands more. The elements cannot be deduced by casual inspection of the world, but only by the most exacting scrutiny using all the complicated tools of modern science. This is why, perhaps, some people would like to stick with earth, air, fire and water. They are not the elements of chemistry, but they say something resonant about how we interact with the world and about the effect that matter has on us'.

Scheele in fact discovered oxygen two years before Priestley, but delays in publication lost him the priority he deserved' (Atkins, 2001: 62). The question who can claim responsibility for the scientific achievement is not straightforward; in the literature the debate about the discovery of water (as H_2O) is referred to as the 'water controversy'. Ball (2002b: 27) acknowledges that there is still a debate about who discovered oxygen. Many believe that it was Lavoisier who gave the element its name although he was not the first one to make it nor to recognise it as a distinct and important substance. Also the discovery of both hydrogen and water as H_2O seems to be debated. Atkins (2001: 62-63) argues that 'hydrogen had been prepared long before it was recognised as an element by the eccentric misogynistic recluse and chemist Henry Cavendish'. According to him, it was also Cavendish who in 1781 argued that water, 'which is formed when the two gases are sparked, is not in itself an element' (ibid: 63). Mason (1962: 310) states that Cavendish repeated Priestley's experiment and discovered that water was produced by the union of one volume of oxygen with two volumes of hydrogen: 'His result implied that water was a compound of hydrogen and oxygen, not an element, but Cavendish refused to accept the implication'. Ball (2002b: 29) states that it was Lavoisier who concluded in 1783 that water 'is not a simple substance at all, not properly called an element, as had always been thought'. He named the constituents of water 'hydrogen' ('waterformer') and 'oxygen', which combine in a two-to-one ratio reflected in the familiar chemical formula H_2O. Chemical bonds link each atom of oxygen to two atoms of hydrogen in water, and only a chemical reaction will separate them.

Miller (2002: 149) takes a step back and does not treat 'discovery' as an event but as the 'outcome of an after-the-fact process of attribution of credit'. In the footsteps of Thomas Kuhn he discusses the fact that if discoveries were natural events, then it should be straightforward to find out what really happened. However, there is no context-independent way to favour one story about the real discoverer over another. Miller (ibid.: 170) shows that different ideas about what constituted the discovery of water were at stake; 'proceeding 'scientifically' was seen by both sides of the controversy as a crucial characteristic of a discoverer. Where they disagreed was in what it meant to so proceed'. He contextualises the 'water controversy' by showing the discussion between the different sides about what they regarded as proper science. Was it more important to do the experiments properly or to come up with thorough theoretical reasoning about what happened in the experiments? Should Watt be the discoverer since he was the first to write down his ideas whereas

Cavendish's claims had been orally communicated? Was it important that a good researcher had received good training in a well-respected institute? Miller shows that who should be regarded as the discoverer of H_2O depends on the question one asks:

> If the question then be, who reformed the expressions and logic of chemistry, or who furnished the simple terms in which we now state the elements of water? The answer is, Lavoisier; but if it be, who discovered and unfolded the most important facts on which that reformation relied? Who detected and proved the composition of water, and deduced the train of corollaries which flowed from it? The answer is, Cavendish.[60]

Goubert (1986: 35) does not get involved in the debate about who discovered what. He just explains that several people in Britain and France conducted similar experiments which resulted in the idea that water was a combination of oxygen and hydrogen. For this section the important thing is to remember that people started regarding water as H_2O. As we will see, this definition of water became relatively dominant over other definitions of water and has therefore had a large impact on contemporary practices and regulations around water and water quality.

The second half of the 18th century was the age of 'pneumatic chemistry', when the properties of gases, typically called 'airs', were the focus of the discipline. Many 'airs' (hydrogen chloride, ammonia, etc.) were isolated, but initially these compounds were not seen as compounds in their own right. 'The legacy of Aristotle's elements was still strong, and the 'pneumatick' chemists preferred to regard each gas as 'common air' altered in some manner, for example, in states of greater and lesser purity.' (Ball, 2002b: 34) The same was true for water. Water had been regarded as an element and principle and something that was thought of as having several qualities and uses instead of greater and lesser purity. Water that was impure for drinking purposes (stagnant pond water) might have been regarded as excellent for dyeing, bleaching or tanning (Hamlin, 1990: 78).

Lavoisier came to two conclusions that were different from what the Greeks had believed. Firstly, in 1773 he published an essay that argued that substances could change their physical state without changing their elemental composition. Ice is not water turned to 'earth' – it is frozen water. The same body (of the same chemical nature) can pass through the physical states of solid, liquid and gas. Secondly, of the three contenders for the discovery of oxygen, it was Lavoisier who was the first one to come to understand that this 'pure air' was actually a substance in its own right and that as a consequence of that air itself was not elemental but a mixture (Ball, 2002b: 39). In 1789 Lavoisier published a textbook in which he defined an element as any substance that could not be split into simpler components by chemical reactions (ibid.: 42).[61] He listed 33 of them. More elements would be out there and it was up to chemists to find them. The subsequent 'periodic table' was drawn up by Mendeleyev in 1869 (Atkins, 2001: 107).[62] Only with this knowledge and definition of what water was, could modern water analysis start. However, even with this knowledge of or views on water, water analysis was not a straightforward or easy practice.

Water analysis started with analysis of mineral waters and springs. According to Burnett (1999) drinking water from holy wells became popular in the sixteenth century.[63] It was considered healthy to drink renowned mineral spring waters with their tonic and curative properties. An extensive trade in bottled mineral waters also ensured that consumers would continue to be supplied at home. The commercial success of spas depended on the authentication by physicians of the therapeutic qualities of their water and the dissemination of their researches by books, pamphlets and advertisements. According to Hamlin (1990: 17) 'many saline springs worked as gentle purgatives; sulphurous springs were recommended for spring conditions; chalybeate or iron-containing waters restored patients to former vigour'. A chemical analysis of that water was vital for making a claim for the virtues of one's mineral water. However, these analyses were not an easy task. As early as the fifteenth century analysis had been practised, but it was little more than an examination of

[60] 'Address by the Rev. W. Vernon Harcourt', *Report of the Ninth Meeting of the British Association for the Advancement of Science held at Birmingham in August 1839* (London, 1840), pp. 12-13. In: Miller 2002: 162.

[61] However, according to Ball (2002b: 40), Lavoisier still had a somewhat traditional view of the elements: as if they had some intrinsic property. Instead, a single element can exhibit very different characteristics depending on what it is combined with. Chlorine for example is a corrosive, poisonous gas, but combined with sodium in table salt, it is completely harmless. This was difficult to accept for chemists. Lavoisier himself came under attack for claiming that water was composed of oxygen and hydrogen, for water puts out fires, whereas hydrogen is hideously flammable.

[62] Ball 2002 acknowledges that Mendeleyev was one of the people who wrote the table down, but argues that more people came with similar ideas around the same time and that Mendeleyev's table had to be adjusted afterwards as well.

[63] According to Hamlin (1990) mineral waters became really popular at the end of the eighteenth century, although interest in mineral waters had existed in earlier centuries.

prominent physical characteristics of the water – odour, taste, temperature, colour – following suggestions of Pliny or Aristotle.[64] During the Renaissance these observations were supplemented by manipulations and tests with reagents (ibid.: 23).[65] In the 18th century, multiple analyses of the same water differed enormously both in the constituents reported and in the quantities of those constituents. There were no standard methods of analysing the water: 'What chemists offered for sale was credibility, authority, and rationality, as much as it was new knowledge' (ibid.: 48). Chemistry was seen as an important science and people found that the problems with assessing water quality lay in nature rather than in chemistry.

When the analysis that had started out as mineral water analysis, became analysis of potable water supply rather than spring water in the second half of the eighteenth century, the same problems occurred. There were disputes on whether organic contaminants were more serious than dissolved salts and a discussion on what standards of quality ought to be expected of a public water supply. Christopher Hamlin, in his very thorough and fascinating book *A Science of Impurity. Water Analysis in Nineteenth Century Britain*, argues that the disputes on water quality need to be seen in the light that the term 'water' itself had distinctively different connotations than it does now:

> Though the composition of water as an hydrogen-oxygen compound had been established in the late eighteenth-century, older ideas persisted of water as a principle, a set of watery characteristics to which various ethereal spirits might annex themselves. In such a perspective it made sense to think not so much of waters of greater or lesser purity but of a variety of waters with various qualities and uses. (ibid.: 77)

Purity was understood as the tendency of different waters not to become foul (ibid.). After distilled water, rain (and dew) water were purest, followed by snow-melt, spring water, river water, and stagnant pond water. The question was not whether

[64] Brock (1992: 179) suggests that water analysis started earlier: 'From the late fourteenth century onwards, continuous medical demands for the analysis of mineral waters and urine led to many advances in inorganic and organic chemistry. (...) Water analysis dominated British chemistry well into the nineteenth century, when attention shifted from its analysis for therapeutic purposes to its potability for town water supplies'.

[65] Burnett (1999) claims that in the early days of water analysis, the scientific knowledge on the quality of water was not considered as important as the many works on cookery and household economy which devoted several pages to the qualities of different waters.

there was a threat from organically contaminated water, but how serious it was. Few people expected to encounter 'pure' water; purity would be a matter of degree (ibid.: 78).[66] Both determining water quality and purification of water lay within the competence of the layman at that point. Halfway through the eighteenth century disagreements were often based on what the water's composition signified, what effects such water must have on the health of those who drank it owing to its composition, rather than about what was *in* the water (ibid.: 90).[67]

In the late 1820s a commission tried to uncover the quality of London's water, but when three scientists thought the water satisfactory, a fourth found it 'appallingly polluted'.[68] The conclusion was drawn that nature herself, the variability of the Thames, was probably the cause of these opposite judgements. A professor of physiology was asked to analyse nearly 40 samples taken from a number of locations. This did not resolve the issue: 'he found some of the samples dreadful, others quite acceptable for a public drinking water supply'.[69] Hamlin acknowledges that there may have been some sampling variability, but he argues that the main causes for contrasting judgements and disagreements about the quality of water were the different systems of analysis which were based on dissimilar and incompatible conceptions of whether responsibility for water purity laid with the company or the

[66] Goubert (1986: 34-35) argues that water purity has been defined in yet another way. The current theory of the (atmospheric) hydrologic cycle remained controversial until the middle of the eighteenth century. Another theory, the subterranean cycle, based on Aristotle and Plato and sustained by Juadeo-Christian tradition and supported by the story of the Flood, was dominant at that time. This theory stated that the sea, in which the overheated centre of the earth was steeped, was the source of all water. As the result of evaporation and capillary action, the water rose as far as the 'ceiling' of the caves which formed the substratum, thus forming the rivers that then flowed away towards the ocean. According to this theory, water was purified by the fire burning at the centre of the earth and protected from pollution by an impermeable layer which extended downwards for several metres. Water pollution was a phenomenon that could not exist. The atmospheric cycle, which prevailed after demonstrations by Clairaut in 1743 and which was confirmed by Buffon's arguments, stated that all water 'even the purest, contains germs from a host of microscopic animals that develop over time, depending on variations in temperature, movements, the nature of the mud, etc.' For chemists and doctors water became the polluted element par excellence, the favoured place for 'spontaneous generation' of microbes, a theory supposedly confirmed by the serious cholera epidemics that broke out in the course of the nineteenth century. It was to take all the perspicacity of Koch and Pasteur to demonstrate that microbes did not breed in pure water. In the meantime, the danger was there, omnipresent, invisible, and it was necessary to fight for the health of human beings against the noxious, supposedly fatal, vapours given off by water.

[67] Goubert (1986: 38) mentions that also in France 'the quality of water analysis varied a great deal from one doctor to another'.

[68] Royal Commission on Metropolitan Water Supply (RCMWS), p. 84-99. In: Hamlin 1990: 84.

[69] RCMWS, pp. 77-83. In: Hamlin 1990: 84.

consumer. The last section of chapter 6 will demonstrate that conceptions of the responsibility for water purity are in some cases still contested and that different water companies may have (slightly) divergent approaches to this issue.

Mineral water chemistry, the most relevant body of analytical procedures, did not treat the issue of potability. Potability had always been a matter of common sense; this made the role and authority of chemical water analysis unsure. The lack of an agreed chemical definition of safe water set chemists free to interpret analysis as they wanted to. Water analysts themselves were often reduced to using experience and the senses. Goubert writes that Dr Joseph Browne of New York wrote in 1798 that water 'that is clear and from a running source, that boils leguminous vegetables tender, in which soap readily dissolves and has no bad flavour, may be pronounced good water'.[70] However, in the second half of the nineteenth century 'a society in which chemistry informed decisions in matters of health and industry was vastly superior to one in which it did not' (ibid.: 67-68). The problems that had arisen with assessing water quality were regarded as problems that found their origin in nature rather than in chemistry. They would be resolved by more chemistry. Yet, 'while they might agree that water assessment was a matter for chemistry, they disagreed intensely on what constituted an adequate analysis, on which processes were reliable, on what skills an analyst had to possess, on how results were to be interpreted, and what public responses they indicated' (ibid.: 9).[71] The main questions to answer were what the composition of the water was and to assess its harmfulness. Before one could answer these, one had to think about other questions. Firstly, how did one

[70] J. Browne (1798). "Memoir of the utility and means of furnishing the city with water from the River Bronx". In: *Report of the Committee on Fire and Water relative to introducing water into the City of New York*, Documents of the Board of Alderman and Board of Assistants, no. 61 (1831), p. 266. In: Goubert 1986: 37.

[71] This was an issue in environmental river pollution too. As Wohl (1983: 256) says: 'And while chemical analysis at the furnace or chimney was possible to ensure cleaner air, there were more variables where water pollution was concerned. The objection was frequently raised that pollution levels varied with tidal flows, rainfall, and other factors. During the first three-quarters of the century the pollution of rivers proceeded largely unnoticed, insidious and silent. When attention was drawn to the situation in the 1870s, it had become a problem much too widespread to allow for easy solutions, and the voices of reform were not powerful enough to convince a public which either accepted the inevitability of some pollution or simply calculated that it was better than urban sewage problems, evil-smelling sewage farms, or industrial hardships. In the last quarter of the century water pollution seemed the unavoidable price to be paid for all the social and economic benefits of industrial and urban growth. (...) The pollution of rivers called for a degree of administrative centralization and professionalisation that the nation was not yet ready to accept: central boards for the entire watershed of rivers were late in coming, and in 1914 the government was still trying to determine if it could accept the evidence of experts and establish chemical tests for standards of water purity'.

know that all detectable entities were indeed distinguished? In the second place: How does one know that the analytical operations do not change the material that is being analysed? And thirdly: How does one know that one has chosen the appropriate analytical scheme and that one is analysing water on the right level? (inorganic salts, organic matters, numbers of bacteria, species of bacteria). Hamlin asks us to remember that these scientific or 'neutralised' questions often had a basis in conflicts over power and struggles for justice. The analysts were not disinterested public experts, but people immersed in policy conflicts.

In 1827 a pamphlet appeared in which the author complained about the intake of a water company being very close to a sewer. In Hamlin's analysis it was however not the health issue (drinking of sewaged water) on which people concentrated. Instead, they focussed on the issues of high costs of the water supply and poor service. He explains this by pointing to the problems that needed attention first: people were not sure what sort of a problem public water supply was and whose responsibility it was; they did not know what process of evaluation was appropriate for judging water quality; and they were uncertain about the effects of drinking sewage-polluted water (ibid.: 82).

Water and bacteriological science

From the chemical water analysts' point of view, water could be a means of transport for harmful substances and therefore needed to be analysed. Despite all the disagreements and various approaches to similar problems, they agreed that chemical analysis was the way forward. Chemical analysis remained important, but after theories of germs appeared and suggested that water could actually produce harmful substances, the germs themselves, a new science started to develop: bacteriological science. In this section, which is necessarily limited and reduced to a history of a few key actors (acknowledging that many other have played a role in these developments as well), it will become clear that, like chemical water analysis, the bacteriological science developed along a very complicated route from the starting point of the miasma theory.

As we have seen Edwin Chadwick and other hygienists played an important role in drawing attention to water pollution. According to Chadwick the cause of diseases like cholera and typhoid was atmospheric impurity; water could help by 'cleansing and removing solid refuse and impurities'.[72] The atmospheric impurities could, according to him, also be transferred to and by water. Chadwick's contemporary, John Snow, had different ideas about the cause and spreading of diseases like cholera.

Snow was born in York in 1813. Before going to London for his formal medical education, he had three apprenticeships with medical practitioners. His first apprenticeship was in Newcastle upon-Tyne and started when he was fourteen years old. This was where he had his first encounter with cholera. During the outbreak in 1831-32 Snow was sent to provide medical assistance in Killingworth where the miners from the local coal mine and their families were victims of a cholera attack. This experience likely gave him a sense of mission, which continued in his future epidemiological investigations. In October 1836, seven months past his 23rd birthday, he went to London to start his formal medical education at the Hunterian School of Medicine. According to Hamlin, Snow's first edition of 'On the Mode of the Communication of Cholera' which he wrote to explain the cholera epidemic of 1849 and in which he recognised water supply as causing the disease, was 'indistinguishable from the stack of contemporary speculations on cholera' (Hamlin, 1990: 106). It was the investigations Snow did during a local cholera epidemic in London in 1854 and which he wrote down in the second edition of the paper (1855) mentioned earlier that distinguished him from and convinced many of his contemporaries. Snow managed to trace all cholera cases to a single well in London's Broad Street which was contaminated by the excreta from a cholera victim, an employee of a nearby brewery. By having the water pump handle removed, he managed to stop the spread of the disease.[73] It is interesting to note that one of the first known uses of chlorine for water disinfection was by John Snow when he attempted to disinfect the Broad Street Pump water supply. Yet, Chadwick had also linked contaminated water to cholera outbreaks. Snow argued that something in the water was the cause of cholera rather than an important contributing factor (ibid.: 128). In the second edition of 'On the Mode of the Communication of Cholera' Snow

[72] Edwin Chadwick (1965). *Report on the Sanitary Condition of the Labouring Population of Great Britain.* Introduction by M.W. Flinn. Edinburgh: Edinburgh University Press. Hamlin 1990: 108.

[73] Clendening (1960: 464) calls this one of the 'romantic tales of epidemiology'. In another study Snow conducted, he found that Londoners who obtained their water supply from the River Lea had a low incidence of cholera, while those who were supplied by the sewage-laden Thames River had a high incidence of cholera. Snow compared income, living conditions, employment choice, and other characteristics, finding that the source of water was the main variable.

came up with a germ theory. Others had developed similar theories, but all theories remained in a speculative state despite the earlier work of Pasteur and Koch, and experiments and hypotheses by several other people (ibid.: 161).

Many believed it was too simple to have only one cause of a disease like cholera; like any other event outbreaks of cholera had to have many causes. The term 'germ' remained vague throughout the 1860s and 1870s: 'The term 'germ' was to be used metaphorically, to represent a set of characteristics rather than an entity: 'the terms "germ" of "growth" are used because no better expressions can be found'.[74] Yet, the germ theory became more plausible as people started to believe that diseases could originate through one single cause. Snow's theory and theories of his contemporaries stressed that water contamination needed to be taken more seriously and had serious consequences for the philosophy and practices of water analysis. Hamlin (ibid.: 128) argues however that Snow was 'not the main instigator of these changes; his work both reflected and contributed to them'.

By early 1880 most water analysts accepted that bacteria or similar organisms were the causes of water-borne disease (ibid.: 241). Research of both Koch and Pasteur had confirmed the germ theory in the case of anthrax.[75] Koch's research in bacteriology 'tended to replace the old filth-theory of corrupting emanations with a new germ-theory that seemed to explain the appearance of specific diseases. Instead of contact with foul airs, bodily invasion by microbes was the thing to be avoided' (Illich, 1986: 74-75). Chemical analysis was now acknowledged as insufficient in itself. Bacteriological analysis had to complement it (Goubert, 1986: 40).[76] However, there were no clear bacteriological methods for water analysis. Until then water analysts had only looked at the quantity of organic matter without distinguishing the different components and assessing their potential danger for human health. A new

[74] Cattle Plague Committee in Hamlin 1990: 162.

[75] Koch had done a lot of research. After he isolated the cholera bacteria in 1884, Koch investigated an incidence of cholera in two adjacent 1892 German cities. Both cities pumped water from the Elbe River. Hamburg pumped water from a point upstream, while Altona pumped its water downstream from the city sewer outfalls, says Salvato. Surprisingly, the cholera outbreak occurred in Hamburg. The difference was the water Altona used had been filtered through a slow sand filter, and in Hamburg it was not. Koch had also developed a method to prove that an organism was responsible for a disease. 'One had to obtain it in pure culture from fluids or tissues of a victim of the disease, inoculate it in an experimental animal, and recover it in pure culture from the inoculated animal which had to manifest the disease.' Hamlin 1990: 279. See for more information on Pasteur, Latour 1993.

[76] The guiding principle of such analysis was, according to Goubert (1986: 40) that 'drinking water should not contain any mineral, organic or inorganic substance that may harm the organism that absorbs it.' At the beginning of the twentieth century these mineral substances

science had to be established. This was difficult. As late as 1880 not everyone was convinced of the existence of germs. In 1878 a discussion was held about the circumstances in which germs could survive. Percy Frankland, a chemist-bacteriologist, was pressed to admit that 'the cholera germ was nothing but a theory; Frankland termed it an undiscovered fact' (Hamlin, 1990: 244). Someone else demanded in 1886 that 'the so-called cholera germ be put on the table before him before he would acknowledge its existence'.[77]

People who were convinced that germs caused diseases had to acknowledge that water analysis could not be sure whether certain water was safe or not. There were too many uncertainties. Discussions originated about whether certain water filters killed all bacteria and how that could be measured and as a consequence of that whether the gelatine-peptone medium that Koch had developed and was now used for culturing bacteria did in fact show all possible types of bacteria, what the meaningfulness was of counting colonies on a culture plate if this did not have a necessary relationship to the harmfulness of water and what necessary bacteriological skills the analysts had to have. In unsafe water, it was no longer just chemicals that were out of place; also the microbes were out of place. However, often people did not know how to detect the microbes and how to assess their harmfulness. Hamlin argues that 'water analysts became as expert at raising doubts about one another's bacteriological technique as they had been at criticizing one another's chemical processes' (ibid.: 245-246).

In Paris the 1892 typhoid epidemic gave rise to the first systematic sampling for laboratory analysis. 'The myths relating to some water formerly considered to be pure were destroyed once and for all, and the idea began to gain ground that there should be a compulsory supply of water that was universal in the same way that education and even military service were for young people.' (Goubert, 1986: 4) Water now became analysed by looking at what constituted the water. Pure water was the water that did not contain any parameters that could cause diseases. Under Pasteur's influence the notion of bacteriological pure water became fundamental (ibid.: 3).

Hamlin clearly shows that the development from germ theories to bacteriology was not a straightforward elaboration as the result of a discovery, but

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were lead, copper and arsenic, while the harmful organic substances were microbes, microorganisms and certain vegetable substances.

[77] Rept of the Select Committee on Rivers Pollution (River Lea), QQ 3793-97. Hamlin 1990: 244.

instead a long path full of disagreements. He also demonstrates that this new science did not bring solutions to many of the questions both scientists and policy makers struggled with. 'Far from removing the obscurity from water quality, bacteriology brought in its own obscurity' (Hamlin, 1990: 251). Speculations about germs and the new science of bacteriology changed both the attention for water contamination and water analysis practices; other social, economic and political questions remained impossible to answer just by reference to science:

> Even when techniques were available for detecting the microbes responsible for typhoid and cholera, the answer to the ultimate question of 'is the water safe to drink' depended on how much trust one was willing to assign to analytical techniques, and this in turn continued to be considered in terms of a host of other questions: were present supplies good enough, not just in terms of quality and with regard to health, but in terms of quantity and with regard to industry? How were multiple uses and claims on water to be reconciled? (ibid.: 5)

From contaminants to standards/contaminants standardised

We have seen how uneven the chemical and bacteriological developments in water analysis were, but we can see that scientists have come to a broad consensus on what is important to health and what not, in relation to water. This can be seen in the development of the water quality standards that exist today. These water quality standards are a relatively recent development. For a long time people and communities have had their own individual or communal standards of water quality (see section 4.2.3.1). These various individual or community standards of water quality still exist. In a few communities in Southwest Nigeria water is often taken straight from the source. Therefore they have a number of criteria to determine what is safe water (Rinne, 2001). The main criteria are the origin of the water and people's own practices of acquiring household water. Rainwater, for instance, is considered safe because it comes directly from heaven and has not touched anything dirty on its way down. With regard to people's practices, it is seen as very important that people try to protect water from contamination while pouring it from the container and make sure that no dirt can enter the container. The community members also clean the stream surroundings regularly. They think of water as poor quality when it has a bad odour or taste, includes colour, or contains small particles such as insects, worms, excreta, or any other particles of foreign bodies in the water. If the water comes from a natural source, the communities have additional criteria to assess the quality and safety of the water. People regard the water quality best in the morning, since it has had time to settle during the night when nothing has disturbed the flow in the stream. It is worst during mid-day, because then water has become muddy and the heat of the sun is at its peak. In a study by Jan-Olof Drangert (1993: 108) about Tanzania it is said that 'the Swahili word for clean water, *maji safi*, alludes to its physical appearance i.e. clean as opposed to *maji machafu* (dirty water). Water is not considered *safi* if it contains small creatures or smells bad, but it does not necessarily have to be clear. Clear water may be rated as less tasty, while milky water may be rated as more filling'.

These criteria for determining what safe water is are very different from the current criteria Western societies use. The first regulations with regard to drinking water quality pointed at the treatment of the water and the necessity for the water to be fit for human consumption.[78] In 1852 legislation required that water companies who took water from the Thames and the Lea had to store it in covered reservoirs if these were located within five miles of St Paul's and to filtrate it before it was distributed to the public. However, as Luckin (1986: 37) explains, 'technical and legislative enforcement were little more than rudimentary and official investigations continued to provide testimony both of gross insalubrity and of differentials between the companies'. The role and effectiveness of filtration was heavily contested around this time. Despite the insecurity about what safe water was and the best means to achieve that, local authorities and water companies undertook actions: filtration practices were spreading and water quality was officially monitored in London in the

[78] In France it took a long time to develop water treatment even though the governments in power between 1780-1810 were convinced that 'contaminated water is one of the commonest causes of sterility in women, of endemic diseases, of autumnal fevers and of epizootic diseases' and one of the causes of depopulation, they did not do anything to develop treatment. 'With few exceptions, neither central Government nor local authorities played any part in laying down standards to control the quality of water.' In 1819 building purifying stations was seen as a private business, not something the government should deal with. (Goubert 1986: 39-40). However, 'among the many items of legislation introduced from the 1850s onwards, the laws of May 1922 which laid down standards are of particular interest; they justified the monitoring of water in the name of 'the patriotic struggle against the depopulation of the French nation'.' An adequate legislative framework was emerging, as Parliament became increasingly interested in the number of annual analyses of water purity relative to the number of inhabitants in a town, in thousands. (Goubert 1986: 6).

1870s.[79] It was the bacteriological analysis of the water that showed that filtration could remove most micro-organisms from the water.

The Metropolitan Water Act of 1871 gave city authorities the responsibility to ensure that the water supplied by the private companies was fit for human consumption. Two people were selected to investigate the water and this task was brought under supervision by Parliament (Goubert, 1986: 59). However, a definition of water fit for human consumption was not given and contamination could still not always be detected. There are very few secondary sources that write about water quality regulation and I have not found an extensive source on the history of drinking water quality standards in England. However, as chapter 5 will show, it seems that for a long time the chief chemist and microbiologist of water companies determined what water 'fit for human consumption' was: they had their own (local) standards by which to measure the quality of their water. When national water quality guidelines were published, they were not enforced or audited. Hassan (1998: 144) writes that there was an 'absence of the designation or enforcement of drinking-water quality standards'. If standards had been applied, he argues, it would have exposed regional variations in water quality. From the 1970s the British government invoked World Health Organisation (WHO) standards, but it was only when the European Directives were established and Britain had to comply, that, according to Hassan (1998), the absence of previous drinking water quality standards became clear. In the European Drinking Water Directive standards were laid down in relation to a wide range of parameters for drinking water. All European member states would have to comply with this directive within ten years.

The criteria that are used to determine what safe water is are written down in the drinking water directives. The origin and locality of the water have entirely disappeared from these formal criteria (although treatment plants have to take them into account). The criteria are the same for all European member states and are determined by a large number of different parameters to most of which the lay-person cannot relate because they cannot be seen, tasted or smelled. Only 'experts' can, with help of laboratory equipment, determine the presence or absence of the parameter and measure how much of it is in the water. Hamlin sees this development as a process of singularisation of water. The many waters that existed before and still do exist in other cultures have disappeared in the industrial west. He places the start

[79] Hardy, A. (1993). *The Epidemic Streets: Infectious Disease and the Rise of Preventive Medicine, 1850-1900*. Oxford: Clarendon Press. In: Hassan 1998: 24.

of this process in the nineteenth century. In Hamlin's words (2000: 315): 'A paradigm shift in the concept of water occurred in the 19th century, in which water went from a class of infinitely varied substances to a monolithic substance containing a greater or lesser concentration of adventitious ingredients, known as 'impurities'.'

These water quality standards that, one can say, represent the process of singularisation, could only be developed after science had established a common definition of what water was and had the means of investigating and comparing results of analyses (photo 4.3 (page 160) points to the singularisation of water through showing standardised water bottles). Chemical and bacteriological water analysis had to have gained authority. Water treatment had to be developed to a point where pollutants could be removed and water quality changed (see photo 4.4 (page 160) for an indication of the transformation of water). Science and policy have to establish reasonable agreements about what constitutes safe water. Most parameters are now well-established, but Hamlin (1990: 5) reminds us that once also these parameters were subject to debate: 'I suggest then that development of the kinds of water standards we now have (or of any standard of environmental quality) was not the result of scientific discovery, but that scientific arguments were wielded on all sides in an effort to obtain whatever set of standards various parties regarded as desirable'. As we have seen earlier safe water was not the only question people were worried about and it was not a question that could be answered just by reference to science. It is important to note that what constitutes safe water and what good water quality standards are is, as chapter 5 will show, sometimes still subject to debate.

Original in colour

Photo 4.3: Standardisation and singularisation of water: standardised sample bottles in microbiology lab

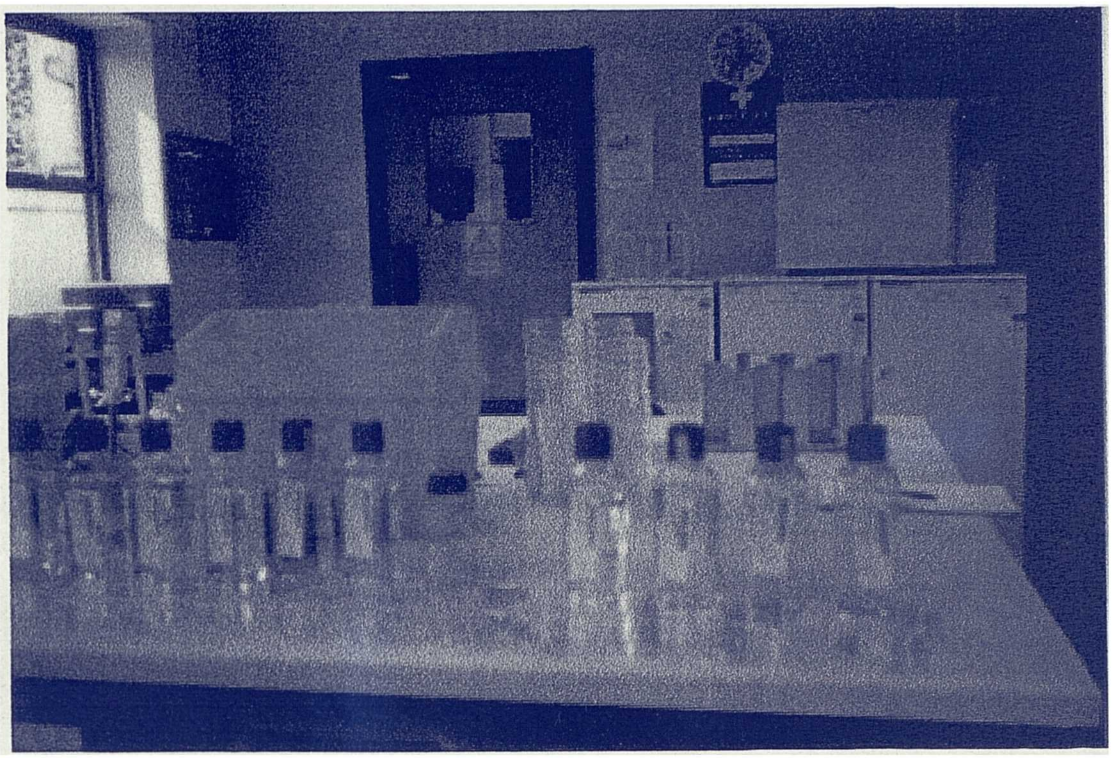
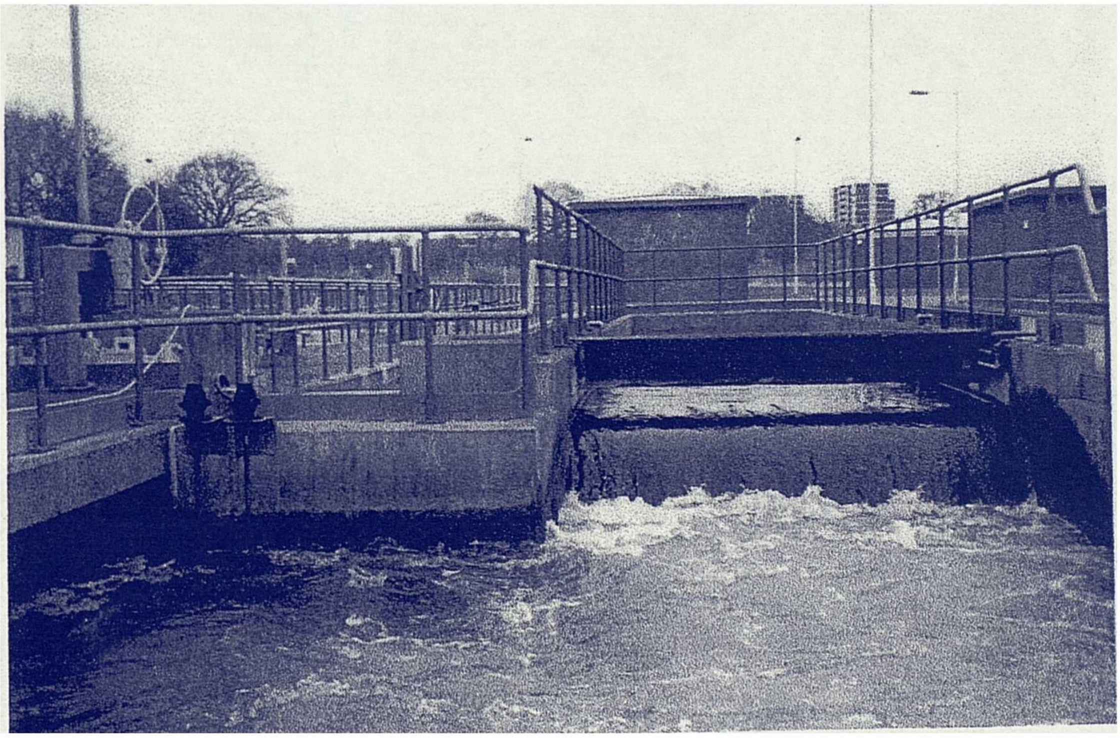


Photo 4.4: Becoming drinking water: water is highly processed nowadays



Standardisation and diversity

Drinking water, although sometimes supplied by private companies, had slowly become a public enterprise. Hassan (1998: 61) states that during the inter-war years 'the supply of water was regarded almost as a civic duty on the part of local government'. With sampling of water for laboratory analysis in France 'the myths relating to some water formerly considered to be pure were destroyed once and for all, and the idea began to gain ground that there should be a compulsory supply of water that was universal in the same way that education and even military service were for young people' (Goubert, 1986: 4). As we have seen in the last section, slowly water quality standards were developed and implemented. These can be seen as a sign that water supply came under public scrutiny and had therefore to become more singular or standardised. Globalisation processes and increasing trade between countries have played a role in the development of the European directives on drinking water quality. Water intended for human consumption was defined in the European 1980 drinking water directive as:

> All water used for that purpose, either in its original state or after treatment, regardless of origin, -whether supplied for consumption, or whether used in a food production undertaking for the manufacture, processing, preservation or marketing of products or substances intended for human consumption and affecting the wholesomeness of the foodstuff in its finished form.[80]

The export of for instance fish requires that the water (in the form of ice cubes) used during the transport fulfils the standards of the directive. In order to be able to compare the water quality, all countries have to comply with the same quality standards. Kinnersley (1988: 168) remarks that even the material network has as a consequence that 'that service remains highly standardised in that the network cannot deliver more than one quality.' The modern treatment works, pipelines and laboratories, attention for public health and the drinking water quality standards that emerged as a consequence of this, have managed an increasing control over water.

However, during the last quarter of the twentieth century some product differentiation has taken place as well. Hamlin argues that this is the case for bottled water which is to be associated with the healthfulness and purity of the place from

[80] Official Journal of the European Communities; OJ L 229, 30/08/1980, p. 12.

which it comes. It has 'reawakened interest in water taste and water quality' (Hamlin, 2000: 321). Roberts (2001) states that the reasons for the growth of the bottled water industry are subject of much debate. Some argue that the privatisation of the water industry has led to fears concerning water quality; others say it is due to changes in leisure and lifestyle trends. According to Burnett concerns about possible health risks of tap water are a main, though not the only, reason for the recent very rapid increase in bottled waters, now the fastest growing of all food and drink sectors. Bottled water is associated with fitness, jogging and health food shops and its consumption has been encouraged by campaigns against drink driving and by the social cachet that attaches to bottled water in restaurants and at dinner-parties.[81] Marketing has played an important role in increasing the popularity of bottled waters. Vince Gardiner:

> Bottled water is strongly branded, with the product name, poeticising the text and scientific analysis being important elements of much labelling... bottled water is found to be cleverly associated with purity, health and nature, lifestyle and social identity, place, tradition, region and rurality, and environment.[82]

The origin of the bottled waters is much more important than the origin of the water that comes from our taps. The labels on bottled waters often show a wild and rural landscape, far away from the cities. Kinnersley (1994: 160) states critically:

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[81] The social profile of bottled water drinkers has moved somewhat down the scale in the last twenty years, partly because of the availability of cheaper supermarket brands. According to Burnett 'the heaviest consumers are still non-manual workers aged under 45, especially professional and managerial classes in the south of England and the Midlands, among whom health consciousness vies with fashion'. Burnett also says: 'There is some irony in the fact that enormous cost and labour are involved in ridding tap water of all extraneous substances while increasing numbers of people are willing to pay for 'natural' spring waters, which contain various minerals and live bacteria'. (Burnett, 1999: 28). Water is mainly regarded as quenching thirst, although the rise of bottled water might indicate a change in the social status of water and social occasions in which water is used. Bottled water is not needed for survival. Campbell (1995) argues that the focus on the primary consumption processes of eating and drinking is understandably matched by an interest in the body itself. Much of the recent writing is, according to him, more about the image of the body than about its biological reality. There seems to be a need for more empirical studies of these primary activities, which involve individuals interacting with their own bodies. He also argues that there should be more attention for the material basis of consumption.

[82] Gardiner, V., 'Welcome to the Soft Parade – towards a social science of water resources?', inaugural professorial lecture at Liverpool John Moores University, 21/4/1999, p. 6. In: Roberts 2001: 9.

> As tap-water is the subject of massive investment and much more thorough and precise independent monitoring than before, the British have taken to drinking bottled water on a scale hardly imagined earlier. (...) In fact, bottled waters are subject to far less independent monitoring: maybe the illusion that they come almost direct from the spring into the bottle is part of their powerful attraction.

Globalisation and standardisation have therefore also led to a process of localisation and diversification in which (symbolic) notions of naturalness and cleanliness play an important role.

4.3 Conclusion: Waters and purities revisited

In this chapter we have encountered a variety of notions of purity, cleanliness and hygiene in relation to water. Water can purify the soul as in baptism or a last bath after death; it can cleanse the body on the outside and on the inside; and it can heal both body and soul. Water that can perform these purifications can be specified in different ways: sometimes it is the source of the water that gives it its characteristics, sometimes it is the components of which the water is built up. This may differ in different times and contexts. In fact, Table 4.1 below shows four different columns with different notions of water performances, water purity 'essences', water determinations and affordances. Each of these can mean a number of different things in different periods. The different roles that people can ascribe to water (see especially the first column) reveal the affordances of use of water. Water is a material substance, but allows for many different practices, some of which are considered in place and others out of place.[83] Each column can be read separately (i.e. vertically), but in different historical periods the individual columns can connect horizontally in various ways. The Table gives a broad overview of some general types of affordances that I identified in this chapter. There will be many others. In chapter 5 and 6 other types of affordances may be identified.

[83] Lynch (2003) makes a similar point about DNA. He does not problematise the materiality of DNA but shows how this materiality is reconfigured over time to serve different legal groups, and is inscribed in new forensic science protocols. Materiality is 'there' but (re-) constructed within limits for new purposes. This is similar to the raw material of water and its articulation within water standards.

Table 4.1: Water performances, determinations, affordances, and water purity "essences"

Water performances	Water purity "essences"	Water determination	Affordances
Cleansing body		**Liquidity**	**Enables/performs socially defined hygiene**
Washing sins **Ritual purity**	**Holy source**	**Primal element**	**Purification** **Salvation**
Healing			**Social and bodily repair**
Potable	**Source/locality** **Taste/smell/sight** **Movement**	**Liquidity**	**Hydration**
Social life		**Public/private good** **Social marker**	**Urbanisation** **Social hierarchies** **Water as commodity**
Knowledge	**Chemical composition** **Bacteriological composition (absence/presence)**	**H_2O**	**Standards** **Singularisation**

In baptism, the water cannot be muddy or come from a bottle. Bottled water in the church would be 'unnatural', whereas outside the church it is promoted as the most natural, much more natural than our treated tap water. Muddy water is not a problem for the Hindu's in India as long as the source of the water is the river Ganges. Here it is the source that gives the water its properties. As we have seen, also in drinking water the source was long seen as very important, some thought that well water was much better drinking water than other water. In this case the purity of the water is defined by sources like rivers, streams and wells; not so much by a specific river, stream or well. Nowadays its chemical and microbiological characteristics are seen as much more important. This may have to do with the long period of pollution of the waters and the population moving to the cities. In large cities not every house can possibly have its own well and know what the quality of the water is. With increasing dependence or large technical systems and on treatment, because the water cannot be drunk as such, chemical and microbiological parameters become the means through which is determined whether the water is safe and how it should be treated. Different contexts and time periods thus define the characteristics and properties of water.

In some specific periods water purity can be regarded as a boundary object. A boundary object refers to an artefact, object or idea that is available to different social worlds and different actors at the same time. Monks in the monastery were not allowed to wash each other unless it was for ritual purposes, so ritual purity offers a compromise in the way water is used for washing; people would not wash themselves because water was bad for one's health, but would, at the same time, look for eternal springs. However, as we have seen, my account of water purity mostly refers to different temporal and spatial contexts within which purity is defined. The materiality of water affords many different notions of purity.

It has been mentioned a few times that several people believe that these different notions of purity and of water have disenchanted the world. Waters have turned into one water, that is H_2O. Whereas Hamlin in his book *A Science of Impurity* only stated that 'the people of pre-industrial Britain would probably have been familiar with a greater variety of waters, possessing different degrees and kinds of impurities, than we are today', his statements in his article *'Waters' or 'Water'?* are much stronger. The paradigm shift from 'waters' to 'water' as Hamlin (2000: 315) calls it 'as well as marking the transformation from many to one and from empirical to essential, also involved the secularizing, materializing, and disenchantment of water'. Also Illich is convinced that modern science and industry have disenchanted the water from its many different affordances of purities:

> In the imagination of the twentieth century, water lost both its power to communicate by touch its deep-seated purity and its mystical power to wash off spiritual blemish. It has become an industrial and technical detergent, feared both as a poisonous stuff and as a corrosive for the skin. (...) Water throughout history has been perceived as the stuff which radiates purity: H_2O is the new stuff, on whose purification human survival now depends. H_2O and water have become opposites: H_2O is a social creation of modern times, a resource that is scarce and that calls for technical management. It is an observed fluid that has lost the ability to mirror the water of dreams. The city child has no opportunities to come in touch with living water. Water can no more be observed; it can only be imagined, by reflecting on an occasional drop or a humble puddle. (Illich, 1986: 75-76)

Goubert reinforces this by noting that over the period of the nineteenth century older notions of what water was were replaced by new notions of purity:

> Since Lavoisier, the old mythology of water had been called into question; nevertheless, the classic distinction between stagnant water and running water still persisted, with the latter being considered healthier. Under Pasteur's influence, this criterion lost some of its importance; the notion of bacteriologically pure water became fundamental, at the same time as a new obsession with pure water (this time 'scientifically' based) was spreading in certain quarters, with people constantly washing their hands and refusing to drink water unless it had been filtered or boiled. (Goubert, 1986: 3-4)

What has happened? Has the matter that is water indeed lost its ability to perform metaphorically? Have the chemical and bacteriological notions of purity really taken over all the other notions of purity? Science has been portrayed as the discourse that has replaced all other possible notions of water and water purity and science has indeed proved itself a powerful discourse. However, if we look back at the scientific developments regarding water quality, for a long time science seemed to be in accordance with the broader conventions and values about purity and cleanliness at the time. For example, when people started to grow ashamed of their naked bodies and washing in public or washing at all was considered immoral, this was supported by scientific evidence that water was bad for the skin and people's overall health. In the debates about whether upland water that would be transported to the city by aqueduct or well water that could be found in and around the city was most pure, scientific arguments were used on both sides to support the contesters. Since then the chemical and bacteriological sciences have matured and have themselves become more standardised. Science is often still used to assist the different sides of the debates. One example is the need of fluoride in the water (see chapter 2). Science can be said to have replaced older scientific notions of water and water purity. However, not all older notions have disappeared. The four elements are still a recurrent theme in for instance literature, poetry and paintings. Other notions of purity (baptism, bathing) remain important and exist almost independently of the scientific notions of purity. Sometimes new understandings of water purity may even deploy older notions of purity and draw on them.

During the last fifty years national and European standards and regulations have been developed in regard to especially drinking and bathing water. Increasing governance, regulation and commercial/proprietary practices caused a reduction of the diversity of these waters. Other waters, like holy water, have not been subject to this process of standardisation in a regulatory and perhaps commercial sense and prevail in their variety. Holy water is a cultural standard which defines when water is 'in place' and when 'out of place'.

However, the reduction of diversity in bathing and drinking waters has not just been a one-way and linear development. I will explain this by looking at drinking water. Drinking water purity, as we have seen, has undergone quite a drastic development. In Western societies what is regarded as safe has largely been standardised. With this, people's expectations have been standardised as well. The possibilities of treatment have in many cases resulted in less need to take into account, for instance, seasonal variations and sources of the water. Water quality has become fairly constant because substances can be removed or added if necessary. A whole new system to judge water quality has emerged, a system that is led by experts. This, however, does not mean that other, perhaps more common sense, judgements have disappeared entirely. Taste, smell and sight are still used in modern water treatment and when one goes on holidays or into the mountains and has to collect water oneself, the 'old' notions of good drinking water surface once again. Standardisation and commodification do not just incorporate older notions of purity, but also define new ones. The bottled water industry uses scientific analysis to convince the customer of the good quality of the water, but perhaps more important than that, directs the customer's attention towards the natural environment and clean source from which the water is taken. In this case, science does not replace these 'older' images and the notions of taste, smell and sight, but incorporates them and draws upon them. In some cases these images are even reinvented. Drinking water quality standards have been formulated to ensure that the drinking water tastes, smells and looks good. Science seems to add another additional discourse here, but does not replace the old one. The story is a much more complex one than one of simple, linear replacements. Purity, as Douglas sees it, is defined in terms of appropriate uses of water. Water is out of place (or unfit for human consumption) where it creates impurities, pollution, (physical, emotional or psychological) harm. These appropriate uses, at least partly, depend on the context and as we have seen, especially with regard to the relationship between water and cleansing, this context can change from period to period. In some periods or social, cultural and political contexts certain notions of purity may have grown stronger or weaker or even disappeared for a while, while other notions either took over or were pushed to the background. The emphasis in different periods or societies may differ and sometimes different notions of purity may be in conflict with each other. The water of the Ganges may not comply with the bathing quality standards that are used in western societies and may even be regarded as harmful for health, but be pure in the sense that it can still wash away sins.

One might say today that the 'globalising' process of standards/standardisation produces less diversity in some ways, but via localisation, a post-fordist/postmodern diversity too. I mentioned post-fordism to focus attention on the way in which global companies have used mineral waters for niche marketing. Postmodern waters are related to life-style (fizzy waters, mineral waters) rather than to what is in the water. Like some older notions of water, they are associated with status roles. Status roles in this period are however not derived from accessibility in times of scarce water, but instead from accessibility in economic terms, from how much one is able to pay for water. Whereas the standardisation that plays a large role in the drinking water (i.e. tap water) industry is a modernist process, the differentiation in specialist water suppliers is a more postmodern phenomenon. If Baudrillard would have studied this, he could have suggested that drinking water has become a simulacrum.

Water has always several creative stories that surround it. This chapter shows that water as a material object has been interpreted and given meanings in different periods and has increasingly been controlled, managed and intervened with. In recent years water has become a value-added site for private capital investment. It has helped to identify where standards are targeted and what they do. New standards are managing material properties in political ways. This is addressed in the next chapter.

5 Regulated Science, Regulatory Plateau, Mobilisations, and On how Standards and 'creeping' Regulations manage Materiality

5.1 *Introduction*

> I think they cover virtually everything. They may not be the specific regulations related to water quality, but from protection of your catchment and monitoring the source right the way through. There are regulations nowadays on just about everything, procurement of products and the way in which we specify and purchase things. There is something there that covers just about everything. It may be not imposed upon us by the regulators that most people know of, but there'll be something somewhere affecting just about everything all the way from the source to the tap. And you know, we even impose our own in terms of the sorts of standards of service that we all commit to. So, the whole thing is regulated and as I say, some of it is even imposed by ourselves. (Samuel, WQM/251102)

'Creeping regulations' is an expression one of my respondents used to point to a situation in which a regulatory agency is asking water companies to do more and more and the distinction between regulatory agencies becomes blurred. This chapter, much like the quote by Samuel above, discusses the co-construction of standards and materiality in a period in which the number of standards has increased and the regulatory regime has become strict and ever present. The previous chapter provided a broad context within which the rise of water quality standards was addressed. It was argued that water quality standards (partly) reduce the diversity of ways of judging water quality. This chapter focuses explicitly on the water quality standards that are currently in place and demonstrates - in line with chapter 2 - that although the standards may have reduced the number of 'water qualities' we talk about, constructing, implementing, and dealing with these standards is not straightforward. They are part of a socio-material environment in which the standards are negotiated, translated, and have to take into account the local and material circumstances in which the standards are put to work.

Both this chapter and chapter 6 focus primarily on the role of standards in managing material properties and will develop a few ideas on co-constructions of standards and materiality. Whereas chapter 6 concentrates explicitly on standards at work in the specific material environments of one particular water company and analyses how the materiality is constructed by the regulations, in this chapter the co-construction is explored by looking at the way in which regulations are constructed by materiality and the way in which standards are dealt with in light of material circumstances. The distinction between materiality constructed by the standards (construction of 'actual' water) and standards constructed by materiality is an analytical one; I will argue that materiality and standards are co-constructed and that the two cannot be regarded separately from each other.

This chapter has another important task. It introduces the reader to the current and complex 'waterworld' and explains who are involved, how standards are set, how standards are policed, and so on. The notion of 'waterworld', as mentioned in the *Introduction* to the thesis, refers to all institutional settings that deal with drinking water in one way or another: the water industry, the regulators, the policy makers, and so on. I focus explicitly on England, since the waterworld is organised differently in Scotland and thus the United Kingdom (UK). Scotland also applies different water quality regulations. I use the word 'regulations' to refer to the status of a text as carrying specific authority and authorisation while 'standards' are the specific inscriptions that set down what is being regulated (sometimes numerically).

Interviews held across the English waterworld help to map out the institutional settings in which the standards operate. However, it is important to note that I use the institutional settings as a socio-technical space within which standards can be mobilised in different ways. It is thus a heuristic for understanding mobilisation and does not make an *a priori* distinction between the macro and the micro. Space itself can be mobilised in terms of the macro and the micro; what is often understood as the macro is likely to affect the micro level in for instance a treatment plant as we will see in the next chapter.

The chapter starts by providing a short overview of the organisation of the waterworld and how this has developed over time. In 5.3 the construction of and increase in the current drinking water quality standards will be addressed. It will become clear that, as chapter 2 has shown, the construction of standards can be a 'messy' process in which negotiations take place about what the best standard is. The final standard is often an outcome of a compromise between the different parties.

This section will also demonstrate that it is often very difficult –if not impossible– to know the intention of the policy makers once the standards are there and have been black-boxed. The script of the regulations and the notion of 'good' water they incorporate (in the way intended by the policy makers) is subject to interpretative flexibility. Section 5.4 will then try to illustrate what a water quality standard actually is; a standard is difficult to represent in a simple and singular way. It hints at the complexity of standards. Some standards may not have changed much or at all from one directive to the next. In these cases compliance with the standards is relatively straightforward since all treatment technologies, laboratory equipment, analytical methods, and the sampling practices are already in place, providing that other parts of the regulations (on sampling, provision of information, and so on) have remained the same as well. Therefore it may be more revealing to concentrate on a few standards that have changed. Throughout this chapter the parameters for lead and *Cryptosporidium* will be used as the main examples. Section 5.5 focuses on the specific role of standards in an area of regulatory –or what I call 'regulated'– science with regard to the development of analytical methods and treatment technologies. It argues that the number of standards seems to have stabilised and that there are mechanisms in place to maintain this, what I call, 'regulatory plateau'. The formation of such a plateau, whether intentionally or unintentionally, influences the types of research and technology development that are undertaken. It also suggests that 'regulatory science' and 'regulated science' allow for different types of research which again change when a regulatory plateau is established. It is in this setting of regulated science that the role and co-construction of materiality and standards is explored. Throughout the chapter attention is paid to notions of materiality and how it is considered to influence for instance the development of analytical methods and treatment technologies. In section 5.6 the relation between standards and materiality will be further explored, as will the relation between water companies and the drinking water inspectorate when it comes to managing material properties. There will also be attention to the different ways in which standards can be mobilised by water companies. The conclusion, section 5.7, will summarise how standards have to incorporate materiality and will develop a few first ideas on the co-construction of standards and materiality.

5.2 *Organisation of the water industry*

Saunders and Harris (1994) divide the functions of the waterworld into three categories. Firstly, it abstracts water from rivers, reservoirs and underground sources. This is then treated and transported to the domestic, industrial and agricultural users. The waterworld has also taken on the role to take away the dirty water and treat this before transporting it back to the rivers and the sea. Lastly, it maintains the water environment by monitoring water levels, maintaining sea defences, and so on.

These three functions have been carried out by different institutions in different places and periods. As we have seen in chapter 4 the supply of piped water began in England in the nineteenth century with the development of the new industrial towns. Water supply was organised by both private companies and public authorities. Between 1913 and 1974 local councils supplied eighty percent of the water (ibid.: 35). Saunders and Harris regarded this system as fragmented and inefficient since there were over 1400 local authorities in England and Wales. In 1945 a Water Act was established which brought together previous water legislation and provided a Waterworks Code. It encouraged amalgamations of water companies and boards. Around 1915 2160 water undertakings existed including 786 local authorities. By 1963 the numbers were reduced to 100 water boards (each comprising two or more local authorities), 50 local authorities and 29 privately owned statutory water companies (Ofwat, 2002).[1] These privately owned companies, some of which had been operating since the seventeenth century, provided approximately one quarter of the water supply in England and Wales.

The second branch of the waterworld - effluent disposal - has a different history. Private enterprise was never involved in collecting and treating sewage; municipalities operated the sewer farms. By 1974 there were 1393 different sewage authorities in England and Wales. According to Saunders and Harris (1994) many of these were very small and unable or unwilling to finance their operations adequately. The third function of the waterworld is closely related to the other two since in most parts of Britain drinking water is drawn from the rivers into which the treated wastewater is pumped back. River management, like the other two branches of the

[1]Saunders and Harris (1994: 35) mention slightly different numbers. According to them the amalgamations the government enforced to increase efficiency from 1945 onwards led to a reduction of the number of municipal water suppliers from 1186 to 150 over the next thirty years. The local councils that had controlled the water previously were now replaced by clusters of neighbouring councils organised as joint boards. By 1974, therefore, most local councils only indirectly controlled and managed the water supply in their areas through nomination of councillors to sit on these joint boards.

waterworld, has historically been organised by a distinct and fragmented set of agencies. Thirty-two River Boards were established in 1948 to manage the water environment in England and Wales. Fifteen years later they were replaced by twenty-nine River Authorities which were given additional and important powers to regulate the use of the rivers. They could now, for instance, license and charge for abstraction of water from the rivers by industry and water undertakers. From 1963 onwards therefore, the River Authorities could in principle maintain river flows by refusing to allow water suppliers and users to take more water out of the rivers, and they could clean up the rivers by refusing to allow more waste to be discharged than the rivers could handle.

By the early 1970s the waterworld comprised around 180 water suppliers, 150 of which were joint boards of local councils with the rest private undertakers; nearly 1400 sewage authorities, all under local authority control; and twenty-nine River Authorities with the power to regulate both abstraction from and discharges into the river system. This changed after the Water Act of 1973 which introduced the principle of 'integrated river basin management'. Ten Regional Water Authorities (RWAs) were set up that replaced the joint water boards, sewage authorities and river authorities.[2] Each RWA would take responsibility for the entire water cycle in each river basin region (from the sea to the tap and back again). The RWAs had regulatory responsibilities for water conservation, controlling pollution of inland and tidal waters, land drainage and flood control, and fisheries as well as for water supply and sewerage. It was hoped that –by organising the water industry this way– decisions affecting one part of the water cycle would be taken with due regard to their impact on all other aspects of management of the river basin system.

In February 1986 the then Department of Environment (DoE) published a White Paper in which the possibility of privatising the water industry was discussed. I will address this in a little more detail, since the privatisation of the water industry has led to the current organisation of the water industry. The White Paper proposed

[2] The history I sketch here is very brief and does not discuss the detailed changes that took place. Saunders and Harris (1994: 37) provide a more detailed history in which they discuss the opposition of local authorities and the scale and extent of the reorganisation they regard as dramatic: 'it represented the culmination of a technocratic period in the British politics when governments sought to modernise public administration by creating huge new bodies which would benefit from economies of scale and which would be run by technical experts freed from the petty concerns of local politicians'. They argue that when the local authorities lost the little authority they had left in 1983, the RWAs were run more like nationalised industries than like the old local authority joint water boards.

privatising the 10 water authorities in their existing form, i.e. with responsibility for providing water and sewerage services and with regulatory aspects including river water quality and the control of abstractions (Ofwat, 2002). The White Paper encountered opposition from a number of organisations, mainly with respect to privatising the regulatory aspects of the water authorities. The original proposals were then amended and a DoE consultation paper (July 1987) proposed privatising the water and sewerage provision aspects of the boards only and setting up a separate non-departmental public body - the National Rivers Authority (NRA) - to take on the responsibility of water quality in rivers, lakes and bathing waters and the associated functions. In the Water Act of 1989 the privatisation became official and the NRA was set up. Table 5.1 on the next page gives an overview of the most important developments that occurred in the organisation of the water industry as a consequence of regulation. The Table is based on information from Ofwat (2002).

With the 1989 Water Act England was the first country that privatised its water industry entirely. The reasons for privatisation are heavily debated. The government justified privatisation by saying that the private sector could fund the water industry much better than the state in the years following 1989 (B.B.C., 1998). Oliver (WQM/120503/WaterCo) says about this argument: 'The cynics amongst us may well say: 'well, instead of the government having to raise that money through tax, the customers pay through increased bills'.' Others add that ministers responsible were threatened with prosecution on water quality standards that were set by the European Commission (EC) and that came in at the same time as privatisation (Ward, 1997). According to Bakker (1998), yet others regarded it as a strategic manoeuvre to redraw Britain's political landscape. Bakker (1998: 7) argues however that it is not important to discover the 'real' reason(s), but that instead 'each perspective on this debate captures something important about the privatisation process'.[3]

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[3] For more information on privatisation and the water industry, see Bakker (1998), Kinnersley (1994), Ward (1997), Huby (1998), and Saunders and Harris (1994). Bakker (1998) addresses the political economy of water production and the commodification of water; Kinnersley (1994) gives an account of the economic developments around privatisation of the water industry; Ward (1997) addresses the question of people's rights to water regardless of their ability to pay, an issue also addressed by Huby (1998); and Saunders and Harris (1994) pay attention to the relation between privatisation and capitalism and look at the different reasons for privatising the water industry and the problems that came with it (public distrust, monopoly, charges for water consumption, and so on). I have not included my respondents' comments on privatisation, but would like to note that many of them were against privatisation from the start, even though, as we will see later, they believe

Table 5.1: Organisational developments in the waterworld following regulations, 1945 - 1989

YEAR	REGULATION	ORGANISATIONAL AND REGULATORY DEVELOPMENTS
1945	Water Act	⇒ Brought together previous water legislation ⇒ Encouraged amalgamations of (over 2000) water companies and boards
1973	Water Act	⇒ Water authorities were reduced to ten multi-purpose regional water authorities (RWAs) (and a number of water supply only companies) who were responsible for the regulation and management of the use of water as well as the utility functions of providing clean water and sewerage services.
1983	Water Act	⇒ Change in organisational structure of RWAs: local authorities, press, public were excluded. Consumer Consultative Committees with limited power were set up.
1986	White Paper Department of Environment (DoE)	⇒ Discussion paper on possible privatisation
1987	Consultation Paper (DoE)	⇒ Distinction between privatisation of water and sewerage provision and the public National Rivers Authority (NRA)
1989	Water Act	⇒ Regulation on privatisation ⇒ Founding National Rivers Authority ⇒ Founding Ofwat ⇒ Founding ten regional Customer Service Committees (CSCs) independent of the water industry to represent the customers

The history of the English water industry has been one of constant movement; responsibilities, expertise, and policy making were distributed differently in different periods. Privatisation led to yet a different way of organising the waterworld.[4] As we

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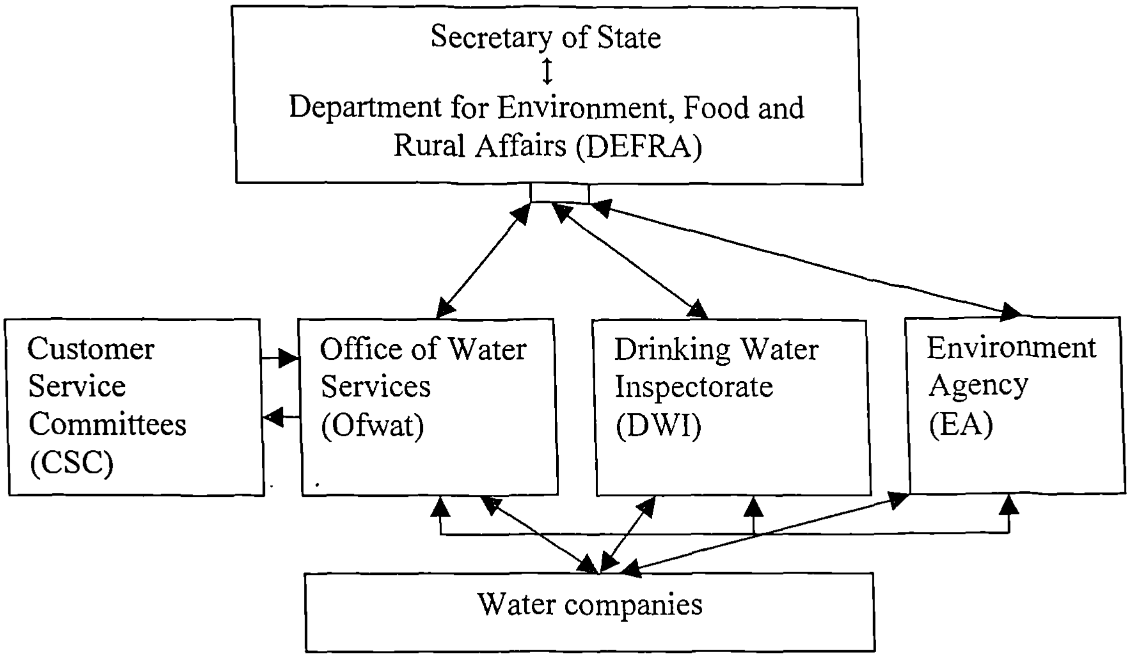
the water quality has benefited from it (or at least from the enforcement of stricter regulations).

[4] One of the developments after privatisation (many of which are too detailed to go into in this chapter) is explained by Oliver: 'The thing that I always find difficult to understand is why we ended up with a two-track approach in the water industry. Because on the dirty water side the regulator said: 'we don't trust you to take your own samples, we are gonna take them and we'll take them ourselves, a completely independent check. On the clean water side they said: 'we trust you to take your samples, we'll just come in and do a periodic audit'.' This two-track approach lasted a number of years, but is currently changing.

have seen the 1989 Water Act separated the supply of clean water and the treatment of sewage from the regulation and management of the water environment. A concern of many people was that if privatised companies would, like the former RWAs, be responsible for both (economic and quality) regulation and water management the customer charges would increase dramatically (in order to make a profit) and the water quality would deteriorate. Kinnersley (1994) mentions the Camelford incident in Cornwall to illustrate the latter concern. In July 1988 a treatment works was run automatically to save manpower when a delivery was made of aluminium sulphate. The driver misunderstood which tank his delivery should go into and as a result 20,000 people became ill. At this time preparations were made to bring the water companies under private ownership. Kinnersley (ibid.: 64) asks: 'if such a calamity happened under private ownership, would it be acceptable to leave the licence comfortably in place for the monopoly to carry on?' In response to these concerns both the Office of Water Services (Ofwat), the economic regulator, and the Drinking Water Inspectorate (DWI), the quality regulator, were founded. Ofwat finances water company activities, facilitates competition, and regulates the charges to customers, whereas the DWI ensures that companies supply water that is safe to drink and meets the standards set out in legislation (Bailey, 2002). In the 1995 Environment Act the NRA was joined with a number of other regulatory bodies and became the Environment Agency (EA) which is responsible for protecting or enhancing the environment, licensing water abstractions and awarding consents for discharges of treated wastewater into the environment (ibid.). Figure 5.1 is based on Bailey (2002) and summarises the (simplified) structure of the water industry after privatisation in England.

Companies can now take their own regulatory dirty water samples and the environment agency audits them.

Figure 5.1: Waterworld organisation in England after privatisation



This dissertation focuses at this point on the role of the DWI in relation to the water companies, since it is the DWI that ensures and enforces drinking water quality standards. The DWI is also considered one of the most important contacts for water companies. Water companies have some contacts amongst themselves, especially with neighbouring companies or with companies that have similar concerns:

> For example there is a lowering of the arsenic standard coming next year. I know that [name of other company] has a number of sites where the raw waters wouldn't make the new arsenic standard, so I'd speak to a chap I know at [name of the company] and say: so, how are you responding to that? But that's a personal contact rather than a company contact really. (John, WQM/271102)

> I would know the guys who work in water quality in other companies and am on first name terms with them. There is a personal-professional relationship that goes on which is part of the informal network if you like. (Fred, WQM/150202)

Privatisation seems to have had an impact on these relations between companies:

> Of course on a personal level one tends to know one's opposite in other water companies. But I don't think the relationship is as close as it was before the industry was privatised. (Victor, WQM/140202)

> Post privatisation there were a lot of barriers put up particularly by the bigger companies to communications with [other] companies, but those really have come down a lot more over recent years with the recognition that we are all in the same boat. There is more consultation between companies again, it is getting back to the sort of situation that it was prior to privatisation. (Harry, WQM/261102)

Martha (WQM/040202) states in a similar fashion: 'There is what I would call a productive and positive exchange of, not necessarily commercially sensitive, but exchange of ideas.' Yet, the main contact for water companies is the DWI. In the words of Samuel: 'Obviously our main contact is the drinking water inspectorate themselves'. He continues by explaining that his company has contacts with the near neighbours, mainly on operational issues such as wastewater treatment or water treatment especially since there is some transfer of water in the areas of the neighbouring companies, and that they will visit each other. However, he states: 'On the sort of water quality type thing and on the regulatory pressures we are all governed by the same thing, the same issues affect us all, so we don't specifically link to them'. When it comes to issues of quality, the DWI is the most important contact:

> We do obviously liaise quite closely with the inspectorate themselves and the inspectorate are organised such that we all have a liaison inspector that we would go to in the first instance when we've got anything to discuss. And they will come and visit us quite regularly as well.

Being 'governed by the same thing' does not seem the only reason for the significance of the DWI. Also the specifics of the water play a role. Sarah (WQM/230502) works for a company that has a very close relationship with a few other water companies since they are part of the same group. Yet, she states: 'I have dealings with my colleagues in [companies part of the group] but I wouldn't answer any questions on their water'. Both the relations between water companies and the DWI and the role of materiality will be further explored in section 5.6.

It is important to note that the DWI, although it is the most significant regulatory agency in this thesis, operates in an environment of other regulatory agencies (see Figure 5.1). As we will see later in this chapter, the relationship(s) between these agencies is not always unproblematic and water companies can mobilise the relation(s) in various ways. Water companies may argue that delivering and managing good water quality cannot be done by water companies alone. In the words of Thomas (HQD/181102/WaterCo):

> Delivering good water quality is something which has to be managed right the way through from the raw water where you take it from your reservoirs or rivers or wherever and right through to where people drink it and the responsibility for that is not just a water company like us.

What exactly has changed with and after privatisation? Kinnersley (1994: 159) stresses that 'innovation lies not only in the formation of the DWI, but in the revolutionizing of the way in which legal requirements are stated and in the refinement of sampling procedures'. As mentioned in chapter 2, it is unclear whether privatisation, the requirement to comply with the European Directive, or the change in organisational structure (which are all intertwined) should be regarded as the largest change in the industry in recent years. One of the respondents argued:

> The proper date was when the Joint Circular was issued, because that was when the requirements of the [EC] directive were implemented in the UK. So, privatisation in a way was not one of the key dates, except that it was the same date that the government had to incorporate the directive into the primary legislation. So, the key date really was the implementation of the Joint Circular. (Victor)

According to this respondent the legal requirements rather than privatisation have influenced the way in which water companies work. In the words of Kinnersley (1994: 159): 'It is not so long since the legal standards were expressed using words such as 'wholesome' rather than precise limits based on forty or fifty specific parameters'. Ward et al. (1995: 20) state: 'The approach to drinking water quality assessment and control contained within the Drinking Water Directive clearly differs fundamentally from longstanding British practice'. Samuel did however explicitly mention privatisation: 'The whole change in a public body to a private body, the way in which everybody operated in that respect. So, the whole thing changed in sort of '89 when the government privatised the industry and the regulators all came into being'. Without trying to identify *the* cause for these changes, it is important to note *that* important changes took place in the way drinking water quality was managed in a relatively short period and partly due to the way in which the DWI enforced the regulations. I will give a few of the many quotes of respondents (and one report) that all point in the same direction.

> The industry was very different. It was run largely by the either private water companies or by water boards which were part of the local government machinery. And each one of those would have had a chief chemist and bacteriologist and they used the WHO Guidelines and also the so-called report '71, which set out how to monitor water supplies for microbiological parameters. It was long used as a sort of bible for microbiologists on how to monitor and assess the quality of public water supplies. (...) The only requirement that was in the UK legislation at that time was that the water should be pure and wholesome. And pure and wholesome was interpreted by the individual chief chemist and bacteriologist employed by the individual water companies. And they made their own interpretation, they made their own judgements on what was pure and wholesome. (Victor)

> Even five or six years ago different bits of the company had totally different standards, attitudes to the regulations. They were just different, everybody had their own idea about what was important and what wasn't. With the regulations things have become a lot more standardised. (Robin, WQM/090603)

> Prior to 1990 there were no numerical standards for drinking water quality although the previous water undertakers did do some monitoring particularly to cover bacteriological safety. (Rouse, 2001)

> Before the drinking water inspectorate were formed, there was very little in the way of regulation against standards. We periodically used to get a visit from the local council who would take a chemical and a bacteriological sample away and they would analyse it. But over the years that fell away until the drinking water inspectorate came into force with the drinking water regulations and we were then measured against those. Before that we basically had to make sure water that was supplied was wholesome. But there wasn't really any challenge to say that it wasn't wholesome. Nobody really seemed that interested in it. (Bill, QWM/201102)

> Part of my job before privatisation was to go around the water companies to look at their capital program and by instructions from above take things out of the program because the government wasn't gonna provide the money. Even though lots of things needed to be done. Before it was just that companies had to provide 'wholesome water' in some guidance that was clarified as clean, clear and palatable and in general meets the WHO guidelines. That's it. Could basically do what you wanted, there was no requirement to the government, water quality or anything. Nothing. (Chris, DWC/040603)

These accounts of the changes in the water industry are, as some respondents explicitly mentioned, based on each respondent's memories. They are also accounts of quite radical changes over a short period of time, which may stress the better and more organised way in which water is managed nowadays according to respondents. They point to a development where certain skills and judgements of specific people (the chief chemist and bacteriologist) seem to have become less important and the significance of regulation, implementation and enforcement of this regulation for managing water and thus materiality has increased. In chapter 3 I discussed the problems that are related to relying on people's memories. However, the above accounts were not only found amongst most respondents in a similar form, they are also are supported by documents (the number and form of regulations in different periods of time) and by wider, although not unproblematic, literature as the discussion of trust, expertise, and objectivity in chapter 2 demonstrated. Timmermans and Berg (1997) argued that specific skills and discretion are needed to deal with (strict) regulations. After having set out the construction of the current directive(s) and an account of a water quality standard, the dealing with and mobilisation of drinking water quality standards will become the central theme of the chapter.

5.3 History and construction of current regulations

As we saw in the previous section, regulations about water quality are not new. However, in the last decades specific regulations for drinking water quality have been developed and become increasingly extensive and international. In Table 2 I give an overview of a number of European and English national regulations on drinking water since in 1980 the first European drinking water directive came into existence. The Table also outlines a (limited) number of the consultations that took place before the final regulations were formulated.

Table 5.2: European and national drinking water regulations and consultations, 1975-2004

Year	Regulation
1975	Proposal Council Directive concerning quality of water intended for human consumption
1976	Opinion of Commission of the European Communities
1976	Opinion of European Parliament
1976	Opinion of the Economic and Social Committee
1980	Council Directive concerning quality of water intended for human consumption (80/778/EEC)
1982	Joint Circular 20/82
1989	Water Supply (Water Quality) Regulations
1991	Water Industry Act
1991	Water Supply (Water Quality) (Amendment) Regulations 1991
1991	Proposals for Modification of Drinking Water Directive 80/778/EEC
1995	Proposal (new) Council Directive concerning quality of water intended for human consumption
1996	Opinion of the Economic and Social Committee
1996	Opinion of Committee of the Regions
1998	Council Directive 98/83/EC concerning the quality of water intended for human consumption
1999	Water Supply (Water Quality) (Amendment) Regulations (on Cryptosporidium)
2000	National consultation on Water Supply (Water Quality) Regulations 2000
2000	The Water Supply (Water Quality) (England and Wales) Regulations 2000
2001	Water Supply (Water Quality) (Amendment) Regulations 2001
2003	Water Act 2003

Although the construction of regulation and standards is not the main concern in this chapter, there are a number of reasons for looking at this construction in some depth. Shapiro (1997) contends that the formulation of standards does not only say something about the stakeholders involved in the process, it may also say something about the use of the standards or products that these standards govern. In addition, standards both reflect and shape the exercise of practitioner judgement and the construction process may shine some light on the way in which standards reflect professional judgement. Before I will explore the changes in the water industry and the mobilisations of set standards further, I will therefore first say something about how both the European and national regulations came into being. This section will demonstrate the sometimes complicated negotiation processes that take place in standard setting procedures and show that the script of regulations cannot simply be read from the regulations. In cases where it is difficult or impossible to know the exact intention of policy makers (or certain policy makers), interpretative flexibility starts to play an important role. There is one more reason to include a section on the construction of water quality standards: it will show that standards and materiality need to be *already* co-constructed in this phase of the process in order to 'work' when they are implemented.

Table 5.2 shows that two European drinking water directives have been developed over the last 25 years; one in 1980 and the other one in 1998. These two directives play an important role in this dissertation in the sense that they form part of the regulatory environment within which the water companies operated during the time of my research. The 1998 directive came into force on 25 December 1998. The member states of the European Union then had two years, until 25 December 2000, to transpose this into national legislation and five years, until 25 December 2003, to ensure that the drinking water complies with the standards with the exception of bromate (the water needs to comply in 10 years), lead (15 years), and trihalomethanes (10 years). When I started the dissertation in 2000, the water companies still operated under the 1980 directive. They were in the process of making arrangements to comply with the 1998 directive, and in 2004, when I am finishing the dissertation, the 1998 directive applies to them. It has thus been a period of (regulatory) transition for the water companies.

The proposal for the first European drinking water directive appeared in the *Official Journal of the European Communities* (OJ) in 1975. The proposal was welcomed by the European Parliament (EP) as 'a useful and necessary instrument for greater and more effective protection of public health' (EP, 1976: 28). Fixing standards for the quality of water for human consumption was applauded. The Parliament also had a few comments that had to be looked into further. It was concerned that the Maximum Admissible Concentrations (MAC) would not bear sufficient relations to the particular conditions of the locality and suggested that the need for Exceptional Minimum Required Concentrations for certain parameters, by analogy with the Exceptional Maximum Admissible Concentrations, would be investigated. It was also recommended that the parameters and attached values needed to be reviewed at least every five years.

The response of the Economic and Social Committee (ESC) (1976) was longer and seemed more reluctant. As we saw in chapter 4, the perceived importance of industrial interests often prevented the enforcement of water quality regulation. Although the Committee welcomed the proposal for setting standards for the quality of water for human consumption, it came with a number of concerns, mainly regarding industry: 'the application of all the standards referred to in the Directive will create, especially, problems for industry' (ESC, 1976: 14). I will sum up a few of the concerns below. Firstly, according to the Committee many of the values seemed arbitrary and unrealistic. The committee suggested the values should be more realistic in their limiting values 'to avoid many existing satisfactory supplies being unnecessarily classified as unsatisfactory, and to avoid subsequent heavy expenditure in seeking to make these supplies conform with rigid and arbitrary requirements' (ibid.).[5] Secondly, the standards should protect human health, so a distinction needed to be made between public health and aesthetic and operational reasons. Heavy costs for sampling and analysis could only be justified if they considered human health. Thirdly, many standards were stricter than the WHO guidelines and the committee wondered how this was justified. The committee did not see an indication of how the standards related to already existing standards in member states and pointed to the fact that the economic burden to comply with the standards could be higher on some countries, for example those that are dependent on river water that was already polluted by a non EU country. It advised that the idea of regional exceptions should be considered. These would be granted nationally if standards were unnecessary

[5] At first the document also said: 'The Committee would point out that in various sectors of the foods and drinks industry, water is in fact used which does not comply with the proposed Directive, and apparently no harm to public health has resulted'. The last phrase was later rejected.

because departures from them would cause no harm or would be unrealistic because they could not be achieved at that moment in time. Fourthly, 'the frequency of sampling should not only depend upon the size of the population served and the capacity of the water supply installation but also on the relative importance of the parameters being measured and their expected variability in concentration' (ibid.: 16).

The Committee was also concerned about a few practical issues like the lack of information about private wells and boreholes held by local authorities (these sources needed to be excluded from the directive until the information had been collected) and problems with enforcement in countries where the public water authorities do not control the pipelines: 'with many of the materials being used for drinking water pipes within the Member States, it is very likely that the limits set will be exceeded on occasions.' (OJ C 131: 15)

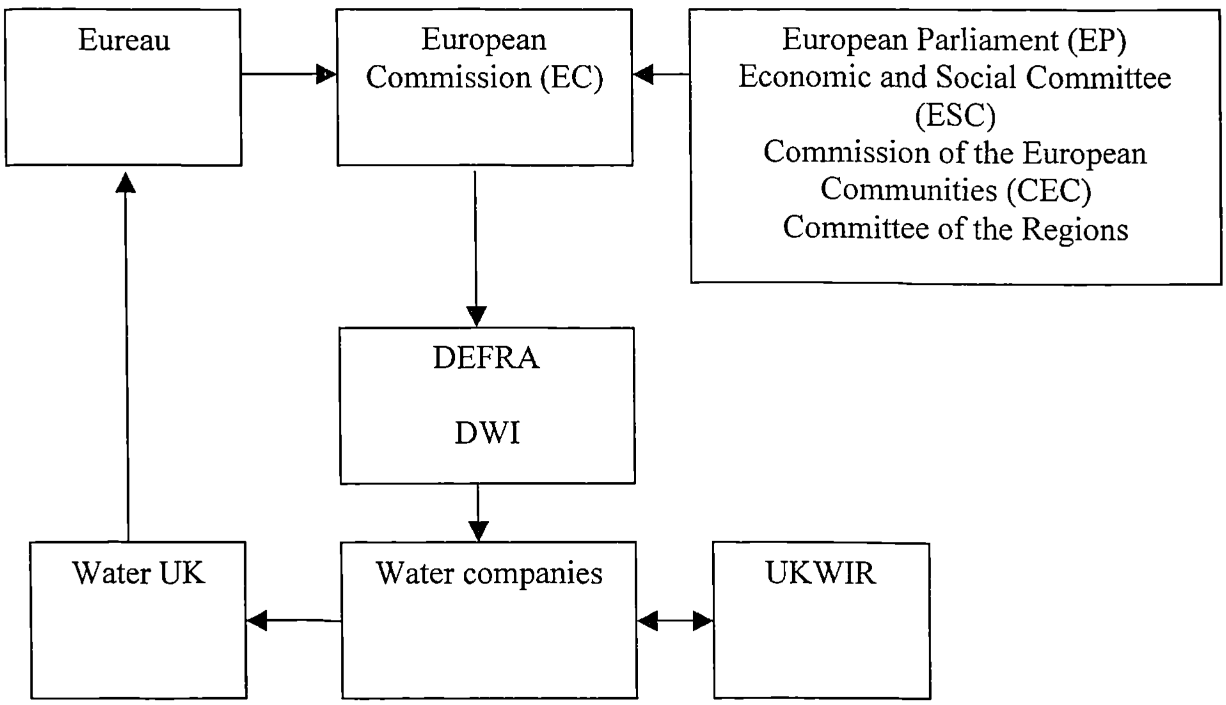
In 1980, after many negotiations and revisions, the 1980 drinking water directive was published in the *Official Journal of the European Communities*. The deadline for implementation by member states was 1982. In 1982, the UK published what was called the Joint Circular that implemented the 1980 directive. However, Victor discussed the objections the European Commission had against this Joint Circular.

> If you look at the historical context, the European Commission were not entirely happy with the way that the UK government interpreted the directive in the Joint Circular. The trouble is, you are relying on my memory now, because it is what, 15, 17 years ago, my recollection is that initially the thing that was assessed against the standards was the average concentration. And of course, the directive contains MACs or maximum admissible concentrations, and I think about '87 or something like that, the Commission required the UK government to not use that method of assessment of compliance. And the basis for assessment went over mostly on to a single sample set against the MACs. One of the other things that the Commission were unhappy with was that the UK government used, what at that time were called administrative means, for incorporating the European directive into the UK legislation. It wasn't incorporated into the primary legislation, in other words, it didn't go through as an act of parliament. And in '89 of course, the government passed the Water Act and the requirements from the directive were then enforced by

way of regulations made under the Water Act, which is primary legislation. And that was the way in which the UK government was able to satisfy the Commission.

In England it was thus only in 1989 that the Water Supply Regulations, which were based on the European directive, came into place.[6] To summarise, Figure 5.2 shows (again a simplified version of) which parties are involved in constructing and implementing drinking water quality regulation. Some of the parties cited will be mentioned later in this chapter. As we will see, many consultations take place before regulations are final. The arrows in the figure could therefore also point both ways. However, in the figure they are used to focus attention on the main direction of information flow between the parties.

Figure 5.2: Parties involved in construction drinking water quality regulation



[6] England was however not the only country that was delayed in implementing the directive. Norway implemented the directive in 1995 after it had become part of the European Economic Area (EEA) and after negotiation of the particular Norwegian situation. Unlike most EU or EEA countries, Norway derives most of its drinking water from surface waters. Norway had to measure parameters that hardly occurred in Norwegian waters (nitrate for instance) and monitoring these, Norway argued, would not make a difference in guaranteeing 'good water quality'. The Netherlands that implemented the directive in 1984, had the opposite problem. Some substances exceeded the European limits (for example nitrates and pesticides). The Netherlands needed more time to develop the necessary treatment technologies and tried to negotiate this.

As we saw in the previous section, the combination of new regulations, regulatory bodies, privatisation, and wider societal developments led to changes in the water industry. The judgements of the chief chemist and bacteriologist were (partly) replaced by an equation of good water quality to compliance with the standards. Respondents often mentioned the impact the directives (and enforcement of them) have had on their direct work in a water company. I will give a few examples.

> Life was much simpler then [ten years ago]. We only just got to grips with the 1989 water regs. Everybody was on a very steep learning curve. (...) The annual water quality report was about five pages, now it is sort of ninety pages, and the depths to which the DWI went into things were not as much as they are now, so I mean the water quality in the last ten years has changed unbelievably.[7] (Sarah)

> Gradually the workload has increased as the regulations have kicked in and the understanding of the regulations has kicked in. Prior to 1989 I think we took samples on one day a week and then sort of if you go back in time before that, all the samples were done on a Wednesday afternoon, but now we are sampling four days a week, and obviously, if anything goes wrong we'll sample over the weekend, but generally it is four days a week. And if we have a new source introduced to pump out sufficient water then we'll go to seven days a week. That is how it sort of increased. (Sarah)

> The whole thing changed in sort of '89 when the government privatised the industry and the regulators all came into being. For the first time we had everything covered in sort of one piece of legislation and associated guidance. All of a sudden it became much more concrete and formalised. I am not saying that that didn't take place before '89/'90, it did, but it did in a much more looser, well, there was no real framework, you know, overarching it. To ensure that we had good water quality, it was not so clearly defined and

[7] Sarah equates (perhaps unintentionally) the change in water quality regulations with a change in water quality. This focuses our attention on the co-construction between materiality and water quality standards and regulations that is the subject of the thesis. I will return to this later in this chapter.

> not so clearly regulated. (…) So, that is the main change. It all became much more structured, much more defined, and all our responsibilities were clear and the actions we had to take were all set out for us. (…) And also, probably over the last six or seven years that the drinking water inspectorate have tested definitions of where the water is wholesome by actually going to court. And you know, the sort of ultimate sanction for a company getting it wrong on water quality is to be taken to court. You know, that is a complete switch, you know that would never have happened 20 years ago. (Samuel)

> It wasn't really until the implementation of the drinking water inspectorate that compliance with them [the regulations] was seen as an issue. Certainly in the early part of the 1980s, whilst we were aware that these regulations existed in Europe, we didn't actually take steps to comply with them as such. Although water quality broadly would have complied with them, nobody actually checked to make sure that was so. (Bill)[8]

Prior to 1989 when the European directive had been implemented in the Joint Circular but not in primary national legislation, it did not seem to have much impact on the practices in water companies. However, when the 1989 Water Supply Regulations came out and the DWI was established, the DWI started to strictly enforce the regulations.

At that time, some criticisms were raised about the 1980 directive. The main criticism was that the standards were 'black boxed': their origin and the way in which they were developed were made invisible. This was a comment we had already heard from the social and economic committee on the proposal for the regulations. In the words of Fawell and Miller (1992: 728-729):

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[8] Hassan (1998: 164-165) contests Bill's idea that the water quality would have complied with the standards early in the 1980s: 'the relaxed attitude towards the directives extended into the 1980s, the NWWA [North Wales Water Authority] claiming that most of the region's potable supplies easily complied with the minimum standards. But this confidence was followed nearly a year later by the admission that nearly eighteen per cent of the Authority's drinking water sources did not comply with the necessary standards, especially in relation to concentrations of lead, aluminium and manganese'. In fact, he (1998: 162) argues that the fact that British waters were failing the standards increased worries about the potential health hazards associated with drinking and bathing waters and that this resulted in an increased sale of bottled water: 'A number of disquieting reports about drinking-water quality led the public to turn increasingly to bottled water. By the early 1990s sales of bottled water were growing rapidly, although by now tap-water was improving in quality'.

> The thinking behind the EC standards remains hidden, and this has led to considerable confusion as to what an exceedence actually means in health terms. Clearly, some of the maximum admissible concentrations (MACs) in the Directive come directly from the WHO Guidelines, but others, such as parameter 55 (pesticides and related products), are based on the precautionary principle and therefore contain a very high political component. It is only possible to speculate as to the derivation of many of the MACs and guide levels in the Directive.[9]

Fawell (1991) adds in another article that this confusion about how the standards were derived leads the public to regard all standards as 'health' standards and makes it difficult to assess what should be done if a standard is exceeded. He (ibid.: 562) says that 'there are even numbers for parameters regarded as toxic which are based on political or other considerations only loosely based in science'. This is also one of the reasons for the establishment of a new directive my key informant (Chris) mentioned. He was one of the scientific negotiators for the UK government on the 1998 directive and we spent a few hours discussing these negotiations and related issues. I was fortunate to have the opportunity to talk to him, because this is information that is not available via for instance journals and it would have been hard –in the words of my informant 'impossible'– to negotiate access to the minutes of these meetings.[10] According to Halffman (2003: 20) this demonstrates exactly how regulatory decisions are taken routinely as opposed to the way they are taken in situations of public controversies:

> Regulatory decision makers and experts defend such secrecy precisely because regulatory action under these circumstances is different from public controversies: it allows regulatory actors to negotiate more pragmatically and be 'reasonable', without concerns of loosing face or constituency support.[11]

[9] See Crowley & Packham (1993) for a similar argument.
[10] In addition, it was difficult to trace people who had been involved in the negotiations of the directive. In the words of Chris: 'There is no one left in Water UK [the water industry organisation] now that was involved. The people that were involved from sort of '95 to '98 when all the work went on have all disappeared, moved on'.
[11] Decisions taken routinely are not always taken in a formal setting. Chris explains: 'A lot of these negotiations are not actually done around the table. You go to the pub, you talk'.

According to Chris, it was primarily the UK and one or two other member states that wanted a revision of the 1980 directive. When the Council agreed, three informal working groups were set up to deal with respectively legal and administrative issues, technical and scientific issues, and consumer issues. Chris regarded the presence of experts on scientific issues as important, but he stressed that it was essential that they also had experience in the water industry:

> One of the dangers of getting scientists involved that don't understand the practical issues associated with water supply is that you can find something that is potentially nasty in most of the materials that are used to convey drinking water. But they are not a risk to health at the concentrations that leak. But there's a tendency for people to say: oh well, that's a nasty substance, therefore we mustn't have any of it. But if you go to that extent, you won't be supplying drinking water.

Without understanding the practical issues of managing drinking water and its material properties, unrealistic and unreasonable standards would be set. The material therefore needs to be taken into account in the setting of the standards. Representatives of the member states fulfilled this role of expert in both scientific and water industry issues, because the members of the Commission's scientific committee are 'merely' theoretical scientists.

In September 1993 a consultative conference took place in Brussels to which all member states, some potential member states, representatives of the water suppliers in Europe (via Eureau, the European Union of National Associations of Water Suppliers and Waste Water Services), and representatives of so-called consumer organisations like Greenpeace and Friends of the Earth were invited. In 1991 Eureau had already published proposals for modification of the 1980 drinking water directive, a document of 187 pages which addressed each individual parameter in detail. In 1995 the proposal for the new directive was published and in 1996 negotiations on the directive started which lasted two years. These discussions consisted of negotiations between member states and opinions given by, amongst others, the Economic and Social Committee and the Committee of the Regions. Here, I will focus on the negotiations between member states as discussed with Chris.

A number of parameters were prominent in the debate. One example is the parameter for disinfection-by-products (trihalomethanes), a substance that can emerge when chlorine is used for disinfection. The Scandinavian countries, the Netherlands and Germany were pushing for tighter standards, whereas most of the Southern member states who use surface water, in which disinfection-by-products tend to form, wanted to adopt the WHO guidelines. The Commission took advice from its scientific advisory committee on ecotoxicity and toxicology and they recommended a very tight standard. However, it was argued that if there would be a tight standard for trihalomethanes, the standard for bromate (which can emerge when ozone is used for disinfection as is the case in many Northern countries) should be based on a similar reasoning. If one would apply the reasoning of the scientific advisory committee on bromate and assumed it is a carcinogen, the bromate standard would be 0.3 mg per litre. It would be hard to achieve disinfection this way and 'disinfection is far far more important than any very small risk from bromate as a carcinogen' (Chris). However, the WHO guidelines also recognised that there may be practical difficulties in achieving 3 μg/l (it was difficult to get much below 10 μg/l with the analytical methods that existed) and suggested 25 μg/l as a practical level for bromate. In addition, toxicologists viewed the carcinogeniticy of bromate differently. Some thought it was a genotoxic carcinogen and others a carcinogen that operates by an oxidated mechanism. In these cases, the standard for bromate has to be formulated differently. In the first case any concentration of bromate could cause cancer in the population, in the second case, which most people support, the standard can be constructed in the same way as non-carcinogenic substances. In the end the WHO guidelines for trihalomethanes were accepted and bromate was set at 10 μg/l.[12]

> With every negotiation, you have somebody that wants something over here and somebody that wants something over there and at the end of the day you end up with something in the middle, which isn't necessarily the best science and technology. It is a compromise that everybody can live with. (Chris)

Another example is the parameter for trichloroethene and tetrachloroethene. The Scandinavian countries, especially Denmark, were pushing for a standard of 1 μg/l. The scientific advisory committee advised the same. However, Chris argued that:

> If you read the scientific articles, there was no way they had constructed a proper scientific argument to arrive at one microgram per litre. What they

[12] Negotiated was that 25 μg/l for bromate has to be met by 2003 and 10 μg/l by 2008.

> were trying to do was to control discharges to the environment by a tight drinking water standard. UK has always argued, if you want to control discharges to the environment, control the discharges to the environment, don't try it through the drinking water.

In Denmark most of the drinking water comes from groundwater. Like the Norwegians, they seek to protect the (ground)water by preventing contamination getting into the water rather than treat the water extensively. The Assistant Director of the Section for Water Hygiene of the Norwegian Institute for Public Health (Rene, ADNIPH/140800) explained this to me when I interviewed him for my M.A. thesis:

> If there is a polluted catchment area and you just trust the cleaning process, there might be pollution that we don't clean, simply because we don't know about it. Using many chemicals to clean might have other health effects of which we don't know yet, but which we might discover in the future. So we feel it is more comfortable to have a clean catchment area.

This is possible because the Norwegians consider their water sources as relatively clean. They do not have a lot of pollution from the population, simply because the Norwegian population is small. Partly because of this, not every small municipality has a good treatment system. Securing the catchment area would for them be the best and easiest/cheapest solution. However, under which directive securing the catchment area should come, obviously became a matter of debate. For Denmark securing the catchment is a drinking water quality issue, a way of purification, whereas for England, where a higher degree of industrialisation has to be taken into account, it is a matter of controlling discharges.

Similar differences exist when it comes to disinfection in the various European countries. As Hydes (1999) nicely outlines, some countries legally require their drinking water sources to be disinfected and to maintain a disinfectant residual in the distribution system, whereas other countries do not disinfect or maintain a residual during distribution because their groundwater is microbiologically of good quality or their surface water has sufficient treatment barriers to remove microorganisms. Other countries do not use disinfectant residuals in order to avoid the formation of disinfection by-products (DBPs)-or simply because the distribution system is well maintained. In long and complex distribution systems like the one that supplies London, often a chlorine residual is maintained and by adding ammonia chloramines are formed which is much more persistent and give the company a bigger chance to get the residual to the end of the distribution system.[13] This is regarded as necessary because of the ever changing quality of the water and because water can come into contact with contaminants during transport. However, chloramines can, under certain circumstances, break down to nitrite. This is not a problem for countries that do not maintain a chlorine residual, but it can be for countries that do and therefore not comply with the standard for nitrite. Complying with one standard may thus have a knock-on effect such that another standard is exceeded. The UK has argued, on the basis of medical advice, that a small amount of nitrite is not harmful for human health and has managed to relax the standard in the new directive.

These examples show that negotiations around standards and pushing for more relaxed standards often emerge from country-specific situations, which reflect different sources of drinking water, the raw water quality, or the (state of the) distribution system. They also show how boundaries between science and politics are drawn and contested. Most regulatory standards are –as was claimed by nearly all my respondents– scientific standards. The construction of the standards shows however that it first needs to be negotiated on which (scientific) knowledge these standards are based. Which view of carcinogenicity of bromate is accepted as the basis for the standard? In the case of trichloroethene and tetrachloroethene no choice needed to be made between two scientific claims that would affect the value of the parameter differently - rather a debate took place about what knowledge was in and out of place in a drinking water directive. The standard for bromate demonstrates that the practicalities of measuring also influence the standard that is set. These examples echo to a certain extent Hamlin's (1990) exploration of water analysis in nineteenth century Britain, where 'scientific arguments were wielded on all sides in an effort to obtain whatever set of standards various parties regarded as desirable' (p. 5) and where it was debated what process of evaluation was appropriate for judging water quality. Majone (1984) stated in chapter 2 scientific methods are influenced by biological and philosophical assumptions. What process of evaluation is regarded as appropriate for judging water quality thus has consequences for the analytical

[13] Other reasons for using chlorine in the distribution system are firstly that, since you can analyse it at the end of the system, it gives reassurance that the water does not contain

methods that are used, as and therefore, for instance, for the way in which lead samples should be taken and analysed.

Other parameters, like the parameter for lead, were agreed upon without much discussion. The waterworld seemed to agree that lead can be harmful for public health. Oliver illustrates this by saying:

> Lead was always fairly clear-cut to me, there is no safe dose. And we've gone to unleaded petrol effectively, haven't we? Well, that's an indication of how, we don't have lead in paint anymore, and it's one of those elements that the literature that I have read, it's fairly clear-cut.

In the words of Fred: 'I wouldn't say any lead is particularly good for you, because it is accumulative within the body. The guiding principles are in all of these things scientific and medical advice.'[14] The majority of member states accepted that 10 micrograms per litre was a number they should try to achieve. Because of practicalities and the time it would take to remove it by water treatment or to replace lead pipes or pipes containing lead solder, it was agreed that the standard for lead can be achieved in two stages: 25 μg/l in 2003 and 10 μg/l in 2013.[15] However, there was discussion about how and where lead should be monitored. As we will see in chapter 6, how a sample is taken influences the result of the sample. If one samples the first water that comes out of the tap, which is what people usually drink, the result for lead can be quite high; if, on the other hand, the tap is flushed for a few minutes the lead result may be low. During the negotiations, member states could not agree on this and it had to be decided on later by the so-called 'article 12 committee'. This committee also had to decide on the radioactivity parameter. Radioactivity is an important parameter for the water companies. As James (WQM/280404) says:

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bacteria and secondly that if there is a burst, there is a little bit of chlorine there that will cope with any intrusive or contaminated water.

[14] Although the waterworld seemed to agree that lead can be harmful and the standard as such was not debated, economic considerations were part of the standard setting process. I asked Fred for an explanation about the difference between the European standard for lead (10 μg/l) and the American standard (15 μg/l). He answered: 'The difference between 10 and 15 is not as great as it sounds in the end. Some people will argue that once you get a limit below 25 then you are into a law of diminishing returns and the more you push away from 25, the situation is less and less significant in terms of body burden for the people drinking the water. The cost benefit becomes harder and harder to justify.

[15] According to Charlie there are only a few lead pipes that belong to the water companies. Most lead pipes are within consumer's properties – usually their part of the service pipe.

> The regulations at the moment for a company our size really say you've got to take something like 700 samples a year. Now we are quite a small company in the scheme of things, but 700 samples is a lot of samples and very very expensive. Not many people in the country currently offer that type of analytical service. Is it realistic that the regulator will want all the companies to do all that sampling when 99%, way more than that, is gonna be completely clear?

On the 4th of June 2003, when the interview with my key respondent took place and seven months before the member states had to comply with the 1998 directive a draft of the article 12 committee paper was there, but nothing had been agreed. The UK however anticipated the answer in its regulations.

Lead, bromate, and trichloroethene and tetrachloroethene are standards that are new to the directive or are tighter than they were in the 1980 directive. These standards were included in the directive with the argument that it is scientifically proven that the parameters can have adverse health effects. Other standards have disappeared from the directive. One example is potassium. All respondents said they did not know why the parameter had been in the 1980 directive in the first place. An example:

Martha:	Potassium, 12 milligrams per litre, the standard, is not health based at all.
I:	So, what is the standard based on?
Martha:	That is a very good question. If you could go back to the European Community in 1980 and ask them and get an answer, you would be doing possibly better than a lot of water companies. We don't know really. There is no deep knowledge of why it was set at 12. I have asked that question myself. It is a little bit of a puzzle that one.

Another, similar example:

Also there is sometimes lead containing solder that has been used historically in the internal plumbing. This is where most of the lead is picked up.

Fred: There were a lot of parameters in the old directive that were just not required to look after public health. They were introduced into that legislation, we believe, for other reasons and those were not really the ones we would support to include. Potassium was a good example, which really has got no health effect, but it was introduced for other reasons which were for mainland Europe and not for the UK.

I: So, potassium wasn't a health related standard?

Fred: No, and it has been left out of the new directive.

I: Do you know why it was introduced at first?

Fred: Well, if that is philosophical, no I don't. We believe it was brought in for control quality of cross international border river flows.

One of the reasons that was given for the fact that it has been left out of the 1998 directive was that it was not a health-related standard. One respondent told me that many people have started to use potassium chloride instead of sodium chloride as salt these days, because they have concerns about sodium in the diet. The quote above almost suggests that it cannot have been a health related standard *because* it has been left out of the new directive. Like in the case of trichloroethene and tetrachloroethene the standard was by some also regarded as 'out of place' for a drinking water directive and should be brought under a different directive with a different purpose. If it was indeed used as a parameter to control the quality of border crossing rivers, this is not a concern for England.

Also two other parameters that were removed from the directive did not bear a relation to health according to my respondents. It was argued that phenols would not have to be monitored for because if there is a problem with phenols, people would experience taste and odour problems and the consumer would inform the water company. Phosphorous did not belong in the directive because it is 'an essential element to build nice strong bones' (Chris).

Yet, other parameters that are not regarded as health related by the water industry at the value they are set, were not so easy to relax, let alone remove from the directive. Pesticides is an example *par excellence*. Thomas explains that in the 1970s, organic-chlorine pesticides were the biggest concern since these were used widely:

> So, at that time, the standard was set on the basis of really organic-chlorine pesticides have no place in drinking water, therefore what we will do is set the standard at the, what was then the limit of analytical detection of organic-chlorine pesticides. And this was the famous point one micrograms per litre.

He argues that the standard was based on the science perception and analytical capability of the later 1970s. As research continued and analytical technology improved in the 1980s, other, much less toxic, pesticides were found. Yet, because the standard was already there, it was almost impossible to relax:

> Because the standard had been set effectively as a surrogate for zero, but only for organic chlorines, it was almost impossible for any political body like the European Union to be seen to be relaxing a standard for pesticides which is what it would have been. The science would have entirely justified a more flexible range of standards for pesticides, but the politics and actually I can believe from a customer perception point of view, if you said to your average customer: would you like a standard which would be as low as achievable, as close to zero as you can get, or would you prepare to tolerate some pesticides in drinking water, all well below any health standard, you know what the answer would be: I don't want pesticides in my drinking water. Because they seem nasty and dangerous and I really don't want them fed to my young child. So, once that standard had been set, which was a political standard, it wasn't a scientific standard, effectively, it became impossible to go anywhere else than keeping that standard and possibly even tightening it.

Although the standard became subject of a large political and technical debate the standard was kept in the new directive and recognised as 'probably the only parameter in there where the standard is not based on a tox-risk assessment':

> Every other parameter, whether it's gone up or down, essentially you can work out the sciences to why that standard is there. Pesticides, because of the emotional perception is an entirely non-scientific standard set as close as it can to zero.

Martha illustrates that Thomas is not alone in his analysis of the pesticides standard: '0,1 milligrams per litre is basically an absence of pesticides. Sometimes setting issues are very emotive and political and it is easy whilst you have got something not to let it go again. The question may be raised: why do we not use toxicological standards?'[16] Oliver raised the same question:

> That's part of the problem that we are driven by regulations, we are driven by a desire to meet the water quality standards one hundred percent. Yet we know for example that the pesticide limit is not set on a health basis, it is set as surrogate zero. So, is that really cost-effective? (...) Wouldn't it be better if, rather than spending the money on pesticide removal that is not required, we spend the money on lead removal which is required.[17]

As we have seen the adding of new standards, the removal of standards from the 1980 directive, and the tightening of standards were discussed during the negotiations on the 1998 directive. In addition, Chris and I also talked about parameters that were discussed during the negotiations on the directive, but were not included in the end. One of these is *Cryptosporidium*, a parameter to which I will also return later in this chapter. *Cryptosporidium* is a single-celled animal, i.e., a protozoa. One species of *Cryptosporidium*, *Cryptosporidium parvum*, is known to infect people (and livestock). This can cause cryptosporidiosis, which is 'usually characterised by an acute self-limiting diarrhoeal illness, commonly of two to three weeks duration, from which the patient recovers fully' (Bouchier, 2001). However, the disease can be much more serious in patients who are immuno-compromised and no effective treatment has been found so far. Chris explained why *Cryptosporidium* has not been taken up in the directive. Another bacteria that can cause similar problems to *Cryptosporidium, Clostridium perfringens*, had already been taken up as

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[16] The wider literature recognises this as well: 'The European Commission's decision to set the drinking water standard for all individual pesticides at 0.1 µg/l was met with disbelief by RA [risk assessment] experts. It went directly against the experts' standing practice to identify the precise health risks of each individual pesticide through technical refinement of testing and assessment.' (E.g. Royal Commission on Environmental Pollution, 1992: 126, in: Halffman, 1995: 266)

[17] Oliver argues more generally that 'if we were serious about public health, then water is a low risk'. Money would be better spent on issues like fat intake, smoking, heart disease, cancer and so on, because: 'if you spend that much money on stopping people from smoking, the health benefit of the nation would be amazing compared to the health benefit you get from spending it on drinking water quality'.

a parameter. In the proposed directive this parameter was a mandatory standard. As he explains:

> It was put there because of some work your colleagues in the Netherlands have done. They claimed, showed that *Clostridium perfringens* was a good surrogate for *Cryptosporidium*. We've got work in the UK that showed it wasn't.

The English negotiator, Chris, spoke for England when he said he did not agree with having *Clostridium perfringens* as a mandatory standard, because it only indicates that at some stage the water supply has been derived from a certain source. He and a few others successfully argued during the negotiations that it was not a surrogate for *Cryptosporidium* and that it should not be a mandatory standard. It was transferred to the indicator parameter values instead. Whether a parameter is a mandatory standard or an indicator standard has consequences for the way in which non-compliance is dealt with, as I will show later in this chapter. The UK was pleased to see the Dutch researchers come around after a while:

> Interestingly enough, the Dutch researchers subsequently agreed that *Clostridium perfringens* isn't a good indicator for *Cryptosporidium*. So, I mean, we were right, in the end anyway.

This is another example where competing scientific claims were at work. However, because of the *Clostridium perfringens* standard, no standard for *Cryptosporidium* had been included in the directive proposal. It was agreed that *Clostridium perfringens* was not a surrogate for *Cryptosporidium,* yet it would probably have been hard to argue that a standard needed to be included that had not even been part of the proposal. England included *Cryptosporidium* in its national legislation in 1999. However, according to my informant, the other member states were not ready to set a standard for *Cryptosporidium*. They had probably encountered the same problems, but not realised that they were caused by *Cryptosporidium* if they had not monitored for this parameter. Very few respondents thought that England would be pushing to get *Cryptosporidium* into the next European directive. In fact, as my informant said, it is covered by the directive by what he calls the 'catch-all' article, article 4, 1A:

> Member States shall take the measures necessary to ensure that water intended for human consumption is wholesome and clean. For the purposes of the minimum requirements of this Directive, water intended for human consumption shall be wholesome and clean if it:
> (a) is free from any micro-organisms and parasites and from any substances which, in numbers or concentrations, constitute a potential danger to human health.

He did say that 'catch-alls' is a difficult concept to work with. When I asked why some parameters are included as standards and others not, he answered that there are more parameters for which standards could have been developed just as there are standards that could have been taken out. This had not happened because the standards are based on the WHO guidelines and on what member states felt was important in a European or national context.

We have seen that cases have to be made if a country wants to see a particular standard removed or accepted. If water companies do take part in the 'lobbying process', they will generally not be lobbying for new standards to be included in the directive. Respondents chose their words very carefully when I asked them about this process.

I:	Have you been lobbying to change particular standards?
Fred:	(hesitating) To make them more relevant

I:	Did you have people lobbying for certain kinds of standards?
Victor:	Well, not lobbying for new ones. If we believe that a standard is being set and it isn't sensible to set it.

It can go further than this. According to Chris the European Parliament raised one major issue during the negotiations of the directive. The Parliament recommended an amendment to introduce endocrine disrupters to the directive. Endocrine disrupters are 'a range of substances suspected of interfering with the hormone systems of humans and wildlife' (European Commission, 1999). The amendment was rejected because .the member states agreed that there was not enough research and information and that therefore nothing meaningful could be said about endocrine disrupters. Since the Commission did not want to completely reject something suggested by the European Parliament, they agreed that a study on endocrine disrupters would be undertaken. This may become one of the issues when the directive is revised, depending on the outcome of the study. In the mean-time some water companies have decided to do some research on this subject as well.[18] Fred talks about this as 'defensive research':

> But that is defensive research, so we can say: sorry guys, we have looked at it and we have looked at all the figures and there isn't any relationship. Because water is a very easy thing to blame.

Harry adds that 'we are taking a wider view of the situation and look at how we can demonstrate that it is not a problem'. Also Bill notes: 'I can't personally see the water industry necessarily driving these increased standards. I think we'll comply, I don't think we'll be driving or pushing for additional standards or tighter standards. We wouldn't be pushing for new standards'.[19]

A similar thing happened with fluoranthene. There was a parameter for polycyclic aromatic hydrocarbons (PAH) in the 1980 directive and when England started monitoring for it in 1989 it failed to meet the standard. This was mainly because of fluoranthene which was one of the six hydrocarbons. The UK pushed for some toxicological studies on this and sent the results to the WHO. The WHO then published a statement in the 1993 guidelines that fluoranthene in drinking water is not a risk to public health. The UK took this into the negotiations on the new directive and persuaded the Commission and the other member states that fluoranthene should be removed from the list of specified PAH. As Fred says: 'fluoranthene was one of the PAHs that was causing problems with compliance and it isn't a health problem, so we argued strongly that it should be removed and it has been removed'.

[18] Water companies often collaborate in research via UKWIR (United Kingdom Water Industry Research).

[19] A nice example of 'defensive research' was provided by Thomas. He explained that it is difficult to relax a standard that has been known. The 1998 directive proposed a tighter standard for boron which is used in washing powders. The borax industry knew that, if this type of standard for boron came through, the water industry would be lobbying to remove boron from washing powder, which would harm the borax industry. 'So, what the borax industry did, instead of saying: this is silly, this is a ridiculous standard, they actually commissioned very good research with the World Health Organisation. The World Health Organisation accepted that the new research was better'. The draft standard was relaxed before it became the final version.

The previous paragraphs have concentrated on the intermingling of scientific and policy judgements which is often referred to as 'science policy', 'trans-science' (Weinberg, 1972), or 'regulatory science'. The notion of regulatory science has been discussed in chapter 2. Regulatory science is regarded as distinct from research science, since, amongst others, it is subject to strict time constraints and the standards for assessing quality are much more fluid because the science operates under circumstances of increased scientific uncertainty. Regulatory science has mainly been defined as science that is developed especially in response to external regulatory demand, in other words, to *aid* policy making (Irwin et al, 1998) Can defensive research be defined as regulatory science? Defensive research is geared to policy making and can be regarded as a response to future policies. The research is subject to time limitations if it is to be considered in the policy making process. Yet, the research is not asked for by policy makers and is undertaken with the intention to stop policies from being implemented. It refers to anticipatory work that is internal to organisations and not undertaken in response to *specific* announcements or calls for regulation made in the public domain by official regulatory bodies. I will therefore not regard defensive research as part of regulatory science. Regulatory science will be further discussed in section 5.5.

Generally, the 1998 directive is regarded by the industry as better than the 1980 directive. Chris describes the new directive as: 'Mainly more scientific. There are one or two things that are not, that have been reached by a compromise. But yes, it's better. And we have purer standards'.[20] Thomas adds:

> I think the new EU directive, the one that is just coming through, by and large, and I suppose that is because we are involved in its formulation, we believe is not a bad model. It gets the right balance between controlling the things that need to be controlled and flexibility. So, broadly speaking we are pretty happy with the directive, it is quite a good model to work from. And we know that what drives new standards is scientific advice from people like world health organisation.

[20] Only Lewis disagreed: '[before privatisation] there were standards, but the standards at that time were more health related whereas now they are becoming increasingly aesthetic standards, you know, taste, odour, appearance, discoloration, that type of standards are coming to the fore. The quality water as such now is not a health risk.'

Chris and Thomas have both been involved in the negotiations on the new regulations, but also respondents who have not engaged in the negotiations think that the new directive is good because it is health related, even though some also recognise the part played by political decision making. A few examples:

> We do go by what our colleagues in the medical profession and the toxicologists tell us. (Fred)

> I assume that the evidence for having a standard for a particular parameter is reviewed. (Victor)

> This directive in 1998 was looked at scientifically perhaps a little more than the 1980. And evidence, scientific evidence, was used to set the standards perhaps more than before. (Martha)

> There are a presence of a number of substances, but as long as they don't contravene those standards, set down by people far more qualified to set them down than I am, like the World Health Organisation, I assume that all of their guidelines are based on scientific study and in conjunction with the EU and other eminent bodies. (Sarah)

> They have been based on political pressure from the different member states, so in turn that political pressure has been brought back by the voters, so it goes back to public perception. But there has to be an element of medical knowledge is there as well. I think the World Health Organisation sets standards for maximum limits for different parameters. So, I imagine that some of them have been based on that and where the politicians think they are too high, they base it on what the public want rather than scientific.' (Mary, WQM/010202).

A European Commission document (2003) points out the main thrusts of the 1998 directive. Firstly the review of parametric values and 'where necessary strengthening them in accordance with the latest available scientific knowledge (WHO Guidelines, Scientific Committee on Toxicology and Ecotoxicology)'. Secondly, the demand for transparency has increased. Companies now measure compliance with the quality standards at the point of use ('Tapwater Directive'), have an obligation to report on quality and to inform the consumer on measures they can take themselves when non-compliance is because of the domestic distribution system (internal pipes, plumbing etc). Thirdly, the new directive streamlined the legislation to 'parameters essential for health and environment': 66 parameters in the old directive have been reduced to 48 in the new one, including 15 new parameters. The main changes in parametric values are lead (reduced from 50 μg/l to 10 μg/l, 15 years transition period to allow for replacing lead distribution pipes), pesticides (values for individual substances and for total pesticides retained (0.1μg/l / 0.5μg/l), plus additional, more stringent ones introduced for certain pesticides (0.03μg/l)), copper (value reduced from 3 to 2 mg/l), and standards introduced for new parameters like trihalomethanes, trichloroethene and tetracholoroethene, bromate, acrylamide etc.

This section has, in line with chapter 2, demonstrated the, sometimes, complex negotiations that are held before standards are set. These negotiations are black boxed as soon as the standards are set. They are not easily, if at all, accessible in the form of documents. One can only learn from these negotiations and the way these standards are formed by talking to those involved in the process and by relying on their memory and accounts of the negotiation processes. From studying the final directive one cannot track the heterogeneous inputs that led to the final standards. However, the final directive can be regarded as a script that people agreed on in the end. This section has also shown that materiality has to be taken into account when discussing the standards. Standards are set because it is believed that certain substances affect people and can cause illness. Sometimes the standards can only be enforced in a number of years because the current material environment does not allow for the standards to be met, that is, in many cases this material substance cannot effectively be removed from the water. The regulations are constructed with the material environment and substances in mind; this hints at a process in which standards and materiality are co-constructed. This is not to say that it is always clear what this materiality is, since opposing scientific claims can be made about one particular parameter. Materiality therefore does not determine what standards will be set. In the case of some of the chemical parameters it is believed that a high intake of these parameters would only affect people in the long term and these effects are not straightforward to measure.

Before exploring this co-construction in more detail, I will now attempt to illustrate what a drinking water quality standard is.

5.4 A drinking water quality standard illustrated and a discussion of the (seeming) inevitability of the standard: the authority of the standard

We have seen how the institutional context of water quality standards is organised and how these water quality standards are constructed by means of heterogeneous negotiations. But what exactly is a water quality standard and what does it look like? These are simple questions, but very difficult to answer. A standard cannot be represented in a simple, singular, and straightforward way. The websites of most water companies provide the visitor with a device to find out what the water quality in one's area is like. By entering the postcode one is likely to encounter a Table in which the water quality as measured by the water company is compared to the regulatory standards. In this case the regulatory standard may be the standard for lead which is set at 10 µg/l in the 1998 directive. However, if one looks at the European directive itself, one finds that lead is one of many parameters in a Table that is found under Annex 1 Part B and has two notes attached to it. The first note says:

> The value applies to a sample of water intended for human consumption obtained by an adequate sampling method [in a footnnote to this is added: 'to be added following the outcome of the study currently being carried out'] at the tap and taken so as to be representative of a weekly average value ingested by consumers. Where appropriate the sampling and monitoring methods must be applied in a harmonised fashion to be drawn up in accordance with Article 7(4). Member States must take account of the occurrence of peak levels that may cause adverse effects on human health.

This note shows that just the 10 µg/l is not the only part of the standard. The standard becomes a (workable) standard by telling water companies how to achieve the standard. As mentioned previously and will be demonstrated in chapter 6 the results of samples taken in different ways varies. If the taking of samples (the where, the when, and the how) is not standardised compliance or non-compliance with the standard does not mean anything. The note also refers to other parts of the directive in which more 'guidance' is given. Note number two does the same:

For water referred to in Article 6(1)(a), (b) and (d), the value must be met, at the latest, 15 calendar years after the entry into force of this Directive. The parametric value for lead from five years after the entry into force of this Directive until 15 years after its entry into force is 25 μg/l.[21]

The standard of 10 μg/l does not have to be complied with until 2013 and water companies are therefore unlikely to mention the 10 μg/l standard on their website. They will instead use the 25 μg/l interim standard. The standards can thus not be regarded as standing on their own; they would not have any meaning. Of the 26 parameters in this particular Table, 13 are accompanied by one or more notes. However, also the ones without notes are necessarily part of a larger document, since the part in which the parameters are classified, whether they are for instance regarded as indicator parameters, can have consequences for the way they are dealt with as well, as we will see later in this chapter.

Some of the European standards have been tightened for England, therefore the national Water Supply (Water Quality) Regulations 2000 may entail slightly different legal standards. As the current chief inspector of the DWI explains: 'the Regulations not only set standards for the Directive parameters but also retains mandatory national standards for certain aesthetic parameters (such as iron, colour and taste and odour) that are Indicator Parameters in the Directive' (Sam, DCIDWI/230404). These regulations are even more extensive than the European directive and give a detailed description of issues like sampling and water treatment. In the words of one respondent:

> They are very complicated, have you read them? They are about 80 pages long and they do take a bit of understanding. They do take a bit of turning in to your internal system. So, you can't just give one person those set of regulations and just say: get on with it. (Victor)

Oliver stated: 'We are having to jump through a lot more hoops than the EU directive requires us to'. For the water companies, the 2000 regulations become the standard. They do not have to refer or take into account the 1998 European directive.

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[21] This is not the entire note, but enough to illustrate my point.

Before the national 2000 regulations came into existence, a 'consultation document' with a proposal on how to implement the 1998 directive was sent to the water companies. Lewis (WQM/181102) describes the consultation process as follows:

> The government did contact the water companies to say: what information have you got regarding this particular standard. At that stage it is basically sort of an information transfer. Whereby the water companies would say: if this new standard came in, then ten percent of our supply would fail and new standards and that would cost us, say, half a billion pounds. So really, it's a consequential type discussion.

DEFRA, which issued the document, received a total of 995 responses (950 of which were concerned with the proposed standards for hardness and sodium). A consultation document includes water companies in the negotiation processes; they can comment and their comments may be (but do not have to be) taken into consideration. Yet, a consultation document has another effect; it will make it harder for companies to complain or disagree with the final standards. In the words of Samuel:

> If you think of new standards, then the directive from Europe that has now resulted in new UK water regs was debated for years. Representatives from all the different countries met time after time after time after time and I'm sure, what probably began as, well, this is what the standard is gonna be for this thing, ended up different. And therefore it's a little more difficult for us once the thing is introduced here, so we can't very well go back to the drinking water inspectorate and say: 'no sorry that is wrong, I am not working to that.

For understanding the seemingly simple Tables of standards in the regulations and the meaning of the sentence '99% of your drinking water complies with the standards', one also has to understand the wider and more complicated regulatory context in which they are placed. This requires skill and a lot of work by the companies that have to work with the regulations. The wider regulatory context consists of, amongst others, associated guidance and information letters which can be more extensive than the actual regulations. One could say that the standards themselves are regulated by the associated guidance. The guidance is not always well organised as the quote of Oliver below illustrates:

> I think it's in here, there is a whole, this is all useful, because in here it gives you a list of documents that contain guidance. And this particular section is about analytical quality control, but there's another list in here somewhere, yeah this is it. Associated regulation and guidance documents. So, there is all these guidance documents which are not produced directly by the DWI but they use when they are auditing us to see that we comply with that guidance. That's that one, guidance for microbiological implications of emergency in water supply, that's that one. You know, it's mind-blowing sometimes, that's another one that they refer to.

Chris explains that the UK regulations have added national standards to the European 1998 directive, standards that apply to the water leaving the treatment works and to the water in service reservoirs and water towers. Also added are requirements about the use of approved water treatment products and materials for construction. He states:

> The regulations take in the wider aspect. The regulations only go so far and you don't want to regulate everything otherwise the regulations become unworkable, unwieldy. So, associated with the regulation is guidance.

This guidance then consists of information on monitoring raw water, key parameters, things that might affect drinking water quality 'not just for the things the regulations require, but as operational control of that treatment'. The companies are then required to have 'proper written down procedures' for the operation of their treatment works and individual treatment processes and criteria for deciding when the treatment process is not working properly. They also need to have procedures for the operation of the distribution system to avoid big changes in flow or reversals in flow that might disturb deposits. The procedures and protocols of companies become part of the complex picture. Greenwood (1984: 84) illustrates this with regard to a health standard.

> A permanent occupational health standard not only includes a specified level of exposure to a hazardous substance which cannot be exceeded in the workplace and perhaps some specific engineering and work practice controls designed to ensure the permissible exposure limit is met, but also may require the use of labels or other forms of warning, monitoring, or measuring of employee exposure, medical examinations of workers, and employee education and training programs.

I will not go into the detailed role of companies' protocols here. Their role and place in the company and wider regulatory environment will be explored in the section on audits and in chapter 6. It is sufficient here to concentrate on the regulations and the associated guidance. James and Oliver give an idea of the work –which can consist of work to prove to the DWI that no further work is needed– brought about by changes in these regulations and associated guidance:

> A major part of the change in regulations is on sampling, the sort of definitions of the samples. Rather than just being compliance and operational, there are gonna be various types of the compliance samples, whether it will be an audit or check sample and the standards which apply and where they'll be taken from. The main changes are how samples are programmed, the types of samples that we take, and how they are then reported either to the regulator or to the local authorities and even internally. We are also working on the potential changes to water supply zone boundaries. Because the regulations allow a maximum population of a 100,000 whereas we have been working to a maximum of 50,000 so we are redrawing all our water supply zone boundaries which again impacts on the samples. (James)

> Some of the parameters that are coming in, in the new regs, are new, some of them are brand-new, but some of them we haven't looked for. For example now we have to look for nitrite at final water. If it is chloraminated we have to look for turbidity at all final waters. Now we never used to have to do that. The fear was that because we haven't looked for them on a regulatory basis before, would we be able to prove to the DWI there wasn't a problem? Or would we have to go to increased frequency? Our advice is that actually

> we've got enough data, historically, that we are not gonna fail the standard and we should be able to go to reduce straight away. (Oliver)

Some of the associated guidance and information letters referred to have not changed for years. Oliver says: 'This is an amazing one, this was published in 1983, first published in 1983. And the DWI still refer to it, it's amazing'. Sarah wished the guidance and information letters would be a bit better organised:

> We have information letters direct from the Drinking Water Inspectorate through to the head of operations and myself and funny enough we were only saying the other day that there is still a number of current DWI letters that are really quite ancient now, you know they could almost be in the centre for antiquities, but they are still very much sort of part of the [guidance]. So, if I had a wish, probably what I would wish for, is that they would sort of comprise them altogether and make them just that little bit easier that you don't have to keep on referring to information letter 12 of 1998.

I have hinted at the complexity of standards and their regulatory environment above and cannot do so more without referring to the many regulations and guidance documents that come with the standards. That would be outside the scope of this dissertation. However, before I turn to the implementation and mobilisation of these standards (section 5.6), it is important to note that these standards are often regarded as unavoidable. James states: 'The standards are the standards. There isn't an awful lot of interpretation. If you've got a standard for a parameter then that's what it is and you have to comply with it'. Others have a similar view: 'They say these are safe drinking levels, this is written in the law, this is what you'll achieve. And all water companies must do that, must implement what government says' (Martha). In the words of Fred: 'These are the agreed standards, the European experts have agreed on these things and you will meet them'. However, this does *not* mean that they are always dealt with in the *same* way, as section 5.6 will show and as Thomas explains:

> I think a lot of the difference is essentially institutional and governmental. So, for example, in different member states there are different responsibilities for public/private sector, there are different models for running water. And there

> are different traditions at managing water. So, you know, there are lots of institutional issues, but the underlying standards tend to be the same.

Yet, the standards have to be met in order not to upset the DWI, which may force a company to undertake work, *and* in order to provide what is regarded as good quality drinking water; these have become two sides of the same coin:

> The standards are an end in themselves. The water is "pure enough" to drink from a public health point of view if it meets the standards prescribed. One is the same as the other: the drinking water standards, if they are met, mean the water is wholesome. (Martha)

Although the standards are the outcomes of a negotiation process in which different actors with different views on what 'good water quality' is (and therewith 'good water quality standards') and most respondents recognise the political process that was involved in setting the standards, the standards themselves, once set, have widely been accepted as representing safe water. The literature in chapter 2 (Bowker and Star, 2000; Mol, 2002) had already suggested this. Martha continues:

> Really the regulations define what wholesomeness means and therefore that the water is safe to drink if we meet those regulations. Wholesome means the regulations.

Whereas standards are often based on judgements about the acceptability of a product or activity rather than their excellence or desirability, once adopted they become 'a measure of *desirable* (or *excellent*) performance, a value to be sought after, a maximum rather than a minimum level of acceptable activity' (Salter, 1988: 24). In line with Martha and Salter, Oliver argues that regulatory risk is identical to health risk:

> One of the key issues for me is about protecting the company from regulatory risk, which in essence, some people say: 'well, your role is about protecting the customers, it is looking after public health'. In protecting the company from regulatory risk, we are protecting, we are maintaining public health, we are protecting the quality of the water that our customers are drinking.

According to James, the goal of the company has become to 'make sure we don't get prosecuted really. At the end of the day, where we don't get any enforcement actions or threat of prosecutions, that's a success story'. By equating the regulatory standards with a definition of good water quality, there does not seem much space left for alternative notions of good water quality, as I argued in chapter 4.[22] This particular notion of good water is reinforced by the fact that water companies can be and have been prosecuted for not complying with the regulations. In the existing institutional settings in which our drinking water is currently produced, some institutions (notably the DWI) have more power to enforce their definition of good water than others. Actor network theory, as discussed in chapter 2, cannot or does not account for this, since it focuses mainly on how power is constructed and how certain meanings and definitions become dominant by convincing others rather than by enforcing a certain definition. In this case, definitions of good water quality are limited and non-compliance with the particular view of good water in the eyes of the DWI can lead to enforcement action. That respondents regard the 1998 standards as unavoidable and accept them rather than trying to contest them can perhaps (partly) be explained by the power relations at work which seem to limit the scope for interpretative flexibility of the standards and their detailed regulatory environment. Another, not exclusive, explanation is that the involvement of companies through consultations makes it harder for them to contest the standards. I will return to this in 5.6. First, however, I would like to discuss the way in which these standards influence some of the practices that take place inside water companies.

5.5 *From regulatory to regulated science*

The previous sections have shown that the drinking water industry is heavily regulated. In addition to water quality standards, the industry is also subject to regulations on how and how frequent samples have to be taken, what should be done

[22] That regulatory standards have taken over other possible notions of good water quality can also be demonstrated by the fact that companies do not provide different water qualities for people with special requirements: 'If people, companies, institutions have special requirements for the water in their process, it is up to them to work out what that is and to treat it accordingly. We are required to comply with the regulations at the point of delivery which is what we are doing' (Victor). I will return to this in chapter 6.

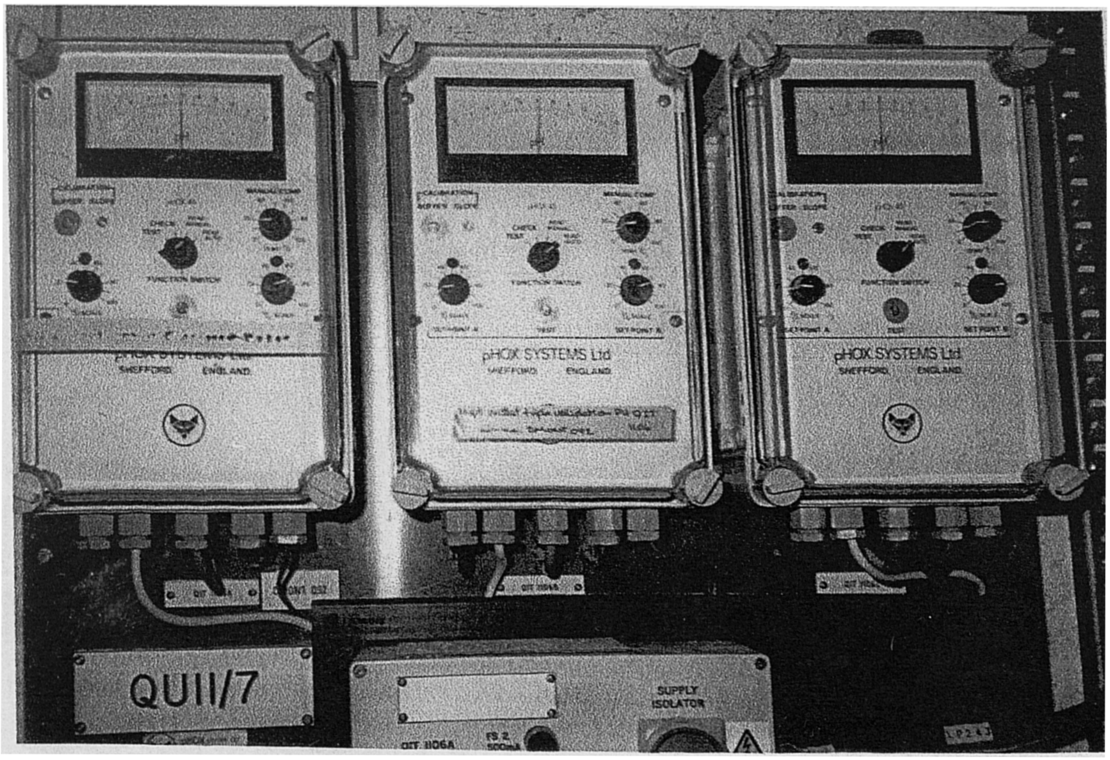
in case of contamination from the distribution system, what information should be recorded and made public, and so on. In chapter 2 I have discussed the concept of 'regulatory science'. It is only during the standard setting process that the water industry collects scientific information to fill a gap in the knowledge of a water quality parameter or to support a specific view on this parameter. Most of the regulatory science in the water industry consists exactly of that aspect that Jasanoff (1990) left out of consideration, but which was mentioned briefly by Abraham and Lewis (2000) and Irwin et al. (1997), namely the aspect of standards governing scientific practices that are geared to regulatory requirements. Irwin et al. (1997) have called this 'regulatory compliance testing'. Webster (2004) talks about 'quality assured science' in a recent research proposal.

Like Irwin et al (1997) and Webster (2004) I would like to distinguish the process in which standards regulate the industry –the industry works towards compliance with these standards without attempting to produce much new knowledge– from regulatory science which focuses on the production and collection of (new) scientific knowledge for policy making. Of course the two processes are related; major problems in the implementation are likely to lead to changes when the next standard setting process starts and may generate searches for new information whereas new standards will influence the implementation process and the practices in which the standards are implemented. Yet, they point to two quite different processes: the setting and construction of standards *and* the operation and mobilisation of standards in specific practices. This is why I maintain the concept of regulatory science for the first process, but make a case for calling the second 'regulated science'. Quality assurance is a large, but not the only aspect of regulated science; regulatory assurance plays an important role as well. Regulated science is then not an aspect of regulatory science as is Irwin et al.'s regulatory compliance testing, but a process distinct from regulatory science.

Original in colour

Photo 5.1: Sterilising bottles in the autoclave, a matter of both quality and regulatory assurance

Photo 5.2: Triple validation pH at treatment plant, a quality assurance matter



Regulatory assurance, as the latter part of this chapter will show, is principally driven by companies to ensure that they are always in a position to make a 'regulatory response' in regard to meeting standards. Companies know, however, that the DWI will always be prepared to acknowledge that what 'meeting standards' means in practice might well be dependent on specific circumstances – which is why relaxations exist as we will see later. In this sense it is distinct from regulatory science, which is principally about future proofing against likely risks where possible according to a much more prescriptive and relatively context-free set of criteria. Quality assurance can then be said to be additional to regulatory assurance in that, although standards feed in and make sense of quality and its meaning, how the assurance is secured relates more broadly to the practices and culture within the water companies as a whole.

I will now briefly address how a regime of regulated science influences the development of analytical science and (treatment) technology according to my respondents.[23]

5.5.1 The development of analytical methods under a regime of regulated science

> It is probably sorted out now. But in the early days that was not the case. There were not many methods for pesticides that would get down to the requirements of being able to measure with a certain degree of confidence, the level on which the pesticides standard was set. (Victor)

According to Victor, it was not until the mid-eighties that companies started to monitor for pesticides. This was difficult because the analytical techniques were not available and had to be developed. In these earlier years a company did not know if it complied with the regulations because it could not analyse for the levels required. The problem of having to develop new analytical techniques seems to occur less and less; the sentence above ('it is probably sorted out now') reflects this. It is not that all analytical methods to look for very small concentrations of all possible substances

[23] I have not related this to the wide literature on innovation. The section is only meant to give a flavour of the role of standards in how the waterworld operates.

have been developed. As we have seen above, the standard for bromate was set at the lowest level that could be detected by existing analytical techniques. In the words of Fred: 'The new bromate standard is as good as we can get it at the moment, because of analytical accuracy'. Many respondents argued that there is no or little point in setting standards for substances that cannot be measured.[24] Lewis goes back to the example of pesticides where the government faced exactly this problem when standards for pesticides were set. He argues that what happened was that the government applied a standard that 'had no bearing on health or anything else and the country spent many hundreds of millions of pounds removing pesticides which have no health bearing'. He adds that 'some of the pesticides that are now found and removed from water, you could almost sprinkle on your cornflakes in the morning'. Catherine (WQM/110401) regards setting standards for immeasurable substances as 'ridiculous':

> Obviously there is no point in setting a European directive if there is no process to reduce that particular thing down to an acceptable level. It would be a ridiculous thing.

If this is indeed the general opinion, no radical new standards will be set and there will be little incentive to develop new analytical methods and the problem of developing new methods seems to be resolved. Yet, not everyone agrees. Samuel says that he does not think that 'the people that are making these decisions will look at it and say: well, we can't measure it to that level, therefore we can't set it at that level'. He argues that there are cases in which the analytical capability is not there, but the standard is set. Product specification for products used in water treatment will allow companies to meet these standards: 'the analytical question is gone, there is no question of analysis at all' (Samuel). There is however another factor that may

[24] Majone (1984) argued that the way in which countries set standards reflects what is regarded as a 'proper' basis for standard-setting. See also footnote 7, chapter 2. Keith (CML/160503) argued that, with the expansion of the EU, there is no point in setting lower standards at the moment, because many of the new member states will not have the methods, treatment technologies, and high level of expertise in place to comply with the current standards. They would need 10-20 years to catch up. Chris argues a similar thing: 'There's no point in doing lots and lots of samples, unless you know the accuracy of the result. And I can tell you, certainly in the Southern member states, they've got no idea about the accuracy of the results. Cause the laboratory is simple, they have not determined the performance of the method they practise. I mean I've heard of local authorities in some southern member states actually trying to analyse samples for fairly sophisticated parameters on kitchen tables.'

reduce the incentive for developing new methods: many argue that analytical techniques are often developed because a new or tighter standard has been set.[25] Victor puts it this way:

> In fact, methods tend to follow the standards. The legislators or the standard-setters decide on lowering the standard and then it is left to the poor old analytical chemist to try and come up with a method that will meet it.

Since the regulations have been around for a good number of years and have not changed considerably in this respect, analytical methods are available to analyse for all the parameters in the regulations. The 1998 directive may cause other problems, but, in the words of Martha: 'It is not as if we can't monitor for the standards that they have put in'. The standards define what the companies are looking for and the company's practices have therefore become very much routine. Unknown substances in the water are thus not automatically identified. William (WQM/271102) gives an example where the water had a very pronounced taste to it:

> It took them quite some time to actually track down this particular obscure chemical that led to the problem. It's not something that you would normally expect to encounter.

As we will also see in chapter 6, unknowns are difficult to deal with under a regime of regulated science that is based on expectations to encounter only what is regarded as 'normal'.[26]

However, although the stable standards and the resistance against setting standards that cannot be measured leave little stimulus for innovation of analytical

[25] Lewis however argues that new techniques can also develop when a new compound has been identified, but no standard has been set: 'What generally happens is that the scientific community identifies a compound which they are concerned about and then the analytical technique gradually catches up with it over the years to show whether or not that particular compound is present'.

[26] At a water industry conference (Water Contamination Emergencies: Can we Cope?) I attended, many talks stressed the importance of being able to detect toxicity rapidly and discussed the different tests and kits and the new developments in this area. The next chapter will show that the water company laboratories are organised to analyse routine regulatory and operational samples. They use large machines and wait until they have enough samples to fill the machines. In case of emergencies, these methods would take too long. In addition, in an emergency situation one may not know what one is looking for, whereas this is usually clear when analysing a regulatory or operational sample. Different methods are thus needed.

techniques, it does not mean that there is no innovation at all. Analytical techniques may be improved in order to be more reliable or easier to operate (see chapter 6) and because scientists may enjoy improving methods:

> We measure our pesticides in terms of nanograms whereas the standard is now set in micrograms. So, sort of a thousandfold further down than that. And we can measure some of our pesticides down to two or three nanograms per litre of water. And sometimes I sort of ask the question: why, you know, but having come from a scientific background I can see the answer and the answer is because we can. It has no bearing, the analytical community sort of moves away from the regulations because they move far further past the regulations. (Lewis)

Many remarked that when one can analyse for more and more things at lower and lower levels, 'one finds more and more problems as a generality' (Victor). In the words of Thomas:

> The analytical chemistry got better, so chemists started looking for smaller and smaller amounts of things. And of course they found them, because if you look hard enough, you'll find anything in water. One of the things you'll have to remember is that technically water is one of the most powerful solvents known to men. It is very very powerful at dissolving things, but (retains) the physical properties of water. So, if you look hard enough, you probably find traces of all sorts of stuff.

When, for one (regulatory) reason or another, it becomes clear that a new analytical method is required either for a new parameter that has not previously been measured or for a parameters for which greater sensitivity needs to be obtained, it will go to the standing committee of analysts. People from the bigger companies, universities, and other interested parties are members of this standing committee. They would then develop a new method. This is cheaper than if each company would try and develop its own method. The resulting information and techniques are shared between the water companies that want to use the new method. According to Victor the bigger companies will probably do some of that research in their own laboratories, 'simply because they have a big laboratory and they have got the resources'.

Yet, many note that it is important to distinguish what is possible in terms of analytical methods from what is necessary in terms of drinking water quality standards that ensure public health. Lewis argues that 'just because something is possible doesn't necessarily mean that you'll tighten the regulations to meet it'. Like many, he stresses that regulations should be health based. If one would set standards according to the possible levels of analyses, it would be a very costly business.

5.5.2 The development of (treatment) technologies under a regime of regulated science

The dominant ideas of my respondents about the development of treatment technologies are similar to their ideas about the development of analytical techniques. In this case they argue however that it is also the technology itself that has been developed to such an extent that there is not much that cannot be treated anymore. In the words of Catherine: 'I think there are probably fewer and fewer things where technical processes are lacking'. James puts it differently: 'The technology is nowadays pretty tried and tested from the suppliers and we are bolting it and we are going'. If the money is there, 'you can treat anything' (Lewis). This is not to say that the treatment technologies do not have to be developed for particular processes; only that it is believed that the development will not cause major problems.

Unlike analytical techniques, the treatment technologies one can use depend on the water that needs to be treated.[27] Catherine explains:

> Treatment processes are different depending on what sorts of raw material you start with. For example, if you are treating a spring source up in the [hills], you might just filtrate and chlorinate it and that will be as far as treatment goes. While if abstracting water from [a river], you have got a much more complicated treatment process.[28]

[27] Analytical techniques can be used for all 'clean' waters without taking into account whether they are surface waters or groundwaters. In chapter 6 we will see that analytical techniques differ between 'clean' and 'dirty' (or waste-) water.
[28] Names of rivers and cities have been removed for reasons of anonymity.

According to William an upland surface water is completely different from a southern groundwater: the characteristics of the water and the geology differ. Therefore 'what you'd need to treat for would be considerably variable. And how the water responds to treatment would be different'. Consequently, unlike analytical methods, treatment plants cannot be standardised:

> So, I don't think you could standardise treatment in any way. You have a certain quality of raw water and you design the treatment plant to cope with that particular water. (William)

The treatment technology is considered as able to treat almost every water, but different technologies are needed because of the *materiality* of the water. The water is said to have specific *characteristics*: 'The treatment processes that are employed and have been employed historically are largely fashioned by the characteristics of the water in a particular area' (Harry). The technology used also differs according to whether the company supplies a rural area or a large city. Depending on the size of the population, the length of and the pressure in the distribution network the water needs to be treated up to different standards to arrive safely at the customer. Also the weather is an important factor. Bill explains this with regard to chlorine:

> One part [of chlorine] in the winter time would probably hold the residual through to the end of the system quite nicely because the water temperatures are low. But if you put one part of chlorine in in the summer when the water temperature is much higher, you may well find that you've got next to nothing left at the end of the system.

Unlike many other products, water reacts with what it is treated with and what it is transported in. It is continuously changing and can never be regarded as a finished and stable product. The technology needs to be quite precise with regard to the water's material environments. For instance, a treatment technology cannot just remove anything from the water. Although distilled water may be the purest water in a chemical sense, people do not like the taste of it and it is aggressive towards metals. Depending on the distribution network it could therefore be difficult to get it to the customer in the state it left the treatment plant. In the words of Fred: 'You tend to want to produce a water that is balanced.' Membrane technologies have the potential of removing too much from the water. In the unlikely case of that happening, one needs to blend the water with other waters or even to remineralise the water. In the water industry there is no dispute about what 'a balanced water' means: 'Everybody has a fairly good consensus about water quality these days, in the developed world anyway' (Fred). The next chapter will focus on the role of materiality in more detail.

When I asked what motivations companies had to develop new technologies, Martha answered: 'the regulations'. She continued: 'the large amount of what we put on treatment works is driven by government'. Also James said: 'They are developed to comply with the standards. It's always driven by standards'. One such example is phosphate dosing. Phosphate dosing is explained by Water UK (2003), the industry association that represents all UK water and wastewater service suppliers at national and European level and provides water companies with information about (negotiations of) new and proposed standards, as:

> In areas where the water is soft (i.e. contains little calcium) minute quantities of lead from old pipes can dissolve into the water. Phosphate – a common chemical present in most foodstuffs – is added to prevent this happening. It coats the lead pipes and prevents the lead pick-up.

Many water companies are installing phosphate dosing at the moment in order to comply with the interim standard of 25 μg for lead and to reduce the amount of lead eventually to 10 micrograms per litre.[29] Phosphate dosing was however not developed for these new standards, but for the previous one. Fred explains the problem one of the large companies encountered:

> In some places where the waters were softer or particularly aggressive towards lead pipes, the old standard, the 50 micrograms per litre couldn't be met. These waters had to be dosed with phosphate to meet the 50.

[29] Charlie, in his commentary on a section of this chapter (130904), states that treatment of the water with phosphate is the most effective way to reduce the level of dissolved lead. He also says that evidence to date seems to indicate that it is likely that in many cases the final standards of 10 ug/l which applies from end of 2013 will be met.

It was this large company that developed phosphate dosing. Installing phosphate dosing is a lot of work: 'To add it you need a controlled dose, you need some equipment, which is going to add it and dose it to the water. You need to purchase that, fit it, test it, make sure it is working properly and then put it into supply' (Martha). However, the phosphate dosing and therefore the regulations do not cause any major difficulties, although it can cause some problems –standards having a knock-on effect– as Sarah explains:

> That brings its own problems, like if your phosphate level starts to take too much of a hike and a hold, that can break down any hardness and scale that was stuck in the pipes, so that turns into sludge so that takes it to the customer's tap. So, you are thinking: god, there is another problem.

Yet, one does not need completely new treatment works, but can instead slot the different specific stages of the treatment together: 'Normally you can put an extra piece of treatment onto a works without adversely affecting it' (Martha). However, one respondent, Bill, argued that in some cases a new treatment plant has to be set up:

> Sometimes you have to build a completely new plant on the site and around the existing one and then at some stage you have to connect from the old to the new and then go into service, which is effectively what we had to do when we put the pesticides removal plants at [name of place].

Another example of standard driven technology development was activated carbon (AC). Activated carbon is a black, solid substance resembling granular or powdered charcoal. It acts as an adsorbent and can remove organic compounds such as pesticides and trihalomethanes from water. Also chlorine can be removed and AC can therewith improve taste and odour. In the early to mid nineties one of the large companies was installing advanced water treatment to remove pesticides and came up with a new way of using activated carbon to remove pesticides.

According to Victor the fact that the development of treatment technologies follows the standards is partly because of the way funding of the water industry is arranged. As we will see later in the chapter, under heading *Section 19*, 'funding in recent years has been driven by new requirements on standards' (Victor). However, there are also other motivations for developing new technology, although these were mentioned less often.[30] Fred clarifies: 'We are all the time looking for more reliable, robust, efficient and effective processes to produce water of the same quality or better quality at lower costs.' According to him not all technology development is standard driven. In fact he argues that the majority is not standard driven: 'The vast majority is driven by the need to provide technology which is more effective, cheaper, cheaper to run, cheaper to install.' The technology is not developed because of a new standard, but uses standards as a benchmark, a yardstick, against which the efficiency of the process is measured. The purpose of the new technology is 'obviously to produce water at least as good as the standards, if not better' (Fred). By becoming more reliable and robust, the technology may then also play a role in the prevention of problems with exceedences of standards.[31]

Since we have seen that the regulations have not changed extensively with regard to (radical) new parameters, the incentive for developing new treatment technologies (not improvements of existing ones) is very low. Victor specifies: 'There aren't any completely new parameters being controlled by way of legislation. So, you could say that the industry has got all the range of treatment processes it needs'. He argues that there is not much new research going on these days: 'not completely novel research, it is more applied research'. Commercial companies that would develop new technologies would not be able to sell them if they did not improve water companies' compliance with the standards.

There is not only little incentive for new developments, a few respondents even warned against such developments:

> There are already quite big safety features in there [in the standards], so for us there is no desire to develop processes which could tighten the standards even further. Would be like making a rod for your own back in a way. (Fred)

[30] New technologies or improved technologies are often developed by the larger water companies, United Kingdom Water Industry Research (UKWIR), and commercial companies. Rosa: 'that is the sort of thing that they [larger companies] might do, but we are too small a company to do anything like that'. Since commercial companies and interests are involved, these developments are more secretive: 'you would not tell your competitors' (Victor). Bill for example could not provide information about the technologies his company was working on: 'a lot of information is confidential, so other than telling you general levels to what we've done, I don't want to go into specifics about it'. In this sense the research into treatment processes is organised very differently from the research into analytical techniques by the standing committee of analysts.

As we have seen in the section on analytical methods everyone agrees that the standards should be set on the basis of medical evidence and not on basis of the possibilities of technologies. However, some acknowledge that having better technologies could lead to a tightening of standards:

> It is always a possibility. It may be that the legislators think: 'ah, now we have got this technology that will remove everything from water or it will remove something that we were not able to a certain level, and we can set the standard. (Victor)

Victor then mentions that it is arguable if that is the right way to do it: 'You should set standards on the basis of their likely effect on health.'

5.5.3 Regulatory plat*eau* and the mobilisation of non-existing standards

The previous sections have shown that the current regulations have been in place for a number of years; they have not been changed radically. This made it easy to analyse for and treat the specific parameters. We have also seen that some people argue that no new standards should be set that cannot be analysed for –this is in line with Jordan (2003: 181): 'Regulators preferred not to set standards which could not be complied with (the philosophy of 'practicability')'– and that companies carry out what they call 'defensive research' to prevent new standards, that they consider irrelevant or not health related, from entering a new directive. This research can then be used as evidence in a case against a possible proposal for a new standard. Endocrine disrupters were mentioned as an example. They were not added as a parameter to the new directive because not enough research about their health impact was available. However, endocrine disrupters as a parameter are a candidate for a future directive. In the words of Lewis: 'I think the endocrine disrupters will be one which will happen at some stage in the future. But let's hope they'll base it on actual scientific knowledge and its actual impact'. He continues to argue that it would be costly to enter endocrine disrupters to the directive, not least because they are difficult to detect with existing analytical techniques. Moreover, the 'actual' impact is very small:

[31] Another role of the technology Fred mentions is to provide customers with confidence.

> You can see the way the argument is going: there is a possibility that this particular compound can reach your drinking water. In reality, the levels are so low that the actual impact is incredibly low. You can never say that nothing will have an impact. It's like saying: if you never got out of bed, you would never get run down by a bus, but the bus hits your house. You see, you get the silly sides of the arguments if you are not careful. But the scientific community is doing what it does and that is drawing links and you can take these links to the endless degree and you can say: anything will turn up anywhere.

Thomas points to the impracticability of setting one or more standards for endocrine disrupters:

> There are thousands and thousands of chemicals that potentially could have effects on hormone systems, but if you analyse them objectively, the number that are likely to be an issue for water, are very small and even those are probably not going to be a problem. It would be crazy to set standards for thousands of potentially endocrine disrupting chemicals in water, but in customer terms it is very emotive.

Like Lewis, he also discusses the costs and analytical problems with measuring endocrine disrupters:

> Measuring endocrine disrupters at the levels you are talking about is almost impossible for a routine laboratory. They can only be done in very specialist laboratories and each sample costs maybe hundreds of pounds. You cannot use that sort of analysis for routine monitoring.

Others, like Bill, suggest alternative ways of regulating endocrine disrupters:

> If it [endocrine disrupters] is there in the raw water, someone is gonna have to legislate what level should be in the water that goes to the customers. So, if there's lots of them in the raw, one way of tackling is to get the environment agency to impose standards on for example sewage treatment work effluent,

> because if you can stop it getting into the environment in the first place, then you may not need to legislate for taking it out through treatment before you give it to the customer.

Here the EA is mobilised in order to solve the 'problem' of possible new standards.

Both Thomas and many other respondents regarded a large increase of standards in future directives as unlikely. Thomas believes the standards will be refined, but says that he would be surprised if the standards change drastically:

> The current information we have is that that [the updated World Health Organisation guidelines] is unlikely to radically change the standards in the new drinking water directive. It is unlikely to come out with whole lists of new standards that have to be issued.

Some believe that the most important parameters have been identified: 'I think that the major parameters are all covered now and I think as we identify the impact of other parameters, there'll be minor changes' (Harry). Others assume that if new standards come along, they will be standards for microbiological and not for chemical parameters:

> It depends if anything new on the horizon becomes apparent. Things like *Cryptosporidium* were unheard of twenty years ago. But then ten years ago someone found this rather peculiar parasite and obviously there has been a considerable amount and investment to control it. There is always a possibility for things like that to come along. They are more likely to be on the microbiological or biological side. The physical-chemistry side is probably rather well taken care of. (William)

James explains that this is not because scientists understand everything on the chemistry side: 'In fact there's far too much that we don't understand at all, we don't even know what to look for; we only look for a tiny tiny fraction of it'. The reason for adding new microbiological parameters to a directive would be that some micro-organisms can cause immediate illness, whereas chemical substances may take a life-time. A few respondents thought that the parameters were likely to increase: 'I think there will be more and more' (Rosa, WQM/270502). Bill puts it as follows:

> I think we'll always be flagging up issues. Even things that in the past were a problem, we've got processes in to treat for them such as pesticides. They are now looking at what do these pesticides break down to in the treatment processes. It you are asking me if in 5 or 10 years time there will be something, I would say almost certainly: there will be something. Quite what it will be or how you measure compliance against it, I don't know. We'll have to wait and see.

According to Samuel future standards depend on what 'becomes topical' and how technically difficult it is to achieve that standard: 'it's a big cost-implication then to change or modify treatment. There is all sorts of factors that come in'. Yet, some of them doubt the value of adding many more parameters:

> It might be that in a few years' time the number of parameters has doubled and all it does is making it very expensive and perhaps come up with a lot of data that you don't really need. (Mary)

Thomas, who is involved in discussions and negotiations at European level, argues that the regulatory regime is changing.[32] According to him there used to be a law in the US which mandated that the EPA was required to produce 'like ten new standards a year or something'. So, in the 1970s and 1980s standards were set for all harmful chemicals that were identified. Now it is recognised that 'just [to] produce longer and longer lists of chemicals is not a sensible way to regulate water quality', because it is very expensive and does not necessarily provide one with better control of water quality. The reduction of 66 parameters in the 1980 directive to 48 in the 1998 directive reflects this trend in which it is thought that the right number of key parameters should be controlled and the member states should be given some flexibility in adding additional ones if they deem that necessary. Thomas illustrates:

[32] This is also reflected in a document entitled *A Framework for Assuring the Quality of Drinking Water in the 21st Century* that was developed at a workshop with senior water quality experts from the USA, Europe, and Australia in October 2001. Likewise, the WHO drinking water quality guidelines move away from large scale microbiological testing, instead, they look at hazard analysis and critical control points: from source to treatment to customer tap.

> What is beginning to emerge now is a debate which is saying: let's get off the treadmill of more and more and more standards and have a small targeted list of the right sort of standards, which are still seen as important. It might legitimately vary from country to country, depending on the sort of types of threat, but then you supplement that with a quality system approach, which is the way you manage the way your water looks, your distribution network, your raw water, whatever, which provides adequate barriers to nasty things getting through your system. And that is where the sort of cycle is converted to at the moment.
>
> [There] is a discussion going on at the moment about how we move from a standard which was set on a precise numeric measurement type of thing to a control system which reassures the regulation and the public that the way we operate our works still provides that very high level of customer reassurance.
>
> It is moving away from just lots and lots of standards to a combination of the right sort of standards, coupled with appropriate system management.

The appropriate system management refers to a system in which water companies can demonstrate that their treatment is effective in removing substances like endocrine disrupters or toxins produced by algae (the type of toxin algae produce depends on the species of algae and conditions at the time, so setting standards for 20 algae toxins is seen as 'crazy'). If companies can find a mechanism to prove that it is unlikely that algae or endocrine disrupters would get through the treatment, there would be no need to spend 'a fortune analysing samples for algae toxins most of which are never there' (Thomas). Thomas compares the endocrine disrupters debate with the pesticides debate. As we have seen the pesticides standard had been set 'as a surrogate for zero'. Thomas thinks there is a risk that the same thing might happen with endocrine disrupters. By proving that the treatment that is in place provides a sufficient barrier, they try to 'get in front' and make sure no such standards are set. Thomas calls this new approach a 'philosophy' that is gradually emerging and that companies are trying to address at the moment. This new philosophy seems to apply especially for substances that are difficult and costly to monitor. The key parameters that, according to Thomas, will remain in the directive are parameters like *E-coli* which is a very good indicator for pathogens and faecal contamination and 'has been monitored for years, is a very sensitive standard, is very effective at protecting public health' (Thomas). Standards like this and for example lead and nitrate 'are relatively easy to monitor, they measure something which potentially causes a risk to health and therefore it is right to monitor' (Thomas). Therefore Thomas sees no reason 'why that shouldn't continue forever'.

Cryptosporidium is mentioned as a standard that partly reflects this new philosophy. It is also an interesting standard to explore since it is one of the few radically new standards that companies in England have had to deal with.[33] According to John *Cryptosporidium* is an example that shows that we do not know what will come along next:

> Crypto is a classic example. Ten years ago Crypto hadn't been invented. I mean, of course it was always there, but we were just unaware of it just the way we are now.[34]

Although the waterworld agrees on the risk that *Cryptosporidium* forms for public health, the *Cryptosporidium* standard has been heavily debated. Most respondents told me that the *Cryptosporidium* standard had come in place because the DWI did not manage to successfully prosecute a water company after the local health authorities told the DWI that they believed that an outbreak of *Cryptosporidiosis* was due to water the company provided. Yet, the lawyers in the case could not use the information available (information on people's medical records) because it was confidential. Many believe that the standard was brought in as a result of the failed attempt to prosecute, in the words of Lewis:

> So a standard has been brought in, whilst the government won't admit it openly, it was a standard which was brought in primarily to get back at the water companies because they failed their legal case. But what they do say is that it is a standard which has been brought in to demonstrate the efficiency of water treatment.

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[33] The *Cryptosporidium* standard was a new standard. However, some companies already monitored for *Cryptosporidium* in the words of Oliver 'as part of that catch-all statement that says: anything else that might be a risk to public health'.

James states it this way:

> They are very paranoid that companies will not do it correctly. There's real paranoia. Cause they fear that if they try and prosecute a company for having 20 ouses in 10 litres [one ouse in ten is the standard], when it gets to court, the lawyers say: you can't be absolutely sure, because they didn't follow the method properly. But they are really paranoid about failing to bring to prosecution.

Oliver puts it as follows:

> The DWI were so miffed, were so put out that they hadn't been able to prosecute this water company, they just said: right, we are gonna put in some real draconian legislation [to make sure that this does not happen again].

As we will see in chapter 6, this legislation covers every step of the process, from taking the sample through to the eventual number on a computer screen and requires a lot of work from water companies. The companies are not only told which standard they have to achieve at the treatment works, but also how to measure for the standards and where to buy the equipment from. The result is standardisation of methods across the water industry: 'We all use exactly the same equipment from the same suppliers and do the method exactly in the same way right across the industry' (James). At least at the level of the water industry, the standard does not encourage companies to develop new methods.

One company did at first refuse to measure the raw water against the standard and waited until the treatment was in place (Sarah). All companies had to make risk assessments of their treatment sites. If they could demonstrate that treatment sites would not be at risk of exceeding the *Cryptosporidium* standards, they did not have to monitor for it.[35] Information letter 3/2002 states:

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[34] This quote does not only illustrate that new standards may be set in the future for substances we are not yet aware of, but is striking because of the way in which it fits in with the realist-constructivist debate. Do we uncover things that have always been there?
[35] Barry (2001) writes that the interest in monitoring is a relatively recent phenomenon and that many air-quality monitoring stations were established at different places in Europe at the beginning of the 1990s.

> Under the associated guidance to the Regulations, treatment that is capable of continuously removing or retaining particles greater than one micron diameter will not require compliance monitoring provided the process is subject to continuous monitoring and shutdown or turn out on failure.

If companies could prove that their risk management procedures and treatment are robust (these, rather than the people, will perform the immediate control of water quality and compliance with the standards), they could reduce monitoring (and therewith costs) and still provide the same level of reassurance. Only at the sites that were at risk, monitoring equipment and treatment had to be installed. The DWI has a number of criteria on which the risk assessment has to be based. Yet, although companies may have some risk sites according to the DWI, in their own eyes this may not be the case. Oliver argues that other companies have nearly ten times more sites at risk than WaterCo, since WaterCo's treatment is 'much more robust'. The few sites WaterCo has, in the words of Oliver, 'we wouldn't classify as high risk for Crypto'. In fact, he says: 'We would argue that we don't have any high risk sites, whereas other water companies clearly do have high-risk sites'. He explains that the regulations say that if a company uses direct abstraction from a river, then it is a high risk site and sighs: 'if that sentence hadn't been there…'. WaterCo disputes that its sites are high risk and is 'in the process of making a case' to prove that the continuous monitoring has shown that the sites are not high risk and that compliance monitoring is not necessary.

Many companies regarded the required measures as disproportional compared to other standards and compared to the health risk that is involved.[36] James:

[36] Of my respondents, only William regarded the measures the DWI took as necessary: 'The UK took a very positive step and again a unique step in Europe to control it. I think there is a sort of sense of denial in Europe at the moment that they don't have a problem with *Cryptosporidium*. But like many things, if you don't look hard enough, you won't find it. So, it depends on the political will at the time as to discover whether one wants to see whether they have a problem or not'. Yet, it has to be noted that his accounts of the water industry and regulators are generally unusually positive. Other examples are: 'We have an open and frank relationship with all surrounding water companies', 'The creation of a drinking water inspectorate in the UK to actively police and enforce the regulation again was a very significant and positive step in the water supply industry', and 'Having the standards and showing that the standards are being complied with is a very positive step'. I could not help but wonder whether he felt the need to sketch a positive description; perhaps he felt the need to defend himself. The number of words referring to excellence, openness, frankness, and so on did (fortunately) diminish as the interview proceeded.

> It costs us a fortune. We've only got eight sites in the company where we have to do this monitoring. It costs us an absolute fortune to do it. It really is staggering, isn't it? And the public health risk is just, doesn't stack up, complete waste of time.

The costs and the amount of (disproportionate) work were mentioned often. One respondent (Lewis) mentioned an additional reason to oppose the *Cryptosporidium* standard. He argued that 'the danger with applying a tight standard for *Cryptosporidium* is that you actually remove natural immunity' and that once one has had *Cryptosporidiosis* one will rarely get it again. *Cryptosporidium* can not only be found in water, but in many other environments. If people come into contact with those environments, they will be much more susceptible.

Yet, the companies did not have much choice; they can be prosecuted if they breach the treatment standards *and* if they do not follow the method properly –both are a criminal offence by law. The companies therefore have to comply with the standard to avoid a regulatory risk rather than a risk to public health. Complying with the regulations is in this case perhaps not so much a matter of quality assurance as it is of regulatory assurance. I will return to this issue in section 5.6.

Many respondents regard the *Cryptosporidium* regulation as a sign that the DWI did not trust them at the moment the regulations came into force:

> The units at the treatment works have got special paint on them that the DWI come along once a year and check with an ultraviolet scanner to see if they've been tampered with. Because the DWI think that: well we know we've got some Crypto coming through those, we just disconnect the sampler and then that water with Crypto in won't go through the filter. (Oliver)

Regulation was perhaps regarded as a way to ensure companies' compliance when they could not be trusted in the eyes of the DWI. However, if regulations were really to replace trust, they would have to regulate ever smaller details and regulate all standards in the fashion of the *Cryptosporidium* which would be practically and economically impossible (Oliver argues that the DWI would not go for that level of detail 'because then you are talking about those 500,000 tests we are doing every year, the costs would be astronomical if we had to do that').[37] The next section will demonstrate that the relations between water companies and the DWI have generally improved since then. Harry does not regard it likely that another standard with the same detail as the *Cryptoporidium* standard would come in:

> The industry and the DWI would fully explore other avenues prior to that, everybody has learned a lot from that. I think the industry could have provided a more co-operative view on Crypto, we could have been perhaps less confrontational.

In line with this, a report in which water companies could give feedback on the performance of the DWI (Price, 2002: 8) stated:

> As has been mentioned in 1999 new policies relating to *Cryptosporidium* were having a major impact upon relationships between DWI and the water companies. Today the sense of indignation and even anger which was apparent then has subsided. Many respondents acknowledge that the *Cryptosporidium* regulations have brought benefits but believe that the time has now come to review the way in which *Cryptosporidium* is regulated.

5.5.4 Conclusion

In this section I have argued that although new parameters may surface at some point in the future, they have largely remained stable during the last decades. It seems that what can be called a 'regulatory plateau' is established, a plateau of which the key parameters have been identified and for which adequate analytical methods and treatment technologies have been developed and are in place. One may even say that companies try to actively establish a regulatory plateau by trying to prevent new standards entering future directives (for instance by proving that the treatment processes are so robust that they would stop or remove any potentially harmful

[37] It would be interesting to undertake a Porter-like analysis of the relation between companies and the DWI in more detail with regard to the approach the DWI took to standardisation in different periods. Exactly when and why did the DWI exactly feel the need to control water companies by what can be called 'extreme' standardisation and what were the reasons for less stress on standardisation in other periods? Unfortunately that falls outside the scope of this dissertation.

substances). The European and national regulations are based on lists of parameters, which in themselves incorporates the idea of a plateau: the regulations are not developed to embody endless lists of parameters. In fact this resembles Callon's (1991) explanation that networks resist translations or changes when the different parts of a network are tightly related. He argues that when a network becomes robust and durable, it also becomes normalised and standardised. Star (1991) maintains that once a network has become stable and irreversible, creating an alternative network or new and alternative standards may be expensive or impossible. It is with the end of the construction processes that many STS work stops; yet, this is where I want to begin.

Irwin et al (1997) categorise regulatory research in five stages, of which regulatory compliance testing is one, but do not say anything about the specific sort of research and innovation that are connected to these stages. I would like to identify five types of research that form part of what I call regulated science and are more or less significant in a regime of regulated science where a regulatory plateau has been constructed. Firstly, there is standard-driven science and innovation. Innovation to meet new standards seemed an important part of the research in a water company a number of years ago; the industry is regulated by standards. However, since the standards have not changed significantly and are not likely to change radically anymore, this type of research becomes less important once a regulatory plateau seems to have been established. Secondly, I have identified incremental innovation or efficiency research, which is often indirectly standard-driven. This type of research is focused on meeting the standards better, more efficiently, and cost-effectively. The standards provide a benchmark against which one measures the effectiveness of the process. This is an important type of research, also under the regime of a regulatory plateau. Thirdly, there is innovation or research to anticipate standards, but, like the first type of research, this is not a major type of work in an area where research tends to follow the standards (companies are likely to wait until new standards come in before they do research) and where not many new standards are expected. The fourth type of research I identified is defensive research, which, as we have seen, constructs (and reflects) the idea of a regulatory plateau. There seems to be a set of regulations that is worth defending, while more standards entering the directive should be discouraged. This type of research is closely related to anticipatory research, since defensive research is done when a new standard is anticipated. Lastly, research can be identified that is not linked to the standards. I call this Friday-afternoon research and innovation. This is research that can be done for reasons not related to standards; people can enjoy doing research or do it because the product can result in profit. Yet, this type of research has changed in recent years. As Oliver states:

> You would have these people who would be doing their little bit of research, plotting away doing their research and it wasn't particularly focused or looking or not whether there was any real benefit to it. Just thought: oh, it's a good idea to do that and off you go and somebody could spend ages and years doing it and so those things don't happen anymore. If you want to do something like that, you have to make a business case which is a good thing. Because there has to be some perceived benefit from it. A tangible benefit that is going to be at least cost-neutral.

It still happens, but has become a lot more formalised and specific goals have to be formulated before the research is approved.

The plateau is seen as a means to reduce the workload of water companies without reducing the quality of the drinking water. It adds a specific type of research to the research that would normally be done under a regime of regulated science (standard-driven science, incremental innovation, Friday-afternoon research, and perhaps anticipatory research), namely defensive research. If a plateau occurs (spontaneously or carefully managed by for instance water companies), standard-driven science and anticipatory research, to the extent this is undertaken, become less extensive and (radical) innovation in analytical methods and treatment technologies seems to be prevented.[38] Table 5.3 illustrates the different types of research under the different regulatory regimes.

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[38] If we accept that a regulatory plateau is at work, an interesting question is when and how –under what circumstances– this plateau is or can be disturbed. The plateau might define when standards are in and out of place. Standards outside the plateau might not be working or accepted and standards might be defined as out of place if they disturb the regulatory plateau. However, this is something that I need to leave for future research. A close case study on the relatively new standard of *Cryptosporidium* might help to answer these questions. Empirically we can ask how this standard found its way into the plateau, whether there was resistance against it and in what ways.

Table 5.3: Types of research under different regulatory regimes

	Regulatory Science	**Regulated Science**	**Regulated Science and a regulatory plateau**
Standard-driven research and innovation	Absent (research precedes standards)	Present (research follows standards)	Absent/Present (small presence since plateau prevents new standards from entering regulations)
Incremental innovation/efficiency research	Present (small knowledge gaps are filled and methods and technologies are made more efficient)	Present (methods and technologies are made more efficient)	Present (methods and technologies are made more efficient)
Anticipatory research	Present (regulators may think about a standard, but need the relevant knowledge)	Absent (research follows standards)	Present (in the form of defensive research)
Defensive research	Absent (research is done to *aid* policy making)	Absent (research only follows standards)	Present (to construct and maintain the plateau)
Friday-afternoon research	Present (not standard-related)	Present (not standard-related)	Present (not standard-related)

However, one has to be careful with the notion of a regulatory plateau. Although it seems likely that water quality will be managed by control systems rather than by explicit regulatory standards in the future, it is important to note that it is not (just) the water industry that decides on new regulatory standards. If the European Commission or a national regulatory body sets a new standard, companies will have to comply (although a certain co-construction takes place through consultations). Also the extent to which water companies would like to go to prevent new standards from coming in is questionable. If standards are deemed necessary because they form an unmistakable risk to public health, few water companies would object to these. None of my respondents mentioned for instance that they objected to or had lobbied against the new lead parameter. Lastly, it has to be mentioned that defensive research is something that is more likely to be carried out by larger water companies, since the smaller companies may not have the number of people and/or expertise to do this. The construction of a regulatory plateau should therefore not be overstated, since only a few companies are able to defend and construct the plateau. The other companies are likely to wait for new standards to come in before they do any (anticipatory or defensive) research. The next section will show that anticipatory research is not seen as necessary under a regime of regulated science. Anticipatory research, although it happens under regulated science, is therefore more likely to be found in regulatory science. In the words of Robin: 'The standards are so far ahead of us that we are unlikely to anticipate regulations. No reason why we should'.

We can conclude that regulated science is mainly reactive in developing analytical methods and treatment technologies. The establishment of a regulatory plateau (whether this was actively established or a consequence of regulations that have not changed for a period of time), contributes to the 'reactiveness' of the water industry since there is not much incentive to change the work routines without changing standards. The only proactive activity in this case is preventing new standards from entering future regulations; in that sense a regulatory plateau would encourage defensive research (and in a sense, anticipatory research) which is otherwise more or less excluded from regulated research.

5.6 Mobilisation of standards

Drinking water quality standards once set are regarded as unavoidable. They cannot be changed (at least until a review of the regulations takes place) and can be legally enforced.[39] Water companies will therefore organise their practices, analytical method development and development of technology so that compliance with the standards becomes possible (regulated science) and are in this sense mainly reactive. However, this does not mean that there is no discretion and interpretative flexibility to the regulations, that standards cannot be mobilised, and that non-compliance is regarded as a case for enforcement action for every parameter and in all circumstances. In this section I will address these issues with specific attention to the way in which the regulations and materiality are co-constructed. The relations between the water companies (who have to ensure material compliance with the regulations) and the DWI ('the guardians of drinking water quality') are central.

First it is important to have a broad understanding of the way in which water companies deal with new and incoming standards. Section 5.4 hinted at the complexity of standards. A standard is not a simple number, but a number that is related to different articles and notes in a text and to other texts which together prescribe how a water company should be organised in order to comply with this number in a meaningful way. To make sense of these complex regulations water companies often have a specific department, or, in the case of smaller companies a specific person, which deals with the regulations. This in itself is an organisational change that occurred in many water companies as a consequence of the ever more complicated and extensive regulations. The companies have to interpret the (general) regulations in such a way that they will make sense to the particular company. An example:

> We have people who are working out exactly what the regulations mean. We have working groups within the company working out what it means in terms of changes in emphasis on the monitoring program. (Victor)

The person or department in charge often makes an action plan for the different departments in the company to ensure that the number of samples that is required to be monitored is estimated for the specific company and incorporated into budgets, the electronic systems that produce sampling programs (place, time, and frequency) are adjusted; the laboratories ensure they can analyse for any new standards; and so on. When I asked one respondent to describe how the 1998 directive or rather the English drinking water supply (water quality) regulations 2000 were implemented in the particular company, the answer was: 'well, that in itself is an essay' (Martha). I will not go into the (technical) details of the implementation of these new regulations, partly because they are slightly different for each water company. However, it is important to note that all my respondents stressed that a change in standards never occurs suddenly. They all knew about, or were even involved in the negotiations about, the standards before they were set and would come into force. The policy makers realise that new or tightened standards can generate a lot of work and once set, the directive leaves enough time for companies to make arrangements that make it possible to comply with the regulations. I will give a few illustrations of this:

[39] In chapter 2 we have seen that this is not always the case. Salter (1988: 27-28) argued there that 'standards developed by government departments or agencies can be viewed as voluntary, and used as guidelines not regulations for conduct'.

> The directive came out in '98 and really the draft was already there by '97. And all the discussion was going on around '94, '95, '96 really. So, it has to be quite a number of years in advance. (Martha)

> Strictly speaking [we learned about the new regulations] when we saw the near final draft, which would have been in about October 1998, but we were aware through the technical issues and consultation documents what was going on before then, because we are aware what representations Britain was making through the vehicle called Eureau, where water affairs are discussed within the European framework. So, we had a pretty good idea of what was going on.' (Fred)

> They put out a consultation paper to sort of let us know exactly what is changing, like over the next few years the lead level, the lead PCV is coming down from 50 as it is now and to 2013 it will be down to ten. And it is just really giving us a bit of a chance to prepare for that task, put in treatment where we need it. (Sarah)

> The biggest [change] would be lead, the new lead regulations, but we have known about them for so long. They didn't come as a big surprise. You just know of these things through the DWI and such, you know what is coming, it is all being talked about beforehand. (Rosa)

These illustrations refer back to the consultation paper that was distributed to water companies. The consultation document was thus not only an opportunity for water companies to give their opinions about the new regulations and a way to make it harder for them to disagree with the regulations once they are set, as we saw in section 5.4, but also provided water companies with information on new regulations early on. It gave companies a chance to make arrangements to achieve compliance with the new regulations and carry out defensive research and in that sense anticipate them. An important role in these respects is reserved for the DWI. The DWI not only keeps water companies informed about new developments, but also provides guidance on how to implement the set standards by means of information letters. I will now turn to the role of information letters in mobilising the set standards and in getting them to work. In addition I will discuss the relationships between the DWI and water companies. I will then explore various ways in which standards can be mobilised and explore these mobilisations in cases where the water does not comply with the standards or is unfit for human consumption. The discussion of section 19 undertakings will show that regulatory agencies themselves can be mobilised to achieve compliance with the standards. Lastly, by looking at auditing practices I argue that, like compliance with the standards, audits can become a goal in themselves and self-audits are used for regulatory assurance.

5.6.1 Mobilising standards through Information Letters

When one visits the DWI website the homepage has a link to the information letters. Together with the regulations, DWI publications and a number of other issues amongst which are lead and *Cryptosporidium* they are classified under the heading *technical information*. That lead and *Cryptosporidium* are mentioned separately, whereas none of the other regulatory standards are mentioned, is interesting in itself. Apparently these standards are regarded as more significant in one way or another than the other standards, whether this is in terms of health effects, in terms of the amount of work companies have to do in order to comply with the standards, or in order for the DWI to ensure the companies have been given enough information on the subject and can be confronted with this if they do not comply.

The information letters that can be found on the website are issued to 'all water companies giving advice, guidance or requiring information' (DWI, 2004).[40] In the words of one respondent:

> The drinking water inspectorate do liaise with each water company by means of their information letters, directives, various communications, telling water companies: this is what is coming, this is what we expect you to do and this is the date on which it will be reportable. So they don't just suddenly drop something on us one day and tell us to do it the next. There is communications and reasoning after why. It is a lot of work. (Martha)

[40] The website is regarded as very helpful by respondents: 'I must admit that the big sort of plus of recent years has been the DWI website, because if you do have any queries, you can go on to there and pick up all the current legislation and the current information letters and general information really. That has been a great help and I think, you know, as a, when you speak to any other water companies, they may mention the same.' (Martha)

They help to make sense of the standards and bring them to life by dealing with them in a less abstract way. In fact, they make the standards more concrete and give them a sort of materiality in terms of their role in practice. Information letters do not just help to implement standards; they mobilise them in particular ways. By making the regulatory standards more concrete and deciding what counts as evidence that supports a certain sampling regime (or non-compliance as we will see later), the DWI interprets the standards and sets the regulatory regime in a certain way. Whereas the standards are mobilised in specific ways by the information letters, the letters themselves mobilise companies or departments within companies in certain ways.

I will now go into the role of information letters in a little more detail. The frequency with which the information letters are issued differs, but the average is around two per month. The ones that are published on the website are selected by the DWI as 'letters of particular interest'. To illustrate the diversity in subjects the information letters handle, the Table in Appendix 4 gives an overview of the information letters (of particular interest according to the DWI) issued in 2000 and 2003. The Table shows that the information letters give guidance on new regulations, such as the Water Supply (Water Quality) Regulations 1999, on how to use geographical information systems, and on how to deal with specific circumstances like the fuel supply problem. It also demonstrates when the water industry deals with certain issues. In 2000, 8 of the 29 information letters were about how to deal with sampling and analysing *Cryptosporidium*, whereas *Cryptosporidium* was not mentioned once in the 2003 information letters. However, if one looks at the information letters of the last four years the only parameters to which several information letters are devoted are, again, lead and *Cryptosporidium*. I would like to discuss these in a little more detail.

As we have seen in section 5.5 and will see when I discuss programmes of work (undertakings) later in this section the tightened standard for lead requires a lot of work from water companies: 'The more stringent lead standard will have the biggest influence' (DWI Press Notice, 2000). An information letter of 2000 (12/2000) on lead requires companies to have a strategy of action to meet the interim and final lead standard. The strategy of action should consist of plumbosolvency treatment (phosphate dosing), replacement (relining) of companies' lead pipes, and advice to property owners on the action they can take to reduce their exposure to lead. It also addresses in some detail the taking of lead samples and the criteria for determining whether new plumbosolvency treatment is necessary.

Like other information letters, this letter refers frequently to previous information letters and to regulations and will itself form a reference point for future information letters. It can change the regulatory regime by adding new information and prescriptions and by stating which past information (and ways of dealing with a standard) is still relevant and which has become irrelevant. The script of this letter thus enables and constrains other scripts and thus ways of mobilising certain standards. The letters do not only change the regulatory regime, they also change companies' practices. The letters, since they are part of the regulatory regime, have to be followed up. Companies have to formally acknowledge the receipt of the letter that is printed on paper and sent by mail. John states that '[official correspondence] would always come through in writing and it's a very formalised system of information letters that are all categorised'. An information letter can therefore also be regarded as a reference point for the DWI. If companies do not comply with the information letters, the DWI can check whether the letters were received and can use them consequently to legitimise a warning of or action against a water company. The consequences of non-compliance with the letter (the action that can be taken or the action that a company is required to take) are often specified in the letter. One example from the above mentioned information letter on lead:

> Where the water company has completed whatever actions are required, according to the criteria specified by the Inspectorate both for plumbosolvency treatment and control and for a programme of pipe replacement (relining), but there is nevertheless an occasional failure to meet the standard in force at the time at a consumer's tap, the water company will be required to replace (reline) its lead pipe (if there is one) to that property alone. (DWI, 12/2000)

When a company decides that it does not need additional plumbosolvency treatment on the basis of a (too) small number of samples, it is the DWI that determines whether the evidence can be regarded as appropriate proof:

> The Inspectorate would consider a statistical projection from a smaller but sufficient number of results or an extrapolation from results of a similar

treatment works supplying zones with similar water quality and a similar proportion of premises supplied through lead pipes. The Inspectorate would also consider other appropriate evidence such as plumbosolvency propensity or modelling.

Because of the power relationship, a water company that would regard different evidence as appropriate is at risk of having to redo the risk assessment according to the criteria of the DWI if it cannot convince the DWI of the appropriateness of the evidence. Very few companies would take the risk of doing double work. Information letters thus attempt to standardise work the companies do and the cases that can be made to support companies' decisions. Oliver explained that his company is undertaking a large survey on lead and phosphate 'to meet DWI requirements, to provide them with enough information to demonstrate that our plumbosolvency treatment meets the new standards, is adequate'. A number of people in the company do the lead sampling: 'We have to do a hundred samples because they provide sufficient data to demonstrate that the treatment is optimised and effective' (Oliver).

The information letters have to be taken as seriously as the regulations. Oliver illustrates that in addition to the regulations:

> They [the DWI] put out information letters periodically and there`s probably ten, 20, 30 a year of those. They [are] on the DWI website and you have to refer to all those as well.

Information letters on *Cryptosporidium*, like the one on lead, demonstrate cross-references across and between other information letters and regulations, specific mobilisations of proof, and standardisation of the practice of monitoring for and reporting on *Cryptosporidium*. Striking, however, in the case of *Cryptosporidium*, is the number of information letters on reporting information. As we saw in section 5.5, *Cryptosporidium* is more strictly regulated than other parameters. Likewise, provision and storage of information on *Cryptosporidium* is regulated more strictly than information on any other parameter. Information letter 12/2002 states:

> Paragraph 3.5.1 of Part 1 of the Standard Operating Protocol specifies that all documentation and receipts must be kept in a secure location for a minimum period of twelve calendar months following sampling.

It is also prescribed exactly how information should be written down:

> The format for the anomaly reference is xxx/yy/mm/nnn where:
>
> Xxx is the company identification (...)
>
> Yy is the year in which the anomaly occurred e.g. 02 for 2002
>
> Mm is the month in which the *anomaly occurred e.g. 01 for January*
>
> Nnn is a sequential number assigned by the company, restarting at one for the first anomaly each month.

This is perhaps the clearest example of the use of information letters as possible legitimation for a warning of or action against a water company. In the case of *Cryptosporidium*, companies cannot only be prosecuted for breaching the (treatment) standard or not following the method properly, but also for not providing the correct information. The more detailed the requirements of providing information are, the stronger the case of the DWI in case a company does not follow the information to the letter.

Yet, although the DWI has more 'regulatory power' than the water companies, both often emphasise the role of consultation and negotiation. This would fit in with the traditional style of policy in the UK:

> Traditionally, the underlying principle is that standards should be 'reasonably practicable' that is, tailored to reflect local conditions and circumstances, the economic costs of abatement and the current state of technical knowledge. (Jordan, 1998: 180-181)

I will return to the 'reasonably practicable' of standards and the way in which materiality is and has to be taken into account in the regulations (and information letters) in the next section. First, however, it is important to concentrate on the role of negotiation and consultation in the relation between water companies and the DWI. Respondents generally stressed in interviews that they have a good relation with the DWI (which implies that they follow the regulations and provide good water quality). I will give a few examples:

> The relationship is that they are the regulator and we are required to provide all sorts of information to ensure that the company complies with the UK regulations. So, it's a good relationship. We try and maintain a relationship that is very professional. (Victor)

> They are in charge and that is their job to police what we do. And in terms of the quality of the relationship: I think it is good. (Fred)

Robin remarks that 'it took quite a long time to work, but now everyone is comfortable'. Some respondents went into more detail about their relationship with the DWI:

> I am actually in favour of the drinking water inspectorate and not just because it keeps me in a job. But because what they do is to look from the outside. We have a very good relationship with the inspectorate in that they are not hard and fast regulators, they do not say: you will do this. It is a case of: well, you ought to do this and the reasons are such and such and have you considered this and this and they react to us very good, almost like a sort of mentor in some ways. Because they are made up of people who generally worked for the water industry in the past, so they have a wealth of expertise and are not simply pushing regulators so to speak. (Lewis)

The possibility to negotiate with the DWI and the fact that most people actually worked in the water industry and know the practical issues that water companies face in their day-to-day work seems very important for the 'working' of both the DWI and the standards. Instead of forcing the water companies into 'alien' regulations, the regulations and information letters take practicalities (and materiality) into account and make more sense for companies to comply with. Yet, the relation remains one of regulator and regulated. Charlie (IDWI/050603) mentioned that the DWI is careful to maintain the role of regulator, although it would advise companies through this 'free consultancy' to improve things before it would force them to carry out work or even prosecute them as we will see in the next section. Some respondents clearly showed how important maintaining a good relationship (or a perception of the relationship) with the DWI is; they seemed to defend the DWI. The quote below demonstrates, in my eyes, the relationship between the DWI as regulator and the company as regulated:

> I must admit, on a lot of things, I don't find the drinking water inspectorate unreasonable. They are human just like anybody else. You know, if you talk, which I think is a big issue. If you don't talk then nobody knows where the other side is coming from. I don't find them unreasonable, but obviously they get data from all over the country and if there is a predominant issue sort of rising up from a number of places then they take that, I assume, as a cause for concern. So, they may ask everybody to look into it. Like over the winter of, or the autumn of 2001, sorry 2000, there was a great deal of rain and they were obviously getting indications from the monthly returns that the nitrate was starting to go up. So, they asked everybody to put in some information about nitrate levels, which everybody, well, I certainly did, I don't know whether, I assume everybody else did. So, you know, a lot of the time I don't think they are unfounded in their questions. (Sarah)

These answers are not surprising; it would have been more surprising (but possible) if respondents had told an outsider how bad their relationship with their regulator was (and thus that they may be providing water that does not comply with the standards). Yet, James is more sceptical about the DWI:

> We have had disputes with the regulator saying there is not a problem, it should be an event, and they've said: no, it's an incident. [for a discussion of events and incidents, see next section] And generally we'll put forward our case and they'll ignore it, go their own way, cause that's the way they work. It's very difficult to change their opinion once they've made up their minds, it's very difficult to change it.

A report in which companies gave feedback on the performance of the DWI also mentioned that a number of companies criticised the Inspectorate's 'reluctance at times to acknowledge that they may be wrong' (Price, 2002: 13). When I asked Samuel what happens if a company does not agree with something the DWI wants the company to do, he answered:

> I guess, the easy answer is, that is tough. But I think in any of these things, if there is disagreement, then you need to talk to whoever it is who is responsible either for setting the standards or enforcing them and you know, have a logical debate. Some things can't be changed. I'm sure we'd all like the pubs to stay open all night, but you know, at the moment they are not and we can't change it.

Sometimes companies just accept what is expected of them. However, as we will see in the next section companies themselves also want to provide good quality water. We have already seen that they equate providing good water with following the regulations. This, in addition to avoiding regulatory risk, might be a reason why companies sometimes even press the DWI for information on how to comply with certain standards.[41] Victor:

> This morning I have been talking to the Inspector about a letter we were expecting from him which we haven't had yet and it is becoming urgent in the company to have that letter. And I've been asking him if he can possibly send it to us quickly.

Rather than organising the water company or the work that has to be done according to own insight, companies are asking the DWI for guidance. The guidance, if followed, will assure them that they are not at regulatory risk and will not provide unwholesome water and water unfit for human consumption. Yet, the next section demonstrates that, despite their effort and the fact that they follow the standards, associated guidance, and information letters, water companies cannot always control the quality of the water they provide.

5.6.2 Mobilisation of standards and the problem of (material) compliance: the (im)possibility of management (purely) by numbers

We have seen that the DWI provides information letters to guide the companies and advise them on best practice and on implementing new standards and other regulations. They sometimes ask for advice from companies too. The DWI and the water companies generally try to establish a good relationship in which they can consult each other.[42] As we will see, whether a good relationship and trust has been established or not has consequences for the way in which the DWI 'polices' the companies. Although the DWI is mainly reactive as a function of the regulation (they can only undertake action when something has happened), they try to be as proactive as possible: 'We gear ourselves up as an inspectorate to try and ensure things are put in place to improve things before the regulations will be breached' (Charlie). The information letters are one way of being proactive. There are others. The DWI can be proactive in the form of specific advice, suggestions, and recommendations to individual water companies following inspections (audits) of the company:

> Clearly one of the roles of inspection is not just 'are you doing that right?' but if we see that something is about to happen we can say: you are in danger of breaching the regulations, we recommend you to change your practice. (Charlie).

Whereas a 'suggestion' refers to good practice and can be seen as advice from the DWI, a 'recommendation' is a technical term that is used by the DWI when 'they think that is you don't put something in place to stop it, there will be a breach of the regulations' (Fred). It can therefore be regarded as a warning. The company does not have to listen to the DWI at this point, but according to the DWI, or at least my key respondent (Charlie) there, companies would be 'foolish' not to. The company is getting 'the benefit of a free consultancy'.

For various reasons, the companies are likely to take this 'free consultancy' seriously. If they would not respond to a recommendation and standards are breached, the chances are that the DWI will be more inclined to take enforcement action. They cannot respond by saying that they were not aware of the problem. It is

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[41] There may be a third reason: the customer. This will be explored in the chapter 6.

[42] It is also crucial for companies to have a good relationship and establish mutual trust with other institutions like the public health department and the local authorities. If there is an outbreak of illness in the community and the health authorities advise a water company on measures that the company does not follow, the company is likely to get prosecuted by the DWI. Oliver explains that just after privatisation some local authorities, mainly labour-controlled councils were against privatisation. They took and analysed all the samples the company took as well to make sure the company worked properly. After 2 or 3 years trust started to build up. 'We try and in the short term maintain those good working relationships and honesty and trust really come into it.'

plausible that the DWI will be harder on them than on companies that encounter problems but have not had recommendations and time to prevent these problems from happening. However, the power relations do not seem to be the only reason. Water companies do not want to contravene the standards. According to Charlie most companies are sensible and 'they want to get the water quality right, otherwise they are creating problems for themselves'. Fred confirms this: 'We are constantly striving to improve the service to our customers and other stakeholders and this is part of the DWI on helping us to do that'. Companies generally appreciate the suggestions and recommendations because they consider it their duty to provide the customers with good water quality, although a report by Price (2002: 14) stated that some companies resent this and 'saw it as telling them what their job was'. And, as we have seen before, the standards have come to represent good water quality. Companies also want to comply with the standards, because non-compliance leads to a lot of work: 'then you are into resampling and notification. So, we don't like failures. We had two this year and we don't want anymore' (Sarah). Others argue that a reason for complying with the standards is simply that nobody likes to admit failures: 'The fact that we have to notify when things go wrong, nobody likes to do that. We don't like to admit that we have failed in any respect, so there is a lot more focus on making sure that we don't' (Samuel). However Chris points out that there are a few water companies that 'do try to sail as close to the standards as they possibly can'. Of course most, if not all, companies would deny that this is what they do and would give an account similar to that of Oliver:

> Different companies have different approaches to the effort they are prepared to spend to meet the quality targets: do you just meet them or do you have a comfortable [margin] [WaterCo] is a fairly risk averse company. And it will usually go the [utmost] to put that at some level of safety margin to reduce the risk perhaps a bit more than you need to. Well, strictly, no, I can't say a bit more than you need to, to go a step further than strictly needed, but that reduces the risk of failure and you can see that if you look at our performance in relation to other water companies and we are always up at the top.

According to Chris the DWI 'has a perception of water companies: the majority is very very good, but there are 2 or 3 water companies, as you get with any group of organisations, that are not so good'. These companies are watched more closely than the water companies the DWI trusts and has a good relationship with. I will return to this when I discuss audits.[43]

The standards generate a lot of work for water companies in maintaining and improving water quality and companies may, in some cases, undertake 'defensive research' to prevent more standards entering the drinking water directive in the future. Yet, at least at some moments and perhaps in specific situations, people regard strict standards as a proof of the good water they provide and as something to be proud of. In the words of William:

> The regulation is very strict as it should be for maintenance of water quality and so the requirements to supply water are very rigorous. Of course the DWI are aware of shortfalls that are in companies and have made sure that standards have been tightened. All in all, the progress in the water industry has been very substantial and we now have an extremely robust water supply system in the UK which I would say is unparalleled. Plus of course, we have all the water quality data to support that.[44]

John shows a similar sort of pride: 'We've got the most stringent Crypto regulation in Europe, probably in the world I would think'. Not only the quality standards themselves, but also the wider regulations are often proudly mentioned. Victor states that 'one of the great national differences in Europe of course is that no one, including the Netherlands, produces such a comprehensive report as our own chief inspector'. Harry also talks about the collection of data:

> From any other countries in wider Europe and across the world in fact, ours is probably the unique situation that we have this databank of water quality data that is consistent for the last twelve years now. And we can demonstrate

[43] This is information that would have been difficult to obtain through interviews with water companies only, since they are unlikely to tell me that their purpose is solely to meet the standards and that they are hiding things from the DWI. For example, when I asked respondents if they had heard the abbreviation 'CATNAP' that stands for 'cheap alternative technologies narrowly avoiding prosecution' - a variation on BATNEEC (best available technology not entailing excessive cost) which is a lawful approach to choose a technology - they just took it as a joke and laughed. Yet, it is not an unknown term since even the EA glossary online mentions it. Another variation is CATNIP (cheapest available technology not involving prosecution.

[44] Although this respondent is here in line with what many other respondents said, his accounts of the water industry are unusually positive as was pointed out in footnote 36, this chapter.

> much better than any other country the quality of the water over that period, compliance with the regulations. Because we have got these regulations and the imposing system, it is a much more transparent and auditable system than other member states.

The standards are mobilised as evidence of good water quality, as a measure of comparison against other countries and perhaps even other water companies. In this sense, the same strict standards that may cost (or have cost) companies a lot of effort and money are also used to express pride in the company or country people work in: we deliver a good and healthy product. Water companies' websites and annual reports mention the percentage of samples that complied with the regulations over the year covered to demonstrate to customers that they are provided with a high quality water. I will give two examples from annual reports:

> During the year, 99.6 per cent of the tests we carried out on drinking water complied with the government's stringent standards, maintaining our high level of compliance. (Anglian Water, 2001: 1)

> During 2001, Mid Kent Water carried out over 49,000 tests as part of our monitoring programme and we achieved 100% compliance with the limits in the Regulations for all but six of the parameters. Our overall compliance for all samples was 99.84%, which continues the trend of improving water quality. (Mid Kent Water, 2002: 5)

A little further in the report (p 6) Mid Kent stresses the number of parameters that complied with the regulations: 'In 2001, 86 parameters achieved 100% compliance, with an overall compliance of 99.8%'. This mobilisation of standards can also be seen when people working in the water industry compare tap water to bottled water. Catherine mentioned that the standards for bottled water are 'absolutely terrible' and much less stringent than those for drinking water. It is almost as if bottled water cannot be of a comparable quality to tap water, since the regulations cover less and less stringent standards.

As we will also see in chapter 6, many companies set tighter standards than is required by the regulations, although, as Bill argues: 'to be honest you are not going to make the water comply vastly above the standards because it's a business nowadays, it costs money. You are clearly not going to raise the standards significantly above what they need to be to comply'. A tightening of the standards can thus simply be to ensure that the regulations will be met. If a company standard is exceeded, the company knows that something has to be done before the regulatory standard is exceeded and the company is liable to enforcement action by the DWI. Harry explains:

> For the treatment works, the company set tighter than the regulations in order to ensure that everything else is actually met. We have parameter specific definitions for treatment works; we have company treatment target groups which are tighter than the regulations.

The companies thus work hard to maintain compliance and seem to want to avoid non-compliance with the standards at all costs. Avoiding enforcement action and prosecution appears to be the main reason for the fact that companies set even tighter standards themselves. Later in this section it will become clear that companies, in non-compliance situations, make cases that exceeding a standard is not always serious in terms of health effects. Tighter standards therefore can be said to reflect a way of dealing with *regulatory risk* rather than *health risk*.

Companies also set tighter standards for other than operational reasons, although these are contested. Fred says that the tighter standards in his company are mainly with regard to aesthetic things like iron, manganese, and turbidity and that there are tighter operational values for those standards 'which we think as a business would be desirable to achieve'. Victor discusses the fact that the company goes beyond the regulations to please the customers:

> There isn't a standard for total hardness, but we do total hardness tests, because it is something the customers are interested in. So, I suppose it is true to say that we do monitor beyond the strict requirements of the regulations to provide information that our customers require.

However, Rosa stated that in her company they 'treat the water, not the customer'. Chapter 6 will explore the relation between customers and (tight) standards in more detail. Here it is important to point out that setting tighter standards for operational reasons is indeed a way of handling regulatory risk, but that this risk is not as easy to control as it would be in perhaps other situations. Why is it that *tighter* standards are needed? Mary and Samuel explain:

> What we normally do is design the treatment works so it will treat the water to 20% less to what it is in the standards. When you are taking the samples, it is only an indication of what it is like at that time. So, the 20% is really to give us a sort of cushion to make sure that we are always complying. (Mary)

> We'd look to achieve results that are much better than the regulatory standards. Within a treatment works we would have our own internal target value for a number of parameters. So for instance, if the standard required for aluminium was 0.2, we'd look to be putting water out that is 0.05. So, that is the sort of way in which we would work. Whatever the standard was, we'd be looking to be quite considerably below it. Because you know, for some of the parameters, they deteriorate in the distribution system and therefore, to ensure that you meet the standard at the end of your distribution system, you'd aim to be three, four, five, six, ten times inside it before you left the treatment works. So, yeah, I mean our aim would be, for all of the parameters that have a standard to be well inside them. Not just meeting them, but *well* inside them. (Samuel) (emphasis added)

Samples are an indication of what the water (quality) is like at the time you take the sample. This will be further illustrated in chapter 6, but the quote already hints that water quality is not a stable feature of the water. Since companies cannot monitor parameters continuously, they need to set a safety margin. This safety margin is not directly set by the standards, yet one could argue that the standards that are at work here mobilise *other* standards. Setting the safety margin is however not always possible:

> In some instances, for instance on nitrates, we might set an operational limit which is below the formal standard for drinking water in supply, so that we can be sure that we don't exceed the standard in the supply. But that will vary from parameter to parameter and I guess reflects the degree of control that you have over that particular parameter. (Victor)

The control one has over particular parameters and thus over compliance with the standards is different from the degree of control one has over many other products. The source of the water, unlike the 'source' of many other products is not fully in control of the 'manufacturers': rainfall, temperature, and spillages can all change the water quality. Water cannot be totally standardised; two different waters both treated in accordance with and complying with the standards will be different. Catherine states that there will always be regional variations: 'You have a different shower in [London] than you would have in [Manchester] or in the [hills] for example'.[45] Martha puts it in a different way:

> Both final waters would meet the regulations, but the actual characteristics of the water might be different enough. But I don't think that would [be due to] the regulations so much as [to] the fingerprint of the water, so to speak.

Whereas in chapter 2 I used standards and standardisation processes often interchangeably, this is not possible when one talks about water quality.[46] However, not only can different waters not be totally standardised, there are cases in which companies cannot get the water to comply with the standards (with the means available to them at that point in time). As we saw earlier, everyone agrees that the water quality has improved since the regulatory changes in the industry. The compliance with the standards is much higher now. In the words of Oliver:

> We were able to put right years and years of under investment and the improvement in water quality is staggering, really. I mean, you go back, the 12, 13 years that we've been privatised, the improvement in the number of failures, or the reduction in the number of failures against the water quality standards has been staggering.

Yet, this is not necessarily solely due to a better water quality, but also to having specific ways in dealing with the particular set standards. In the words of Victor:

> The overall compliance with the standards that we are getting at the moment is above 99,9% so we are getting very few failures now of standards and that

[45] For reasons of anonymity the names of the cities have been changed.
[46] This may apply to food quality, air quality, and so on as well.

> is because of the mechanism that has been in place for the last twelve years or so. Unless we get new standards, the failures are going to gradually reduce possibly a bit more. But I don't think any company will get 100% consistently.

So, if not many new standards are constructed, the compliance with the standards will increase. Yet, the 100% will remain difficult or even impossible to achieve. Martha says about *Cryptosporidium*: 'I don't think any water company will ever guarantee that there is not even one who is still in the water'. According to John 'it is accepted that no one will get a hundred percent compliance. So, the name of the game is to get as far towards the hundred percent as you can'. In chapter 2 I said that water cannot be expected to comply with the regulations by itself. In some cases even the hard work of the water companies does not lead to compliance. They may be trying to be proactive, but as James states:

> By the nature of the industry we are operational, so things happen minute by minute and day by day and they will be reactive. You've got a base, an underlying proactive element throughout the company pushing and driving water quality to ensure we get better water quality, so it's not an accident that we get good water quality, we will always have this reactive stuff bouncing along the top. And some months it's worse than others and it's when you have a bad month in terms of reactive stuff is when you start to see things sort of break through and affect compliance.

Lewis argues that non-compliance could have major consequences for water companies and customers if the directive were to be followed precisely:

> In reality, because you simply fail a standard does not mean that you have to do something straight away. If you would follow the European directive to the letter then all water companies would be on hold within six months, because they wouldn't be allowed to supply the water because it would fail the standards. I am not saying the water fails the standards all the time, but if it were to fail a standard and you follow the interpretation literally, then that supply of water has to stop.

Lewis suggests that the regulations do not take notice of the many practical issues. However, the materiality (or material agency) has to be and is, although perhaps not in detail, incorporated by both the regulators and the regulations. This makes the regulations and certainly the issue of (non-) compliance more complicated and much less straightforward. There are cases in which the water does not comply, but the companies do not have to undertake work and are not prosecuted. Charlie explains in his commentary on this section (13/11/2004) that prosecution would only result where there had been an incident (see later in the chapter) and water was supplied which was unfit for human consumption – this offence is set out in Section 70 of the Water Industry Act 1991. Non-compliance is legitimated by arguing that in most cases a (temporal) exceedence of the standard does not (immediately) affect public health:

> We are talking about ingestion over a life-time and that is the basis on which the standards are set, plus a very generous safety factor of probably at least a thousand in there. So if a certain person drinks a glass of water with a concentration of a particular element or substance, they are not going to fall to their knees poisoned, so people need to remember that the standards are set with a wide margin of safety. (Fred)

Earlier we saw companies setting safety margins to ensure regulatory compliance. I argued that these safety standards could be considered as mobilisations of the regulatory standards. In this case, the 'real' standard that can be found *in* the regulatory standard, the one without the safety margin included, is mobilised. Fred continues: 'If someone is just over the top of the standard, generally, there isn't any acute health effect or any effect at all. So, you do have time to respond without affecting public health'. This supports the idea that the hard work of companies to maintain compliance is partly a way of dealing with the regulatory risk of prosecution rather than with a health risk for the population. This is not to say that companies generally do not try to provide a good quality water to their customers; as we have seen previously, companies can be proud of providing good water quality and they have no incentive to provide a bad quality water.

Even if an exceedence of a standard would have health effects, one has to balance the risks of providing this non-compliant water with not providing water at all. In the words of Fred: 'If you don't drink, you might die. And against that the medics have to weigh up the risks of not supplying water or supplying water marginally above the limit'. Also in this sense the water industry differs from many other industries. Water, in the eyes of Catherine, is 'absolutely crucial':

> You can choose whether you will have a chocolate bar, whether you want a car, you can choose whether you have a telephone or not, but you can't choose whether you drink water or not. So it is absolutely fundamental.'[47]

Non-compliance is accepted in a number of specific cases. One of these cases is when the classifications and parametric values of the standards are being adjusted. In the 1998 directive a few parameters from the 1980 directive are relaxed or disappear and this has partly been taken over by the UK national regulations. Exceedence of these parameters was accepted as soon as the new directive was agreed on –although the old one was still in force– as long as the parameters would not exceed the standard in the new directive. Exceedence in this case was not punished by enforcement action. The classifications of the standards in a directive thus determine what action companies and the DWI are taking. Nitrite is a good example:

> In the past we have entered into undertakings to do all we can to decrease the incidence of levels above the standard and we have been successful in that over the years. But we have now got down to a level which is probably irreducible given the disinfection process that we are using. However, because the standard is changing, all the current failures that we get will not be failures. There was then decided that it is not in the public interest to require to either change the disinfection process or to strive to get zero failures on nitrite. (Victor)

Also Martha argues that the company is 'allowed' to 'exceed the nitrite as long as it doesn't go too high'.

However where a standard that will not be relaxed or disappear is breached, prosecution will also not follow automatically.[48] Companies are required to tell the

[47] This was one of the arguments many people used to argue against the privatisation of the water industry and an argument that keeps coming back in other discussions on privatising drinking water elsewhere in the world.

DWI about any breach they have. If a sample fails, the company has to explain why it failed and what it has done about it to prevent it happening again. Charlie: 'Most of the time we get full explanations to what action is taken'. The DWI then judges the breach of the standard as trivial (a single breach is usually considered as trivial) or non-trivial and assesses whether it is likely to recur.[49] If it is trivial and not likely to recur 'we don't have to do anything' (Charlie). In other cases the DWI may give the company a program of work (undertaking) that will prevent further breaches. In both cases the breach will be noted, but no action in the form of prosecution will be taken. Prosecution will only take place when the company supplies water unfit for human consumption and cannot explain the cause of the failure and what it has done about it or when the company could have done something about it to prevent it and did not do that. As we have seen previously:

> Just because it breaches a standard, doesn't mean that it's unfit for human consumption, because a standard, most of them, have a wide margin of safety. (Chris)

Water that is unwholesome, that is breaching the regulations, is not necessarily water unfit for human consumption. Yet, if the company was responsible for the breach of the standard, cannot defend itself on the basis of due diligence, and is accused of

[48] This is perhaps unlike the police who would undertake action in the case of any breach of legislation, because they assumes that people are always in control and make (good or bad) decisions.

[49] Exactly what the DWI regards as trivial was neither straightforward nor easy to find. Chris explained where to look for a description of the 'trivial': 'DWI has some rules that it applies and they're quite complicated. They are published in some of the annual reports of the drinking water inspectorate. Probably not in the most recent ones, because the most recent ones have been rather shorter versions, but I think if you go back to something like 1998, in the introductory text to the chapter that sets out the individual water company results whether they comply with standards for the various parameters you find a description of what DWI regards as trivial'.

supplying water unfit for human consumption, the DWI can prosecute. Prosecution is based on 'being capable of doing something' but not doing so. Martha: 'The government can prosecute a water company for not reacting and acting fittingly. You have to show vigilance when these kinds of things happen'. She gives an example of something her company was prosecuted for:

> Two properties were supplied from the raw water main instead of the treatment water main, somebody connected them to the wrong main. It [prosecution] could be for anything the government sees as a breach of standards or significant and we could have done something about.

The DWI will prosecute the company for supplying water 'unfit for human consumption'. Companies sometimes contest the label 'unfit for human consumption':

> Most of the prosecutions are about breaching the standards and I think they are all done now under the head of 'water unfit for human consumption' cause they are breaching the EU legislation. But it doesn't necessarily mean that it is unfit for human consumption. It is just breaching the standards. If it is unfit for human consumption, technically in law that means it breaches EU standards. So, you have either breached the standards or you haven't. We go to court and defend ourselves, but it is not like that. (Catherine)

She argues that sometimes you might have to supply something that is not aesthetically pleasing, but that you can drink. In 1999 Yorkshire Water challenged whether dirty water which posed no apparent threat to human health should be regarded as 'unfit for human consumption'. According to the ENDS Report (1999: 59) it has been generally sufficient for the DWI to show that consumers rejected the water on the grounds of unacceptable taste, odour or appearance, 'no evidence of a threat to health has been required'. Leeds Crown Court however ruled that water could be 'unfit for human consumption' if 'it was of such a quality that it would cause a reasonable consumer of firm character to refuse to drink it or use it in the preparation of food' (ENDS Report (2001:56). As we will see later in the chapter, the DWI would not quickly prosecute if it does not have a good case.

When a company is not considered responsible for a breach or for providing water unfit for human consumption, there are specific ways in which non-compliance can be regulated. To look at this we have to turn to the regulations themselves.

Regulating non-compliance or unwholesomeness: Undertakings and Relaxations

Article 9 from the 1980 drinking water directive said that member states could make provisions for derogations from the directive in order to take account of:

a) situations arising from the nature and structure of the ground in the area from which the supply in question emanates
b) situations arising from exceptional meteorological conditions

It also states that the derogations cannot be made for toxic or microbiological parameters or constitute a public health hazard. Article 9 from the 1998 drinking water directive maintains the possibility to provide derogations for certain parameters 'provided no derogation constitutes a potential danger to human health and provided that the supply of water intended for human consumption in the area concerned cannot otherwise be maintained by any other reasonable means' (EC, 1980: 37).[50] It also states that the derogation is for a maximum of three years, although a second, and in exceptional circumstances a third derogation can be made. The 1998 directive seems to pay more attention to non-compliance as a result of materiality. Article 8 in this directive focuses on non-compliance and states that:

> If, despite the measures taken to meet the obligations imposed in Article 4(1), water intended for human consumption does not meet the parametric values set in accordance with Article 5, and subject to Article 6(2), the Member State concerned shall ensure that the necessary remedial action is taken as soon as possible to restore its quality. (EC, 1998: 37)

The taking of remedial action was not mentioned in the 1980 directive. The UK 1989 Water Supply (Water Quality) Regulations provided two ways of dealing with non-compliance, other than prosecution: undertakings and relaxations.

[50] Article 9 is another example where the regulations have increased. In the 1980 directive the article consisted of 15 lines, whereas in the 1998 directive it consists of 70 lines. The information in the 1998 directive is far more extensive and specified.

Prosecution, as we have seen, would only result when there had been an incident and water was supplied which was unfit for human consumption. Undertakings and relaxations were a means to deal with failures to meet quality standards where unwholesome water might be supplied. An undertaking can be given where following a breach of a regulatory standard enforcement action is taken under section 18 of the Water Industry Act 1991.

An undertaking is a legally binding programme of work a water company undertakes that ensures that the water will comply with the standard once the work is finished. It was for instance accepted that companies could not immediately comply with the new or even interim standard for lead, since the right treatment (phosphate dosing) was not in place, but the water was still transported through lead pipes or, more likely, through pipes containing lead solder. The companies get a certain amount of time to replace some of the pipes and to install plumbosolvency treatment after which they should be able to comply with the standard. Failure to give an undertaking, or fulfil the requirements of one, could result in an enforcement order being served on the company under section 20 of the Act. Failure to give an undertaking, or fulfil the requirements of one could result in an enforcement order being served on the company under section 20 of the Act. However, as long as the company continues to comply with the terms of the undertaking there is no need to proceed with enforcement action under section 18 of the Act and proceed with the making of an enforcement order.

However, as we have seen, there was a discussion about how and where lead should be monitored, in other words, it is not yet clear *what compliance is* under the new regulations. Fred explains:

> Each of our company areas is split up into discrete zones which aren't more then 50,000 people in a zone and then there is a water supply zone and one takes a number of random day time samples from that zone over the years. If you examine the results of those and more than 5 percent of the samples taken are above ten micrograms per litre, then that is the trigger value for you taking action. It is not the standard, that is an actual trigger, because we have to decide what is compliance. That hasn't been decided at the moment.

It is therefore difficult for companies to decide when they should adjust or renew their treatment processes. The guidance given by information letter 12/2000 notes in addition that the quality of the supply should be taken into consideration:

> After due consideration the Inspectorate has concluded that new or further plumbosolvency treatment and control or optimisation of existing plumbosolvency treatment and control should be considered at each treatment works where more than 5% of samples taken in all the zones supplied wholly or mainly by that treatment works since the last relevant treatment change exceed 10 μg/l. The Inspectorate suggests "mainly" to be interpreted as at least 50% of the supply to the zone originating from the treatment works, but *some flexibility of interpretation may be needed to take account of the quality* (chemical analysis and plumbosolvency propensity) *of the supply.* When a treatment works does not supply at least 50% of its output to any water supply zones, *the water company should consider the quality* (chemical analysis and plumbosolvency propensity) *of the supply to inform its decision on whether new or further plumbosolvency treatment and control needs to be considered.* (Italics added)

Chapter 6 will explore the meaning of (material) compliance in more detail. Section 19 of the Water Industry Act 1991 deals with undertakings; an undertaking is therefore called a section 19 undertaking. I will return to this in more detail in the next section and will demonstrate how the standards themselves and the relation between the economic regulator (Ofwat) and the quality regulator (DWI) are mobilised by water companies.

A relaxation 'changes the standard, legally changes the standard' (Martha). Chris phrases it this way: 'I remember we gave relaxations for potassium and sulphate, but we didn't give relaxations, because in effect a relaxation changed the standard, so we applied a different standard'.[51] Charlie adds in his commentary on this section that a relaxation under regulation 4 (of the 1989 Regulations) gave permission in effect to exceed the standard to a specified extent (for example a

[51] Charlie comments on this quote: 'It does not seem to make sense. Note a relaxation in effect gives permission to exceed the standard. The standard was as always that specified in the regulations'. Yet, if the standard legally changes when a relaxation is given, one could say that a new standard is in place, one that has been mobilised by a company arguing that material non-compliance is outside its control.

relaxation for iron may have been given to 300μg/l whereas the original regulatory standard was 200μg/l). In the UK regulations it says that a relaxation can be authorised if the Secretary of State is satisfied:

> (a) that the authorisation is necessary, as an emergency measure, to maintain a supply of water for human consumption;
> (b) that the authorisation is called by reason of exceptional meteorological conditions;
> (c) that the authorisation is called for by reason of the nature and structure of the ground in the area from which the supply emanates; or
> (d) that the supply is or is to be used solely for food production purposes.
> (article 4, The Water Supply (Water Quality) Regulations 1989 SI No. 1147: (as amended and with references amended to refer to the consolidated Act)

Relaxations did not exist before the 1989 regulations. Then the chief chemist and bacteriologist interpreted and judged the situation. However, things have changed since then. In the words of Chris: 'It has been an enormous change to go from the very very loose system before privatisation to the regulatory control system after privatisation'. It is exactly in the regulatory control system that exceptions have to be made for compliance with stringent standards. The materiality and the regulations have to be co-constructed. Lead could not instantly be removed from the water, but it is only because of the classification under the 1998 directive that this is classified as non-compliance (lead out of place).

Relaxations are different from undertakings in that they do not necessarily require a program of work. Since they are a legal variation on the standard, the standard has changed and the company that has the relaxation now complies with the (different) standard: 'As long as we are meeting the relaxed value, we are complying, they don't consider it as a failure' (Martha). She argues that her company's relaxation for potassium was granted because it is naturally occurring, not health-based, and cannot be economically removed. According to her a relaxation for iron, that Charlie mentions as an example, would not be possible because this can be economically removed. I will return to this confusion about the parameters that may be granted a relaxation in a moment. When I asked whether this relaxation was temporary, Martha answered: 'That's a funny question. It is permanent, but needs to be reapplied for'. As long as the potassium was naturally occurring, the company would get relaxations for it. Charlie however states that a relaxation would be time limited and could be subject to the completion of remedial action within a specified timescale. Fred's company too has a relaxation for potassium. However, he argues that this is not important for the quality of the water the company provides to the customers: 'We don't have any of what we would call *substantive relaxations*. We generally comply with all the regulations' (italics added).

The fact that relaxations existed (in the 2000 Water Quality (Water Supply) Regulations only authorised departures are mentioned), meant that the regulators regarded some standards as more important and health-related than others. Like Berg and Timmermans (1997) (see chapter 2), Lewis states 'you need to be very careful with standards. Standards may be interpreted as absolute, but they all need slight interpretation about their significance'. Relaxations could not be given for toxic parameters, for those an undertaking was needed. However, for very toxic parameters it would be impossible to keep supplying the water until a program of work would be finished. The classification of the degree of toxicity of parameters did not always seem clear to my respondents:

> It goes back to the original directive. They [relaxations] were only allowable for certain things and I think they were not allowable for microbiological parameters and for parameters that were *in certain sections of the directive*. So, I think for those substances that were considered to be possibly harmful to health, they were not allowed as a relaxation. (Victor) (Italics added)

This is an interesting remark in the sense that apparently some parameters in this directive that is meant to protect public health, are not so important for health that the standards are absolutely necessary. It is the parameters *classified in certain sections* of the regulations that can or cannot be granted a relaxation.

> I: But pesticides are not necessarily directly health-related, are they?
>
> Victor: Yeah, but they were in these tables that were excluded from the parameters that you could get relaxations on.

The toxicity of parameters becomes blackboxed and what is left are the ways in which the parameters have been classified in the directive. This then becomes the criterion for deciding whether a relaxation could (under the 1980 directive) be granted or not.

We have already seen that the regulations consist of mandatory standards for microbiological and chemical parameters and of a catch-all that covers everything that can be a 'danger to public health'. Yet, the directive also contains non-mandatory indicator parameters that are used for monitoring purposes. If these parameters are exceeded no action is required unless they are considered a threat to health. In the latter case the water is regarded as unwholesome, as are other parameters in the directive when they exceed the standard.

Apart from the toxicity of a parameter and where a parameter is classified, there are other criteria that help to determine whether a standard can be relaxed for a particular site of a particular company. We have already seen that the granting of a relaxation depends on whether it can be economically removed. Yet another factor is how it affects the public. Many respondents told me that it would be very hard to get the DWI to relax a standard for discoloration. However, companies are not likely to apply for such a relaxation themselves. When it comes to ways of dealing with non-compliance, not only health, but also economic costs and the public have to be considered. And, as we have seen, whether the company is considered responsible or not.

The new directive and the new UK regulations are, according to many, much better than the old ones since the standards are more health related. Despite the fact that relaxations could not be given for health related parameters and the majority of the standards are now regarded as health related standards, also the new regulations had to incorporate some way of dealing with non-compliant materiality. Because even under the improved regulations, non-compliance may emerge: 'Water is very dynamic and there will be occasions when water companies won't achieve the standards' (Chris). Instead of undertakings and relaxations the new regulations talk about authorised departures. These are set out in regulations 17-24 of the Water Supply (Water Quality) Regulations 2000 SI No. 3184. Investigations are required when water fails or is likely to fail the standards or can be regarded as unwholesome. When a failure of certain standards emerges and is not attributable to the domestic distribution system or the maintenance of that system and the failure is not trivial and likely to recur, the DWI may require the water undertaker to seek a departure. To authorise a departure the DWI has to be satisfied:

(a) that the authorisation is necessary to maintain in that zone a supply of water for regulation 4(1) purposes;

(b) that a supply of water for those purposes cannot be maintained in that zone by any other reasonable means; and

(c) that the supply of water in accordance with the authorisation does not constitute a potential danger to human health.

As I have already mentioned, the departure period may not exceed three years. During this period the water quality has to be monitored and steps taken to secure future compliance. This is similar to what was previously called 'undertaking'. The relaxation has disappeared from the regulations.

Although the definition of a failure is clear (a breach of the standard), what is considered a 'likely failure' or 'likely to fail the standards' is not. Oliver argues that it is 'completely grey'. WaterCo, at the moment of my visit, tried to 'to get it somewhere where we as a company are comfortable with how we are reacting to these things, what we are reporting, [and] the resources involved in that'. Oliver says that there is evidence from the analysis of samples taken as required by the regulations that the trend in the concentration or (the value) of particular parameters is generally and steadily increasing towards the prescribed concentration or value. If that trend continues the water is likely to fail to meet the prescribed concentration or value in the future, say within five years. So, he says: 'The easy example, and they always only pick the easy example, is nitrate'. If the nitrate is increasing and it is going to hit the standard in a few years time, the DWI should be notified and told about the investigations into this. But it is not as simple as this:

> But what this means is that somehow we've got to report those and the problem is, the problem that the nitrate resource is gonna fail, we are taking that sample every month, you know, and it's at 45 and we know it's gonna hit it in five years time, well, it's gonna fail every month isn't it. It's gonna be above, it's gonna be likely to fail every month. Do we report that every month? What's the point? We are not gonna redo that investigation each time. (Oliver)

It is up to the companies to find a way to deal with this. Another problem that Oliver recognises is that also failures on non-regulatory samples also have to be reported, because:

> If you were taking the regulatory sample in that street on that day, it would have failed or it might have done, because they are not and that's one of the problems with bacteria is that how representative the samples are is very debatable. But, ok, so how many of those do we report?

The new authorised departures, although necessary to deal with (material) non-compliance, seem to leave much room for discretion and interpretative flexibility, that, perhaps at some point, will be decreased by information letters or new regulations if the discretion proves problematic and the trust between the DWI and water companies declines. However, it is not only on new regulations that there is room for discretion. The next section shows that discretion and interpretative flexibility are a significant aspect of regulating drinking water.

Regulating water unfit for human consumption: Events and Incidents

The results of the analysis of regulatory samples determine whether a standard has been breached or not. If it has been, the water is called unwholesome and undertakings (and under the old regulations relaxations) may be put in place. However, it may happen that there is a problem with the water at a place or time that no regulatory samples are taken and the water is not immediately compared to the standards. Charlie: 'You may have taken your routine sample for metals, not had any failures, half an hour later someone starts working on the main and causes discoloration: you've got an incident'. In this case the water can be regarded as unfit for human consumption, a consequence of which can be prosecution. It is interesting to note that prosecution is thus not directly related to a breach of a standard and providing unwholesome water, but instead to providing water unfit for human consumption.

The regulatory (and routine) monitoring programme does not take into account sudden changes of water quality and seems to assume that water quality is (relatively) stable and would only change slowly, so it can be picked up by the sampling programme and any likely failures reported. However, there may be water contamination emergencies. Yet, in the words of Chris, 'the directive does not say anything about emergencies'. The directive is based on routine monitoring. Article 10 in the 1980 directive mentions emergencies, but these have been left out of the 1998 directive. The DWI however has procedures to deal with emergencies. Emergencies can occur through situations outside a water company's control (pollution of a river, major power failure) or inside a company's control (operational mistakes, an alarm that keeps going off and nobody pays attention to but that results in a major incident). To deal with these sorts of immediate issues the DWI has 'events' and 'incidents' in place.[52]

Paragraph 9 of the Water Undertakers (Information) Direction 1998 made under section 202 of the Water Industry Act 1991 states that a water undertaker shall notify the Secretary of State (which is in effect the DWI) of:

a) the occurrence of any event which, by reason of its effect or likely effect on the quality or sufficiency of water supplied by it, gives rise or is likely to give rise to a significant risk to the health of persons to whom water is supplied. (...)
b) any other matter relating to the supply of water which,
    i) in the opinion of the undertaker, is of national significance; or
    ii) has attracted or, in the opinion of the undertaker, is likely to attract significant local or national publicity; or
    iii) has caused or, in the opinion of the undertaker, is likely to cause significant concern to persons to whom water is supplied
c) any reports of disease in the community which it appears might possibly be associated with a water supply

The DWI should be notified of any of the above mentioned possible events:

[52] As I mentioned in chapter 3, it would have been interesting to follow how definitions of events and incidents have changed over time, however, although information letters say which letters they replace, the older ones are either not on the website at all or just the title is mentioned and they cannot be read. Since there is no archive and they are not relevant for the industry anymore, this information is lost. For example for guidance on the information direction: when to notify something to the DWI, there is now an information letter (13/99) in place that has replaced information letters 2/94 and 4/98. Letter 4/98 has disappeared from the website entirely and 2/94 still has the title but cannot be accessed. This prevents confusion on the site of the companies and the DWI but it is unfortunate for historical purposes.

> Notified events must be confirmed in writing within 72 hour and a full report must be provided within 30 days for all events deemed by the Inspectorate to be incidents. (DWI, 2001, annual report)

The annual report (2001) also stated explicitly that companies are encouraged 'to notify the Inspectorate of events not meeting the prescribed criteria, but which could impact on water quality or cause concern to consumers'. On basis of the 72 hour report, the DWI then decides whether the reported event was an incident or a non-incident. Incidents are defined by the DWI as:

- A non-trivial and unexpected breach of Part II of the Regulations; or
- A breach of Part VI of the Regulations; or
- An unusual deterioration in water quality; or
- A significant risk to the health of consumers; or
- Adverse water quality changes perceived by consumers as significant; or
- A cause for significant media interest.

All information is assessed by an Inspector to determine:

- What caused the problem and whether or not it was avoidable;
- What the company did in response and how it handled the incident;
- What lessons can be learned to prevent similar incidents in the future;
- If there were any breaches of enforceable regulations; and
- Whether the company supplied water during the incident that was unfit for human consumption.

Yet, despite these lists of criteria, it is not always clear what should be reported as an event, whether the event will be turned into an incident, and what consequences the incident has for the company. John: 'There are a few catch-all phrases in there like, something liable to cause widespread public concern. But then the question is: what do you define as widespread public concern?' Robin illustrates the difficulty of deciding what to report:

> We have to decide in the middle of the night: are we going to declare this one or is it going to disappear? A problem is that if you leave it a couple of days, it can suddenly be a huge incident and then becomes long and complicated. But it is a difficult decision making, especially at 2 in the morning. A thousand times a month somebody somewhere is cutting into one of our mains, contractors, or closing a valve or something. Every time that happens there is a potential incident and about 1 time in a 1000 it does that in a big way.[53]

The companies have to decide under which circumstances they will report a cut in the mains. According to Robin many companies used to hide this sort of information in the past. Charlie says that there are now some companies that notify the DWI of everything that may be or become an incident. This has also been recognised in information letter 13/99: 'Some water companies have adopted an approach of informally notifying the Inspectorate of all actual or potential incidents and then subsequently amending the level of notification'.[54] Lewis argues that that is exactly what his company does:

> The definitions of an incident or an event or a non-event are fairly subjective. So, we tell the Inspectorate everything and leave it up to the Inspectorate to say: that is significant, that should be taken further or whatever, whereas other companies take the other route and report very little to them. I actually think that it is to the benefit of [name of company] to tell them everything, because they are then confident that if [name of company] had a problem, it would tell them. And that is the way it should be.

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[53] Charlie comments (130904) after reading this quote: 'It is the responsibility of the water companies therefore to ensure they have in place adequate procedures, appropriately trained personnel who know what they are doing so that the planned work does not go wrong!!'

[54] What is required to be notified has become stricter according to some respondents. Looking through the annual reports of the DWI and the specific sections on individual water companies, it seems that the number of events has increased. Martha explains: 'If there seems to have been an increase in 1999 or certainly in 2000, it is because the report thing was more descriptive and we were reporting more to them. It could be that the number of incidents or discoloration is exactly the same, but it is suddenly more specific that they even want small discolorations reported through to them, not just the major ones'. Yet, when I asked Fred about the cause of the increase in incidents, he answered: 'other than bad luck you mean? It is misfortune'.

Also Robin suggests that his company is inclined to tell the DWI more rather than less:

> We had an unusual one a while ago. They used a big scraper with refurbishing mains which used mineral oil to keep the head of the thing warm. Somehow, they ripped the pipe off and filled the main system with oil. These are the sorts of things that happen all the time. We tend to be on the side of telling the DWI.

Not surprisingly, all respondents said that they tend to provide the DWI with much information whereas other companies do not.[55] Samuel said that there was a lot of resistance when the DWI first began to send out lists of criteria for notification. Now this is not regarded as a problem anymore: 'We've probably all come to realise that it is helpful for them to set out what they think they should know about. I think we all live with that one relatively comfortably' (Samuel). Yet, not everything that is notifiable can be mentioned in these criteria and the water companies have a degree of discretion to deal with possible incidents. A few respondents were prepared to discuss some of the guidelines they use on when to report something. Unfortunately, this is partly confidential information that I cannot use here because companies do not want other companies and perhaps the DWI to know about the company's policy with regard to events. Samuel explains:

> Within all companies, certainly within our company, things will be happening and we will have our own classifications for them and we'll have our own trigger levels for the actions that we take. What might be notifiable by one company isn't notifiable by another.

Yet, what I can say is that a notifiable event is often determined by companies on the basis of the number of customers who are affected by the event and complain. Companies can for example set the number of customer complaints at 25 or 30 after which they will notify the inspectorate. However, also this is not as straightforward

[55] The names of the 'other' companies were often mentioned. Likewise, when asking respondents about problems they had encountered in their company, the response would often be that they have not had specific problem or at least not very often. Samuel stated for instance: 'not having come across them too often, I wouldn't sort of profess to be an expert'.

as it seems. Say a company has decided on a number of 25 complaints and something happened. The complaints may build up slowly and at some point you have around 20 complaints. In the words of John: 'Depending on how many people report it back in, we'd decide whether that was an actual report of an event or not. The numbers start going up and you are moving into events/incidents then'. However, the DWI has to be notified immediately (paragraph 9 of the 1998 (Information) Direction).[56] What do you do as a company?

The DWI recognises that some events 'such as burst mains and other matters fall not comfortably or clearly within those matters dealt with in Information Letter 2/94' (Information Letter 13/99). In information letter 13/99 a list with examples of events to be notified was therefore provided:

> The undertaker has got to make that judgement, but we have given guidance as best we can of what we want to be told about but without being prescriptive. (Charlie)

The DWI argues that it cannot be prescriptive, because it is not possible to give an extensive list of all possible situations. Discretion and interpretative flexibility are thus necessary to assess complex and ever changing situations. The way in which companies deal with this provisionality is part of their regulatory assurance. Regulatory assurance therefore incorporates a recognition of contingency and the knowledge that the regulator has to consider the circumstances of an event.

Charlie gives the example of a hundred people affected by discoloration from a burst main in central London and a hundred people affected by discoloration from a burst main in a village in a rural area. The DWI would want to be notified about the second case because if the total population of a village is affected, people are likely to be much more concerned than the same number of people in central London. He argues therefore that 'every single case is considered on its merits'. See Appendix 5 for the tools the DWI uses to ensure it collects information that may have to be used in a court case.

Also William illustrates that certain events/incidents cannot always be precisely described in advance. His company used a relatively new relining product to refurbish the mains. The customers recognised a distinctive plastic taste to the

[56] This notification is then followed by a written initial report that is required within three working days and by a final written report within 20 working days.

water that they found objectionable. The company discovered, after extensive research, that the taste was caused by one of the components of the pipe. William: 'Because it was good quality groundwater it led to a chemical reaction of the chlorine reacting with something that was leaching out of the pipe. It was something that was very specific to us, to our water.'

If it is difficult to assess whether an event is an incident the decision becomes a DWI group decision. By using the group experience the DWI also tries to avoid as much as possible that similar situations lead to different outcomes, but, as Charlie says: 'At the end of the day there is always a degree of subjectiveness. You cannot be a 100%'. It happens that companies do not agree with the assessment. The DWI might listen to their arguments, but 'if we deem it is an incident then that is what it is' (Charlie). The water companies are aware of this. On the question when something is called an incident, Fred answered: 'When the DWI decides to call it one. It is purely to them. And they will then take what action they deem appropriate'.

As breaches of standards do not automatically lead to enforcement action, incidents do not always lead to prosecution. Due diligence is also in this case a major aspect:

> There's always a pragmatic view taken with any kind of incident and it will come down as much to what the water company did, whether the company caused it in the first place, and any health related impacts associated with it, as much as breaching in itself in terms of whether you get prosecuted or not. (James)

James continues on a more sceptical note:

> Even with incidents it doesn't follow that you'll get prosecuted and quite often if you have something classified as an incident there's no sort of ongoing issue with it. It's just that the DWI in their wisdom considered it to be significant in some respect.

Robin seems to have accepted that events, incidents, and even prosecutions occur once in a while: 'We don't get many these days. Twelve to fifteen incidents in a year, Thirty events, we might get one or two prosecutions'.

5.6.3 Managing expectations of Section 19: mobilisations of standards and relation(s) between regulators

The previous section already mentioned undertakings as programmes of work that ensure that compliance with the standard for which the work was set up will be reached in the future. Section 19 is such a programme of work, in the words of Lewis: Section 19 'is basically a legal document which allows the water company to put water which is out of spec in supply'. James describes section 19 as 'a quality driven rehabilitation, so the driver is iron or sometimes manganese and turbidity, customer complaint's and it's got samples as criteria'. Probably without being aware of it, James seems to take non-human actors seriously.

As part of section 19, a large scheme was developed as a one-off opportunity for water companies to get funding to replace (part of) their iron (and lead) distribution network after privatisation. In order to receive the funding, the companies needed to prove (by means of samples and customer complaints) that they had a problem with the water quality that was supplied via these pipelines. The water quality standards were mobilised to prove to the DWI that the companies had water quality problems, and then to mobilise the DWI in making a case to Ofwat, saying that the companies needed funding to restore the water quality. Ofwat would then make an agreement with the companies on the quality investment. This is where 'lobbying' takes place. According to Lewis standards tend to be very absolute. Lobbying therefore takes place around the interpretation of the standard or regulation (as we have seen in the previous section) and the way in which the regulator enforces it. Lewis:

> What water companies tend to do is to lobby the regulator: if we fail the standard, we are prepared to do this work, but we also need a relevant time-scale and relevant funding in order to do whatever work it is. That is the form lobbying takes. It is really to control the time-scales whereby things happen and when these things happen.

According to him, this lobbying is 'very much to pushing the time-scales as far back as possible, to effectively ease the pain on the customer'. Sarah gives a similar example:

> You do have some time to, and of course, if you don't get up to the standards, you have always got undertakings that you can agree with the secretary of state to say: yeah, we know we are not quite there yet, but give us a couple of years and a bit of money and we'll sort something out. So, yeah, I mean, with time and talking, you can generally sort things out.

Lewis argues that the water companies do not mind when the work gets done as long as they are funded. However, he says, 'in reality you can't double bills, so it puts it in perspective. You cannot separate standards from cost'.

Having to mobilise the DWI to get funding from Ofwat also had disadvantages. Robin says that 'it wasn't until we had outbreaks or definitely proven outbreaks that the DWI would approve'. Charlie stresses that the DWI and Ofwat are independent of each other: 'The DWI role is to satisfy itself that there is need for a quality improvement scheme and to agree the content (remedial work) with the company. The DWI support is provided to Ofwat who then take an independent decision on funding. Usually, but not always, Ofwat agrees the funding'. As we also saw in section 5.5, the way in which funding was arranged had an impact of the possible degree of 'proactiveness' of a company.

I attended a meeting on the section 19 scheme at WaterCo.[57] The meeting was a good example of how water quality issues are linked in with institutional and economical issues and how certain types of information are used to try and mobilise actors for a certain purpose. Parts of this meeting were very hard to follow, because a lot of knowledge was taken for granted. Caroline (CAWQR/150403) who brought me there, said that she experienced the same when she started to go to these meetings. It was only after a year that she could follow everything that was said. She was very kind to drive me back to the head office after the meeting and I used this opportunity to ask her what had remained unclear to me. WaterCo had replaced many pipes under section 19 and used the meeting to plan replacing the rest of the pipes that fall under the scheme. As I understood, some pipes had been abandoned in the process and Ofwat needs to approve each one of those 'abandonment cases'. The purpose of the meeting was to come up with a strategy to manage expectations from Ofwat and the DWI, as Caroline said:

[57] For this section I have also used the minutes of the meeting which I cannot reference with regard to the anonymity of the company.

It is not about managing projects, but about managing expectations. It is about the perceptions of numbers [that stand for lengths of pipelines and finances].

The question was what the best manner would be in which to approach Ofwat in order for Ofwat to approve the cases. This was a difficult issue since it was not known what sort of questions Ofwat would ask them and therefore how to prepare.

The whole question is: how to bring it to Ofwat? (Caroline)

During the meeting, it became clear that they had to prepare the data and a representative sample that would help them to get through the audits on section 19. However, collecting the data for the audit would not be an easy task. The majority of abandonments had taken place in the first years and the data on the new pipes had overwritten the old ones in the computer programs. The information on the old pipes had thus been lost. To prove the changes that had been made –'every millimetre needs to be justified'- one would need 'before' and 'after' drawings. They would need to dive into the archives. However, they did not know where all archive boxes were. They discussed if they could use twenty of the easiest examples and if they could divide the cases into three types in which lengths of pipes were distinguished. In that case it would be better not to tell Ofwat in advance what lengths of pipes belong to each type, because if Ofwat accepts one type and not another there would not be a possibility to change it anymore. One of the things that was taken into account was the way in which 'undertakings' were phrased. This had not changed since section 19 started and therefore the data that counted as evidence years ago should also count as proof now. Ofwat could not refuse that.

Another issue that was discussed and that demonstrates how WaterCo deals strategically with Ofwat and the DWI was the progress on finishing section 19. For WaterCo, the DWI deadline for completing the scheme is three months earlier than the Ofwat deadline. The DWI deadline is regarded as a bit silly since it is Ofwat that provides the money. WaterCo thinks it is possible to ask the DWI for a few weeks extension. They have good reasons and know from past experiences that the DWI is likely to accept the extension. One of the reasons for asking an extension is that it is hard to predict how fast the work is going, because this depends on the weather circumstances and whether people stay on the job or move on to other projects elsewhere.[58]

> We can only show how we manage the program and what steps we are taking. (Caroline)

By mobilising the DWI to give them extra time, WaterCo is likely to be able to provide more water of a good quality. However, apart from trying to finish the project in time and thus to make sure that WaterCo does not underdeliver, because that would mean non-compliance with the scheme, WaterCo has to be careful not to overdeliver as well. Overdelivering may be good for the water quality, yet it also means that the company itself would have to pay for these extra pipes.

At the start of this program, the assumption was that all companies would be up-to-date with the distribution network that had sometimes been neglected in the years before privatisation when section 19 would finish. The companies would then just need maintenance expenses to maintain (and not so much improve) the network. In the words of Sam: 'The whole purpose of the remedial work is to secure compliance, therefore there should be no further failures once the work has been completed – provided it has been done properly!' The scheme however finishes within the next six years and many companies still have iron mains left.[59] If a company wants to replace more pipelines, they will now have to decide whether to go via the DWI (for support) or directly through Ofwat. The money comes from a different place and does not require the support of the DWI. Yet, support of the DWI may increase the chances that Ofwat will provide the funding (by raising the water bills). The DWI would only look at the need for main refurbishment on the basis of quality requirements and whether or not the company gets funding via Ofwat is not important. However, if Ofwat decides not to provide the companies with the amount of money they asked for, the companies may have to look for alternative solutions

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[58] I was told that it is easy for people working with water pipelines to switch to working with gas pipelines. They will need a few days training on health and safety and can then start the work. To change the other way around, they would need more training, because hygiene is involved and they will need to be aware that the water is for consumption and to learn the rules for disinfection. But the methods are similar.

[59] Information letter 17/2003 states that most section 19 undertakings will be converted into Authorised Departures under the Water Supply (Water Quality) Regulations 2000, but that a number of undertakings that relate to parameters with national standards will remain valid, although amendments will come into place.

rather than replacing pipes and renovating mains. Filters may be placed in the properties and local flushing and cleaning may be carried out. It would be difficult to refurbish 50 kilometres of mains when funding is provided for only 25. James illustrates the problem:

> We are in the complicated process of seeing if we can extend some of that [section 19]. The delicate stage trying to, for the industry I mean, establish how we take that forward and how the industry gets funding for it, that's the real grey area. We are happy to do it, but if we are not funded it is going to be very difficult.

He continues by saying that the section 19 scheme is changing from being regulatory driven to being company driven. Companies will get funded through base maintenance rather than through a capital of quality scheme. The DWI will still carry out inspections and tell you what rehab a company needs to do. But:

> It doesn't mean you are going to get funded for it. That's a very tricky one for the future. It doesn't matter what the quality regulator says, if we've got no money, then it does not happen. And that's the problem we've got, that the regulators are still not quite joined up as they could be. (James)

In the interviews, the role of Ofwat and the relation between Ofwat and the DWI came to the surface a few times. For instance, when I said I wondered what the role of Ofwat is, Fred answered (laughing) 'so do I'. This was not a one-off answer, but one I regularly encountered. The question of how companies deal with the different regulators was met with, amongst others:

> With difficulty. No, there isn't a simple answer to that, because the emphasis will be more in one direction than another at different times depending on the situation. (Harry)

And:

> Very carefully. What we have to do is put up robust arguments, hopefully with the support of the DWI for our capital investment program to get funding from Ofwat. (William)

The relation and the division of labour between the different regulators does not seem unproblematic. According to Sarah, Ofwat has started to look more at quality issues than they had done previously: 'The areas are beginning to sort of blur a little bit of Ofwat and the DWI to a certain degree'. Also Oliver notes this:

> The DWI will tell us to do something for water quality standards, but Ofwat won't let us put our prices up. And increasingly I think that those, what was at one stage fairly clear in what the responsibilities of each of our regulators were, it's becoming really blurry now. You've got Ofwat asking us to meet certain quality standards. They have the same standards, but Ofwat wants us to look at different frequencies. More frequent than the DWI want. This is a debate we are getting through with them at the moment. Asking for that information. When we send a water quality report, have a problem to the DWI, they send it to the environment agency and they send it to Ofwat and we now get, we send this report off and then the EA rings and say: that problem you had last week, can you tell us about that? This is what [name of person] calls 'creeping regulations'. It is about the regulatory agency asking us to do more and more and it is about other regulatory agencies getting involved in areas that traditionally haven't been their responsibility.

Harry argues that the regulatory developments of the last fifteen years have made the circumstances in which water companies operate very difficult:

> I think the biggest change for the whole industry is really the operation of the regulatory system. Having to report to three different regulators and each one having a different agenda and those agendas don't necessarily coincide. There are conflicting requirements to each one to a degree and it is trying to ensure that you are actually meeting the requirements of each of the regulators at the same time.

On the 23rd of April 2004, a *Memorandum of Understanding between the Drinking Water Inspectorate and the Director General of the Office of Water Services* was issued. Although the 'Memorandum sets out to build on the good working relationship that already exists between Ofwat and DWI', the need for such a Memorandum in the first place seems to point to the existence of some problems in this relationship.[60]

5.6.4 Audits as quality and regulatory assurance

> *Audit implies compliance to various standards. It also implies the maintenance of documentary records that are open to scrutiny.* (Atkinson and Coffey, 1997: 48)

One of the main tasks of the DWI is inspecting or auditing the water companies to ensure that companies comply with all the requirements of the regulations. In the words of Victor:

> [An] audit takes the form of visits by the inspectors or by consultants appointed by the Inspectorate to investigate certain aspects of the supply of drinking water. And that covers the whole process from how we interpret the requirements of the regulations into our monitoring program, how the monitoring program is carried out, how samples are treated when they go through the laboratory, how the results get on to the public record, whether the information and reports that we provide to the DWI include all the relevant information, and then there are inspections of water treatment works, there are inspections of programs of work that we have in hand to meet new requirements.

[60] Charlie (in his commentary, 130904) pointed out to me that it is in fact the Water Act 2003 requires the memorandum. It says: 'It is the duty of each of those mentioned in subsection (1) to make arrangements with each of the others with a view to promoting, in the case of each pair of them (a) co-operation and the exchange of information between them, and (b) consistency of treatment of matters which affect both of them. (...) As soon as practicable after agreement is reached on any arrangements required by this section, the parties must prepare a memorandum setting them out'. Yet, this does not change the fact that a memorandum was apparently regarded as necessary; quite the opposite, by making it a legal requirement the significance increases.

John describes how an actual audit in his company took place

> We've had them [the DWI] in this week. Look through to see that they approve of our process and things like having to report any water quality incidents to them formally and be prepared to have them investigate our investigation of the incident and then propose actions that we must take as well as us proposing our internal actions.

One part of the audit can be what the DWI calls an audit trail. A DWI inspector will take a result from the public record (by legislation all results of regulatory samples go on a public record) and tracks it back to the laboratory where the result was generated. Here the analytical method is investigated: was the method appropriate and used correctly? This part of the audit is not necessary when the laboratory has obtained a UKAS accreditation which the DWI accepts 'as satisfactory': 'there are measures in place to ensure proper practice'. UKAS stands for United Kingdom Accreditation Service and applies solely to methods of analysis. Samuel describes the accreditation as follows:

> The DWI are very hot on the actual analytical quality control and a lot of the companies' laboratories will have gone through some sort of accreditation, which basically means: yes, this laboratory is of a good standard and the quality control of its analysis and its methods is acceptable and regularly checked. And therefore, whatever method they are using, you can be more than fairly content that you're getting the right results.

According to Victor 'you need to go to an accredited laboratory if you are gonna get a result that makes any sense. There are lots of little test-kits sold, but they are not a reliable method of obtaining the correct result'.[61] Although the DWI does reserve the right to carry out an audit in such a laboratory, it is less likely that it will happen than

[61] In footnote 26, this chapter, I mentioned test-kits that were developed for cases of water contamination emergencies. There was much discussion about the accuracy of the test-kits. Generally they are not (yet) as accurate as the methods used by laboratories. However, in circumstances of emergency, as opposed to circumstances of routine analysis, accuracy may not be the first priority. See for further information on the use of test-kits Kleinman (2003) who discusses how test-kits were both regarded as poor quality material and as ways of quickly completing experimental work in a microbiology laboratory. He also explores what skills are needed to work with these kits.

in a non-accredited laboratory. By applying for accreditation, a laboratory can reduce the audits that will take place. After having visited the laboratory, the inspector will then go back to the place where the sample was taken and checks whether it was taken at the right place in the right period according to the regulations. Charlie: 'We want to see proof of all that'. Sometimes an inspector will track a sample the other way around: from when it was taken until it is a number on the public record. This is what I have done in chapter 6.

Charlie says: 'Arguably people just make the results up and put them on the record'. The audit trail is in place to make sure that does not happen. In previous sections we have seen that it is unlikely that water companies would make the results up; it is not in their interest and they generate information for their own use with the same methods, for instance on operational samples. Yet, if they tried, the DWI has made sure that 'the companies can't really cheat the regulations' (Charlie). He explains that the samples are all pre-scheduled and 'once a sample has entered the system, you cannot change the details of that sample; they are coded, you can't change that'. In fact, water companies would have to spend so much time explaining what happens to the samples to the DWI, that 'they might as well put the effort in to do it right' (Charlie).

The audit trail practice has changed a bit over the years. The DWI used to track many results that breached the standards. However with the years the compliance has increased. Since compliance is a comparison between the 'actual' water quality (or how the water is treated to a certain quality) and the ideal water quality (or at least safe water quality; the standard), one could say that the co-construction between standards and water quality has deepened. It has become more difficult for inspectors to find enough results that breach the standards. Therefore, they now often focus on a selection of parameters.[62] It is likely that for instance the tightened standard for lead will be a focal point for DWI inspection, until it becomes a routine parameter like the others.

Part of all inspections is to see what procedures are in place to deal with water quality issues. In the words of Charlie this 'is a paper exercise'. In the case of an audit trail:

[62] Although the DWI inspectors learn what is auditable, different inspectors will audit differently and regard different things as suggestions and recommendations and events and incidents (Price, 2002). Charlie explained that some auditors pay more attention to the treatment works and others to the laboratories, depending on their own background.

> We have to sort of have paper work for everything. They will pick a few samples at random and then you have sort of five days to get all the paper work together, the certificate of analysis and then order the laboratory quality control data and they'll go through that and point out any inconsistencies. (Mary)

The inspector bears the procedures in mind when going to the actual site as we will see in the next chapter: 'The other aspect is to actually go and inspect the laboratory itself, go through one or more methods, see the analysts doing the work, ask them questions and check that the paperwork is done as it should be' (Charlie).

We have seen that information letters influence practices within water companies. In a similar fashion, Power (1996) has argued that audits can only take place if things are 'made auditable': 'auditing actively stimulates the development of systems and the related forms of accounting for performance which make the control of control possible. (...). Audit presupposes a domain of auditable facts' (Power, 1997: 11). In the English waterworld a checklist has been adopted that gives both the DWI and the water company a clear picture of the overall process (Price, 2002). Companies can therefore organise themselves in such a way that they will 'pass' the audits.[63] Since water quality standards have come to represent healthy and good quality water, the purpose of the company has become to comply with the standards, and the audits are in place to ensure that the quality standards are met, a company organised in such a way that it will 'pass' an audit successfully is a successful organisation. Since the DWI checklist is the same for all companies, the practice of auditing standardises the water companies.

In recent years companies have collected an impressive amount of paperwork. Paper, in some ways, has come to represent water. Only if this information is kept and made accessible, can audits take place.[64] The audits are meant to 'minimise the reporting burden on companies, while placing greater focus on the audit process' (Chief Inspector DWI in Price, 2002: 15).

According to Atkinson and Coffey (1997: 56), 'one of the root metaphors of an audit is that of the *audit trail*'. This is what the DWI uses to track results of the

[63] Materiality is interpreted in the context of these practices and (notions of materiality) may consequently change as well. This could be a topic for further investigation. Likewise, the relation between audit practices as described in the existing literature and audit practices that take into account materiality (see the end of this section) could be explored further. Are regulatory mechanisms like audits especially useful for regulating materiality?

analysis of samples or the samples themselves. They explain how the audit practice and the practices that are audited are tuned in with each other. The inspectors are instructed in how to carry out a detailed audit. Others are aware of that and keep paperwork specifically for audits; they may get rid of paperwork that will not be audited. Atkinson and Coffey (ibid.) argue that documents become very important in auditing processes: 'There is an assumption that reference can and should be made to other documents. An auditor's task is to establish the extent to these relationships and intertextualities'. It is through these relationships that organisations produce and reproduce themselves 'not reflecting reality but semi-autonomous domain of documentary reality in which documents reflect and refer to other documents'. They (ibid.) even define an audit trail as 'following an organizational decision, an innovation or a problem through a sequence of documents'. Although documents have become increasingly important for water companies, it is, as we have seen, not the only focus of an audit. The relation between practice and documents has remained crucial in audits on water quality, unlike audits in many other areas (accountancy for instance). The audit report only partly takes on an independent existence, superseding other files, records and memories.

As a result of the audit, the DWI may give a company a few suggestions and/or recommendations. Audits can in this way be used proactively for quality assurance. This confirms that how quality is assured relates not only directly to the standards, but more broadly to the practices and culture within the water companies as a whole.

Barrett, Cooper, and Jamal (forthcoming) go a step further and argue that sometimes the audit team regards it as important to be regarded as being positive and friendly, something Marginson (2004) calls 'friendly audits'. Like the quality standards and regulations, the audits become a goal in themselves.

It is interesting to note that water companies themselves have started to audit their own company:

> Some of the companies audit internally. And some of them do that before the DWI does. If they know that DWI is coming to do an audit on such and such a day, then perhaps a week before they will do an internal audit to make sure that everything is all right. (Chris)

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[64] See also Coffey (1994), Coffey (1996), and Coffey and Atkinson (1994).

The DWI can advise companies to do this. Robin told me that his company had a comment from the DWI saying that they did not do enough auditing on their own people. As a consequence, many people went to a training program to learn to audit. Internal auditing can be regarded as a (proactive) part of quality assurance:

> The work we are doing as part of the process team in terms of audit, in terms of treatment works, chemicals and new treatment processes is very proactive as well in its approach. That's all aimed at being proactive. (James)

Oliver sketches how the practice of internal auditing needs a water company to be organised in a specific way:

> [My department] was set up independent of operations in '89, to give us that distance and that independence from the operators. And that was seen as a reaction to the concern that we wanted somebody who could come in and give an outside view on, so we could do internal audits, before we were externally audited. It's much easier for us to turn up at somebody else's site, we are not going to be influenced by what is happening at the time at the site. It also means that we see the whole watercycle in effect.

However, internal auditing, like applying for accreditation, can also be regarded as regulatory assurance. Like setting company standards below the regulatory standards, internal audits before the external audits can be a way of reducing regulatory risk and of building up a good relationship with the regulator. There is a regulatory risk in not 'passing' an audit, especially in the case of audits on *Cryptosporidium*, which are very strict and detailed, like anything related to *Cryptosporidium*. James explains:

> A huge amount of effort goes into the audit trails on Crypto, masses, masses, so much more than anything else. Huge amount of paperwork, huge amount of audit, huge amount of data, huge amount of paranoia really on the part of the inspectorate. And on the part of the companies, because if we get it wrong...

Oliver remarks that the DWI occasionally also audits operational rather than regulatory samples, although perhaps not in such a detailed way. He worries that this might increasingly happen now the current regulations state that companies have to report something that 'is likely to fail':

> The fear that I have is that that reporting to the DWI will change how much investigation we do and make us do more whereas it is not strictly necessary, because we are comfortable with the amount we are doing at the moment. But there will be a nervousness in the company, well, we will just do that bit extra because there is a potential for criticism.

Barry (2002: 156) argues, in a similar fashion to Porter (1995), that 'trust in the performance of professionals and institutions has been displaced by a concern to monitor professional and institutional performance' and thus by auditing. However, internal auditing can also be a way of establishing exactly that trust and a good relationship. If a company can show, by means of audits, that it would not make up sample results, the DWI, as mentioned earlier will be more likely to trust them and would spend more time 'policing' companies that are less trusted. Oliver illustrates what a company tries to prove with help of internal audits:

> The DWI's view always has been that if we've got an opportunity not to take a sample because the plant is not performing well, we won't take the sample. And it is up to us to demonstrate that [name of software program] is scheduled for a sample to be taken at that day, so we went and did it. Not that we got to the site and found out: oh, it's not working properly and we'll just reschedule that sample and take it on another day when we fixed the problem.

Atkinson and Coffey (1997: 48) regard audits as 'an increasing pervasive feature of late modern societies':

> Indeed, it is arguable that audit in its various guises is characteristic of what has been called reflexive modernity or modernization, That is, a distinctive mode of modern social organization in which states, corporations, bureaucracies and other agencies are constrained to scrutinize and account for their own activities and their consequences.

If audits themselves are characteristic of reflexive modernity, internal audits are even more so. Yet, Power (1997: 4-5), who recognises that the concept of 'reflexivity' could be defined in terms of 'self-audit', argues that the 'programme of effective 'control of control', in which internal systems can be linked to distant regulators via auditing, is more ambivalent than the hopes that have been invested in it'. Although 'to be audited or to say one is doing an audit is to claim institutional credibility for what one does' according to Power (ibid.: 9), auditing remains problematic in practice, since, as we have seen, it actually changes the practice. Power also argues that what becomes important is *that* an audit is done, not *what* is done. In other words, the process that can be audited becomes more important for the auditors than the product itself. There are two issues Power regards as problematic of which I would argue that they are perhaps less problematic, or at least different, in the waterworld compared to the world of accountancy Power writes about. Firstly, Power (ibid.: 12) argues that 'auditing provides a problematic conjunction between different logics: service quality evaluation and cost-effectiveness. However, since the waterworld is organised in such a way that the economic regulator is different from the quality regulator, the audits of the DWI do not have to take matters of cost-effectiveness into consideration (although the increasing blurring of regulatory responsibilities may lead to exactly the problem Power noted). Secondly, Power (ibid.: 13) argues:

> The rise of audit as the control of control is a challenge to other inspection and assessment type practices which typically attempt direct observation of first order activities. Inspection is becoming more like audit and in many fields it is the arrangements for self-inspection which are being inspected.

He suggests that audits increasingly certify the operation of systems rather than 'look closely at specific service outputs'. Therefore 'the certifying auditor does not, like an inspector, require expert knowledge of the auditee but only a more abstract and portable knowledge of systems' (ibid.: 13). Also in the waterworld it is true that audits often consist of auditing companies' protocols and *whether* samples have been taken without always checking the results of analysis of these samples; the 'paper exercise'. Companies have even commented themselves that 'the existence of adequate written procedures was audited but not their practical application' (Price, 2002: 11). Yet, this section and the rest of the chapter have shown that this is not the whole story. Throughout the chapter the importance of practical experience of regulators and negotiators on regulations has been stressed. The regulators in the waterworld have expert knowledge and need this more detailed and practical knowledge to be able to *regulate materiality* and *negotiate materiality* with the water companies. While they try to make the system auditable and ensure that once a sample has been entered into the process of analysis it cannot be changed, audits take into account the specific analytical methods followed, and, as we saw in the case of *Cryptosporidium* even the paint at units at the treatment works.

5.7 Boiling down to a conclusion

This chapter has explored how standards are constructed, dealt with, and mobilised in their institutional, wider regulatory, and material environment. It has shown that standards operate through distributed activity in which many actors simultaneously play a role. The chapter argued that, in line with the literature discussed in chapter 2, the construction of standards can be a relatively 'messy' process in which not only the health relatedness of a standard is debated but also other (economic and political) aspects play a role. In line with Hamlin's (1990) exploration of water analysis in the nineteenth century, the specific purpose of water quality standards (whether for instance they incorporate ways of securing the catchment area or whether securing the catchment area is a matter of controlling discharges and should therefore be part of a different directive) and the science that should be used for them to be set, was –still in the 21st century– a matter for debate.

Yet, once the standards are set, this process is blackboxed and standards come to represent good water quality. It becomes a water company's goal to comply with the standards and quality and regulatory assurance combine or converge to enable this. Before the implementation and enforcement of the European 1980 directive the chief chemist and microbiologist decided what good water quality was. With the establishment of a strict regulatory regime, the meaning of water quality changed. The singularisation of notions of water quality, as discussed in chapter 4, was brought to a new level with the establishment and practices of the DWI that has the regulatory power to impose its conception of good water quality.

The standards and regulations are necessarily relatively abstract and are therefore accompanied by much associated guidance that advises companies on how to deal with and implement the standards and regulations specifically. The DWI mobilises standards through, amongst others, information letters, undertakings, and audits. Information letters 'regulate' and mobilise standards in specific ways by defining what can be regarded as evidence and proof in particular cases, by setting criteria the water companies have to comply with, and, in some cases, by defining analytical methods the companies have to use. Because of the information letters and the acknowledgement that companies received them, the DWI can then enforce the standards it had mobilised. Information letters can be said to be a means of putting standards at work and of operationalising them. Information letters and audits standardise the standards and the way in which they operate further. However, they cannot prescribe what a company should do in every possible situation it can encounter. Necessarily, they leave room for discretion and interpretative flexibility. Companies' decisions on how to deal with situations are however subject to a regulatory risk. Dealing with the discretion in the 'wrong' way in the eyes of the DWI, can result in prosecution. To reduce the regulatory risk of discretion and interpretative flexibility, companies will ask the DWI for guidance and organise their company in such a way that it will 'pass' an audit, since audits can only be successful if things have been made auditable. Thus, the relationship between regulator and regulated involves some form of boundary work (Gieryn, 1983) through which the lines of permissible and risk-laden discretion and interpretative flexibility can be drawn; this also affects the way in which companies are organised and work.

These standards, as mobilised by the DWI, are regarded as unavoidable. Non-compliance with the standards means programmes of work or can cause incidents which may result in prosecution. It is important to note that many of the standards were subject to consultations and negotiations, which often led to a compromise about or even convergence of views of water quality *before* they were set. In addition to the regulatory risk, this is an aspect that makes it difficult for companies to avoid or disagree with a standard.

However, this is not the whole story. Standards can also be mobilised in different ways, which do not all create the same meaning of water quality. The notion of water 'unfit for human consumption' can be explicitly contested (this water often breaches a standard), but there are more subtle ways in which standards are negotiated and mobilised. Companies often set standards tighter than the regulatory standards. These mobilisations of the regulatory standards can be considered as ways to ensure compliance with the regulatory standard. They can help to avoid upsetting the DWI and even to build up trust between the DWI and the company. They can also be used to satisfy customers with specific water quality wishes or to compete with other water companies. In other cases it can be argued that exceedence of a standard is acceptable since the regulatory standards embody a large safety margin. Here the 'real' standard that can be found *in* the regulatory standard, the one excluding the safety margin, is mobilised. It is also important to note that a standard can have a knock-on effect on another standard which could make mobilisation of one of them necessary.

Chapter 2 criticised the concepts of immutable and mutable mobiles (see Latour, 1997; Mol and Law, 1994; Moore and Clarke, 2001) for being explanatory concepts. This chapter has attempted to develop an understanding of the question when, where, and in what way standards become mobile and can be mobilised. It suggests that the mobilisation of standards should be understood with regard to the specific socio-material circumstances and the context of expectations and practices in which the standards operate. The classification of parameters –whether something is an indicator or mandatory standard– can influence the way in which standards are mobilised. The chapter demonstrates how mobilisation is multilayered within standards. The distinction between a 'real' core standard inscribed within a more broadly framed standard shows how there is not just one layer or level of immutability within a standard. Yet, the mobilisation of standards is not unrestrained; a relationship between regulator and regulated can diminish the (permissible) space for discretion, interpretative flexibility, and therefore action on the side of the regulated.

A water company that supplies unwholesome water or water unfit for human consumption will not automatically be put to work or prosecuted. It is here that materiality, or material agency, comes into place. We saw that the policy makers have to take into account that, due to the combination of the existing water quality and the material environment (treatment technologies, analytical methods), standards cannot be brought into force immediately since no water company would be able to comply. Yet, even if the treatment processes are in place, nobody believes that a company will ever achieve 100% compliance for 'water is very dynamic' (Chris) and it is 'powerful at dissolving things' (Thomas). Sarah said that she prefers to be called 'water quality administrator' rather than 'water quality controller' 'because I think that is a very grandiose title which nobody could even possibly live up to'. It is therefore important that both policy makers and DWI Inspectors have practical experience and understand the possible resistance of the material to its being controlled and governed. If the non-compliance is outside a water company's control, the DWI will not take enforcement action. The regulations have incorporated means to handle some of these cases of non-compliance. Under the 1980 directive a standard could be legally relaxed and in fact changed (or mobilised) into a different standard. Under both the 1980 and the 1998 directive companies can be given a programme of work during which they do not have to comply with the regulatory standard as long as they comply with the terms of the programme. The discussion of the section 19 undertakings showed that standards can be mobilised by companies making cases about the need for such a programme of work. If they are successful, they can delay compliance with a standard. Also the regulators themselves can be mobilised (to get funding for instance) in order to mobilise standards.

The water industry can be considered as operating under a regime of regulated science. The concept of regulated science is introduced to distinguish it from 'regulatory science', a concept that focuses on the creation of knowledge for policy making in order to manage (in theory) future uncertainty and risk. Under a regime of regulated science the development of analytical methods and treatment technologies largely follows, in the present, the standards and the organisation of the companies follows the audit protocols. The establishment of a 'regulatory plateau' (whether this was actively established or a consequence of regulations that have not changed for a period of time), contributes to the 'reactiveness' of the water industry since there is not much incentive to change the work routines without changing standards. This has consequences for the notion of compliance. Compliance with the standards increases through the co-construction of materiality and standards that are part of a regulatory plateau. Compliance therefore does not necessarily point to better quality water, but to the now routine construction of 'actual' water quality in comparison to the long known and stable standards. STS and policy literature on standardisation (chapter 2) had suggested that 'implementation' of regulations seldom follows the expected route, yet, under a regime of regulated science that operates on (the basis of) a regulatory plateau, the tightening of the few standards did not encounter insurmountable problems or discretion. To make sense of a company's argument that 99% of its water complies with the standards, one has to take into account the way in which the standards were constructed, the relaxations that were issued, and the role of auditing practices and regulatory plateaus in the way the company works and is organised. Even if water complies with the same standards, the 'fingerprint' of the water is different; it cannot be totally standardised. This suggests a complex co-construction between water quality and standards. In chapter 6 I will explore the construction of the 'actual' water quality with which the standard is compared to determine compliance. It is in this sense that the water, the standards, and the notion of compliance are co-constructed.

The main source of information for this chapter was interviews with water quality managers. However, as Robin says: 'We ensure the standard. But it's the actual people on the ground who run it'. It is time to turn to them and to explore how the 'actual' water quality is constructed and how materiality manages standards and 'creeping' regulations.

6 Cultural choreographies and On how materiality manages standards and 'creeping' regulations

6.1 Introduction

In chapter 5 I addressed the question of how regulations are constructed and shaped by materiality and how standards can be mobilised in order to deal with materiality. The chapter provided furthermore insight into how the current waterworld operates and standards work in (institutional and organisational) practices that are related to regulated science. This chapter concentrates explicitly on standards and regulatory regimes in their material context and will explore how materiality, in this case the 'actual' water quality, is (co-) constructed and shaped by the regulations discussed in the previous chapter. Materiality, which, as we have seen in chapter 4, 'affords' different interpretations of the same 'stuff', is therefore explored empirically by means of ethnographic fieldwork. Through tracking material objects I examine the objects' relations with the wider socio-technical and regulatory environment and consequently the standards-materiality relationships.

The chapter consists of three parts. Section 6.2 tracks what we could say is a drop of water through its transformation from being regarded as raw water into being considered as drinking water when it arrives at the consumer's house. This section thus explores the delivery of water (through abstraction and purification). In section 6.3 I follow a sample from when it is taken until it is translated into a few numbers on a computer monitor (and may be taken to court). This section demonstrates that a water company's job is not 'simply' a matter of delivery; a certain quality has to be guaranteed and the notions of quality and regulatory assurance will return here. It focuses on the risk management and control of materiality during particularly the processes of taking and analysing a sample. In the third and last section (6.4) customer complaints are tracked: where does the complaint arrive, where does it go from there and what actions are taken as a consequence of the complaint. The materiality is here (re) configured as a complaint. In this section it will become clear that customers' standards may in some cases differ from companies' standards.

The three sections will help to understand how materiality is shaped by the standards and will further explore how co-constructions of standards and materiality are established and operate. They will demonstrate that the regulatory standards are accompanied by other (for example operational) standards and that at different moments and places different standards, although they have the same status in the abstract regulations, play the most significant role.

6.2 Tracking raw water to customer

In this section I will follow a drop of water from where it is abstracted from a source until it comes out at the customer's tap. I use a number of quotes from interviews to illustrate the sort of narratives that are used to describe certain processes and decisions. I spent one whole day with a treatment manager (Jack, TPM/140403/WaterCo) and one with a monitoring manager (Oliver, WQM/120503/WaterCo); with them I discussed many issues about treatment plants in more depth than with many others. Many of the quotes in this section therefore come from the interviews with them. It is thus mainly two narratives that are followed, although other narratives from other interviews also figure in this section.

6.2.1 From source to treatment plant

Drinking water can be abstracted from a variety of sources as we have seen in Chapter 4. That chapter showed that the quality of drinking water today and in the west is defined in a different way than in past periods and in other parts of the world. The use of numerical standards and wider regulations together with the practices of the regulator as discussed in chapter 5 have led to a singularisation of notions of water quality. Yet, although the regulatory standards do not distinguish between different sources, this chapter will show that water companies' practices do need to take the sources into account in order to judge which sources can qualify as sources for drinking water. Not every type of water is considered to be able to make a relatively easy transition from raw water to drinking water. This came up during many interviews I conducted. During the day with Oliver, the issue came to the fore a number of times:

> We used to have a large number of spring supplies up here, but they were poor quality and unreliable and over the years they have all gone and been replaced.

> [name of city] is sat on a sandstone aquifer, but the problem with the water quality in the groundwater there is, it's very poor, a lot of it has been contaminated by industrial waste over the last 150 years. We've looked at using that, we've decided that it's not a practical solution.

If water quality is defined as poor water quality, it will be more expensive and sometimes perhaps challenging in a technical sense to build a plant to treat this water.

> But [the treatment plant] was a difficult works to manage because of the water quality. It is very sort of thin, upland water, it's quite difficult to treat. (...) It has a lot of colour and nothing there to coagulate. Thin water doesn't coagulate well. (Oliver)

Some would argue that poor water quality can be risky to treat:

> If raw water quality is very poor, whilst your treatment plant may well be able to treat it, do you actually want to? Do you really want to bring that very poor quality water onto your treatment plant and take the risk that for example one of the treatment stages may fall over? Then you've got a plant full of very poor quality water. (Bill, WQM/201102)

It is the combination of the perceived raw water quality and the technical, economic and practical issues (its location) that defines whether raw water should be transformed into drinking water. If the raw water quality of a certain source is seen to improve, it may change status and be regarded as fit to make the transition to drinking water.

> Traditionally we never used the [name of river] for drinking water because it was such poor quality water. What's happened in the last ten years is that the raw water quality has improved significantly and three or four years ago we started to use it for drinking water purposes. (Oliver)

However, as we have seen in Chapter 5, the water companies operate in a world that is deeply penetrated by regulations and the quality of water is therefore not the only consideration that needs to be taken into account. If a company has found a source that it would like to use, they have to ask for an abstraction licence from the Environment Agency (EA). The licences that companies have, but do not use, are withdrawn, and new licences are not issued if there are adverse environmental grounds. In those cases, the companies may have to implement more advanced and expensive treatment technologies.

> We were looking for an alternative and we tried to drill a borehole. We wanted to drill a borehole here, but the environment agency wouldn't allow us a licence for that because of their concerns about the impact on the aquifer. (Oliver)

> We have looked for alternative supplies, but the environment agency won't allow us the abstraction license. The only alternative path is to make these treatment works more robust and it has just been rebuilt with some extra treatment stages to give us that additional security. (Oliver)

Sometimes the blending of sources may be an option. If a water quality standard is approached (and the water is thus 'likely to fail'), the water company may decide to blend the particular water with other water that has a much lower content of the particular substance. In order to do this, it is important to have operational flexibility. By linking different sources with each other, operational flexibility is created. If one source dries up or has a temporary quality problem, the water can be taken from another source and transported to the treatment plant without having to build a new treatment plant at a new source. Flexibility also means that a company is less dependent on a particular source. If the water of one source deteriorates, the company can simply switch to another one that can take over the supply.

If there was no operational flexibility and people depended on this source, more expensive treatment would have to be installed. Oliver gave an account of how the operational flexibility can work:

> If the nitrate in one particular zone is approaching the standard of 50, we can put a blend of [name of treatment works] water in there to reduce the nitrate or if we've got a sudden acute pollution at one borehole, then we can take it out of supply and put [another one into supply].

Operational flexibility is therefore essential as a means of 'meeting the standard' and wider quality assurance. If the abstraction licence does not allow a company to abstract a larger volume of water from a source, a company may decide to move the boundaries in the distribution system, so that the area that is supplied by water of a particular source becomes much smaller. Supplies for other areas can then be increased.

Establishing operational flexibility can require a lot of work of the companies, although for some companies the historical material legacy has facilitated the creation of flexibility. If a company has a large main system, an aqueduct for instance, it is easier and cheaper to move water around than if a company abstracts water from a large number of separate boreholes. In some cases operational flexibility may not be feasible, for example in an area where few sources are available and/or where the work that has to be carried out is considered too costly. Then a solution may be to buy partially treated water from another water company. This is a point where the difference in quality standards between companies becomes visible:

> We now buy our water supply in from [name of company] which has an aquaduct here. We buy partially treated, well, we call it partially treated, [name of company] call it treated, but we have different approaches to quality standards. (...) We take the view that, if your standard for colour is 20, [name of company] would say 19 is ok. We would say 5 is our target, because we don't want there to be a problem in distribution. So, we keep a bigger safety margin which costs us resources in terms of treating it, [but pays off] in terms of the quality performance that you see both at the works and in the distribution system. [five years ago] you looked at their annual water quality report compared to ours and the number of failures they were having for iron, turbidity, bacteriology in distribution and at customer's taps is much higher than ours. And that's about how much are you prepared to pay to get that little extra, treatment and quality. (Oliver)

In chapter 5 it was suggested that the regulatory standards here mobilise other forms of the standard or other standards to assure the quality of the water, especially for regulatory purposes since it can be argued that some of the same standards are not directly health-related.

However, every time I came across this in interviews, it was always the company for which the person worked that had higher water quality standards. None of the respondents ever mentioned that water they bought from another company was treated too much. The standards are mobilised by companies to make their company look better than another company.

If a drop of water has gone from the source, through the distribution network, it ends up at a treatment plant. Treatment plants are developed to treat certain types of water with certain qualities on certain scales. Surface water will therefore be transported to a different treatment plant than groundwater. Often large-scale water supply systems rely on surface water and small systems on groundwater. Groundwater usually needs less treatment, because the ground has already filtered it. For groundwater and surface water the treatment thus has to focus on different parameters.

> Surface water normally requires chemical coagulation to eliminate turbidity, color, and taste and odor producing compounds, while well water supplies are commonly treated to remove dissolved minerals, such as iron and manganese, and hardness. (Viessman, 1985: 351).

In 6.2.2 we will see how a drop of water that came from a selected raw water source and has gone through the distribution network to an appropriate treatment plant, goes 'on a journey' through a treatment plant. This particular treatment plant was developed for surface water.

6.2.2 Treatment plant

> Heavily secured entrance: double iron gate, cctv cameras. High fences all the way around. Hard to find a way in. A voice was talking to me and it took me a while to figure out that I had to open a box next to me, press a button, before I could talk to the porter.

This is a little extract from my fieldnotes. The entrance was built for people who came by car. From inside a(n English) car it would have been more obvious that the little box on the side provided a means of communication with the porter. For a foot-passenger, the cameras and 'talkbox' could have been anywhere. In fact the camera was hidden inside a black bulb and the porter told me later on that only by putting my hand on the bulb (I was wondering if the sound came from there) he realised that someone must be at the entrance. When I spoke to that last person at the treatment plant that day, I told him about my little adventure to get into the site. He said he had never walked out of there and suggested I would wait for him to get into his car with him to get out.

For visitors, especially without cars, the treatment site comes across as a very restricted site. That I had gained access to the site, did not mean that I could directly observe the treatment process. Much of the process goes on inside buildings or underground. Only electronic cards supplied to the people working at the site provided access to the buildings. For the water that is going to be supplied to the customers, there are no such obstacles. Water does not have to plan its routes, buses, time schedules, and does not need special security cards to enter the various treatment processes. It does not have to negotiate access. In fact, the water, defined as a substance of a certain purity, is the only substance that is supposed to get through the treatment process without any restrictions. The 'impurities' the water carries with it should stay behind at various stages of the treatment. All pipelines from raw water sources lead to a treatment plant or another form of treatment. To use Latour's notion, the treatment plant is an obligatory point of passage for water that is to become drinking water. He (1993: 44) described that, 'depending on its equipment, the enemy cannot get through everywhere'.[1] The water companies thus have to focus their attention on the specific enemies and lead them through an obligatory point of passage where the enemies will be 'crushed'. In the past, there was one main obligatory passage point according to my respondents and that was filtration. The treatment plant I focus on here stems from the 1930s according to Jack. In the 1930s many slow sand filters were used. Over the last twenty years the treatment plant has 'got bigger, more evolved, it's more complicated, so it's more stages of the process removing all of the unwanted bits' (Jack). However,

[1] Latour took the notion 'obligatory point of passage' from the army and uses the quote above to describe the relation between microbes and hygienists. Also see Latour (1997) for information on obligatory points of passage.

respondents with whom I discussed the historical development of treatment processes thought the treatment process itself had not changed extensively.[2]

> I think that the basic principles probably haven't, but you know the way in which we do things has, and the chemicals that are available, the better control of the processes, but the basic principles are no different than they ever were, although probably we've added some. (Samuel, WQM/251102)

The largest part of this particular treatment plant was built in the 1980s before privatisation. Small adjustments were made after privatisation, although the changes cannot be ascribed to privatisation as the previous chapter argued:

> Fifteen to twenty years ago the plant was open and there were no roofs. If there was sun, algae were growing. Birds could come in, wind could upset the process. After privatisation roofs were built. (Peter, MWS/140403)

The treatment plant has been built and the water can be purified. Therefore I will now turn to the route a drop of water follows through this water treatment plant. At various places enemies meet obstacles that stop them from getting through the treatment process. This means that the water, now the treatment plant contains more stages in the purification process, goes through multiple obligatory points of passage (Latour, 1993: 45). Every point is designed to remove one or more substances and, as we will see, the points have to be set up in a specific order.

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[2] When I wanted to look into the history of treatment processes, I encountered a problem. I could not find sources that describe or construct a history of water treatment processes and bookshops and libraries do not keep books about treatment processes of a hundred years ago. I am also not aware of an archive that collects documents on water treatment technologies. Samuel suggested the following: 'probably the only way you'll see that, the way things have changed is, you know, through various don't want to call them textbooks, but various books on water treatment processes, and you know, looking at what is effectively the new processes. And comparing what was there 25 years ago which was probably, if it was a surface water source, it was clarified and filtered, settled, clarified, filtered and chlorinated. But if you then look at the modern day process, just in operation. I mean the easiest thing for you to do probably would be to visit your nearest company and just talk to somebody who has been there a fair while and look at the sort of process that they may have on a fairly comprehensive large surface water abstraction and compare that just by asking somebody who is suitably long in, you know, what they can remember of 25 years ago'.

The water that arrives at the plant is semi-treated. It has been led through rough filters (mesh screens) to remove unwanted large bits in the water (sticks, water weeds, and as a WaterCo brochure says 'other large foreign objects'). These bits are clearly seen as out of place. They may not necessarily be regarded as contaminating the water, but would make it impossible for the water to follow its journey through the treatment process and distribution network. Also fluoride has been added to the water before it arrives at the treatment plant.[3] The water has been identified as water that does not need to be treated for *Cryptosporidium* or pesticides.

I was told that when the water comes in, it is very important to make sure that the pH is correct, otherwise the next step, coagulation, would not work properly. Here it are not the standards, but parameters that can have a knock-on effect on each other. The pH is therefore adjusted by adding lime (or lime slurry: $Ca(OH)_2$) which raises the pH level. Then the coagulant is added. Coagulation is a much less obvious process to the observer than the removal of large unwanted bits with help of mesh screens. Walking around the treatment plant, I saw three large tanks in which the water was moved around at different speeds. The water looked brownish and nothing like the water one gets from the tap. Inside the building next to these tanks were a number of other tanks in which the water looked even more 'dirty'. A layer of greyish and brownish substances floated on the water. In the room next to these tanks, a number of instruments were attached to the wall. These were the instruments that dosed lime and the coagulant. However, walking from outside to inside the building and seeing the different areas in the building, did not give an obvious story away about what was happening here. Whether the different tanks were connected and whether they were then in turn somehow connected with the dosing instruments could not be observed. If there were a connection between the tanks and instruments, what would be the order? Would the water start in the tank inside where it looked most dirty and move then from the tank in which it was moved around slowly to the tank in which it was moved around fast or the other way around? The material environment left me with a number of possible interpretations. In order to understand the process as the people working at the treatment site understood it, I had to rely on the narratives of the people I talked with. However, these narratives were also complicated and not easy to understand for an outsider. Therefore, I also had to enter the world of chemistry. I used a chemistry dictionary, two 'popularisation of chemistry books', a book on water supply and pollution control, and several Internet

[3] See chapter 2 for a discussion on fluoride as being 'in' or 'out of place' in drinking water.

documents to get a slight understanding of chemical processes that relate to the making of drinking water. These sources, although they should be regarded and analysed as documentary resources (see chapter 4), were mainly used as background information. This is possible, because these sources refer to general knowledge of chemistry to which also my respondents refer. Chemistry education will mainly be based on this generally accepted knowledge. I have not encountered any controversies about these general processes of chemistry. To understand water treatment processes, I also used several overviews and diagrams of these processes from the Internet and brochures from water companies. A diagram (and thus representation) of this particular water treatment plant was used as the basis for the interview with Jack.

So, how can we understand the treatment process? Back to coagulation. Coagulation is used to remove other unwanted bits in the water. However, these bits are not only bits that are regarded as 'foreign' to water; the process is also meant to eliminate turbidity and colour from the water. This part of the plant was built in the 1980s. Before the 1980s, there was nothing in place to remove colour:

> Nothing used in this process to remove the colour. So, it's a very tinged, orangy colour. And then as the years have gone on, that becomes unacceptable to the customer and the rules change and you build a plant. (Jack)

The turbidity can have been produced by the following substances: colloidal solids, clay particles, organics, bacteria, and algae; and colour in surface water, which result from decaying vegetation or industrial wastes (Viessman, 1985: 371). Colour (and turbidity) can be seen as an actual characteristic of the water and, as we have seen in chapter 4, it has different meanings in different cultures. Colour cannot just be filtered out of the water, because it is 'part of' the water. Whereas this colour of the water is perfectly acceptable and thus in place in rivers or groundwater, it is not regarded as tolerable in a western drinking water supply. Although this part of the treatment plant does not form an obstacle for water as such, it is a specific type of water that can move through the coagulation process. The water loses a bit of its identity as surface water here (its colour) and has started the process of becoming drinking water. The only way in which the water can now be referred to is water that is becoming. It does not fall into any other classification (untreated, treated) and it cannot remain semi-treated. The flow in the treatment plant and the pipelines that connect the different parts make sure that there is no way back. The coagulation process mixes the coagulant in the water. The coagulant used at this plant is ferric sulphate ($Fe_2(SO_4)_3$).

> Advantages of the ferric coagulants are that (1) coagulation is possible over a wider pH range, generally pH 4-9 for most waters; (2) the precipitate produced is a heavy quick-settling floc; and (3) they are more effective in the removal of color, taste, and odour compounds. (ibid.: 373)

In 1985 Viessman wrote that because of the complex nature of coagulants reactions, chemical treatment of water supplies was primarily based on empirical data derived from laboratory and field studies. Only in the few years before 1985 a considerable amount of research has been directed toward gaining a better understanding of coagulation mechanisms. What to use as a coagulant and how to use it depends on chemical characteristics of water, pH and temperature:

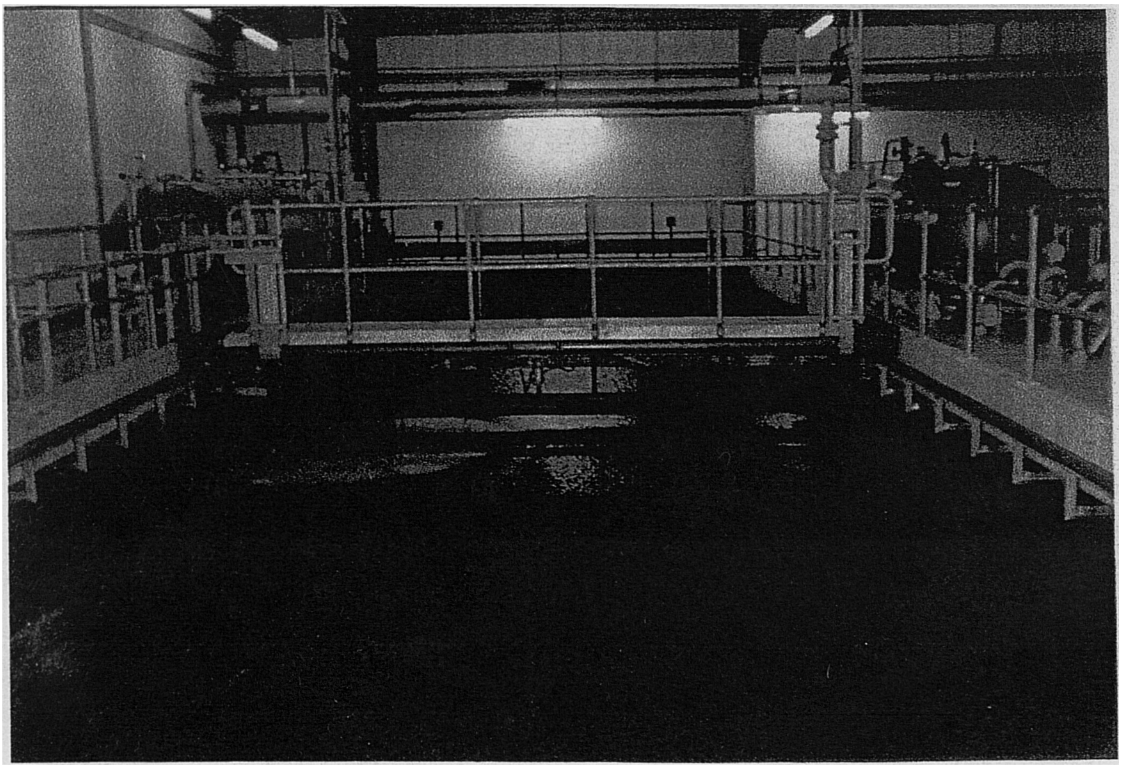
> The most widely used coagulants for water and wastewater treatment are aluminium and iron salts. The common metal salt is aluminium sulfate, which is a good coagulant for water containing appreciable organic matter. Iron coagulants operate over a wider pH range and are generally more effective in removing color from water; however, they are usually more costly. (ibid.: 371-372).

The coagulant makes colour and dirt particles stick together in what is called a floc particle. In the first tank the water is moved around fast to mix the coagulant in the water which will result in the first floc particles. The next tank moves the water around slower to prevent the just formed flock particles to break up again. In the third tank the water is moved around yet slower.

Original in colour

Photo 6.1: Entering the treatment plant: security and data information

Photo 6.2: Scraping off the dirt: 'manufacturing' drinking water



From here, the water goes to the concrete tanks inside the building where dissolved air flotation takes place. Pressurising pumps under the tanks release compressed air into the water in small bubbles (as if one is opening a bottle of mineral water). The bubbles attach themselves to the floc particles and take them to the surface. The sludge floating on the top (sludge blanket) of the tank will get thicker, heavier and denser and will, at some point, start to sink. Materials that were in the water or even part of the water now float on the liquid surface and are not part of the water as it came in anymore. Before the sludge starts sinking, it has to be scraped off the surface to go to the sludge holding. Every three hours or after a certain volume of water has passed, the scraper does its work. Like the coagulant that needs to be added, also this part of the treatment process depends on the materiality of the water.

> Here, because the water is what is called 'thin', so it is high in colour, low in turbidity, you try to push the suspended solids to the top and then scrape them off into the dissolved air flotation. (Jack)

The treatment process is structured in a specific way that allows the different parts of the process to relate to each other. The mesh screens could not have been placed at the end of the process because, as I said above, the large 'foreign' objects could block the rest of the system. The mesh screens are therefore a first obligatory point of passage: they allow the water to go through the process that will make it into drinking water. Coagulation and dissolved air flotation can be seen as the second obligatory point of passage for the water in this treatment plant. Before the (optimum) coagulation can take place, the water has to be softened. Like colour, the pH can be regarded as a characteristic of the water. The hydrogen ion activity is expressed by the term pH (Viessman, 1985: 356; Kijk, 1983 [1981]: 181). However, this hydrogen ion activity seems easy to shift:

> The chemical equilibrium of water can be shifted by changing the hydrogen ion activity in solution. Thus pH adjustment is used to optimise coagulation, softening, and disinfection reactions, and for corrosion control. (Viessman, 1985: 356)

Controlling the pH is thus used to facilitate other parts of the treatment process. If the pH is not right, it might have an adverse effect on the rest of the treatment process. Changing this characteristic of the water could be seen as an obligatory passage point for changing other characteristics of the water (like colour). Coagulation would not work (well) without first having changed the pH. The water quality regulations have a minimum and maximum standard for pH. However, the treatment process does not try to achieve the standard for pH until the end of the process. Whereas treatment for many other standards is organised in such a way that the water complies with the standard immediately after it has passed the specific obligatory point of passage for that standard, this is not the case for pH. It seems that pH is easier to change than many of the other standards and that, unlike many other standards, it has become very important for operational control. In order to be able to treat the water up to the water quality regulation standards, operational control standards have to be developed. At different places in the treatment system, the water is softened or hardened to a certain degree to be able to comply with the other standards. The change in pH makes coagulation much more effective. Jack described coagulation as the core of the treatment and thus the most important obligatory point of passage:

> If that goes wrong, then the soluble irons will be high and we would fail on the final water. So, once it's gone passed that stage, there isn't a lot else that will [take it out]. You have to make sure the dissolved air flotation is working well.

Coagulation was not just regarded as the core of the treatment, but also as a piece of equipment that is very expensive and unique to the water industry:

> I am not aware of other industries that would use dissolved air flotation. It's generally settling tanks and things like that. So, this is quite electrically intensive, stirrers and the compressors and the circulation. Of all the site, this is probably one of the most expensive parts of it. (Jack)

After the dissolved air flotation, two chemicals, chlorine (Cl_2) and carbon dioxide (CO_2), are added to the water. Like the lime, these chemicals are added to remove other substances from or characteristics of the water. In descriptions of treatment processes, the substances in the water that are removed are often referred to as 'impurities' and 'foreign objects' of which it is obvious that they should be removed. The dosing of chemicals is phrased in very different terms. In their brochures companies give an impression of being very careful with adding chemicals to the water[4]:

> We add a precisely controlled amount of a coagulant like ferric or aluminium sulphate.
>
> We add a small, carefully-controlled amount of chlorine to make certain that the water is disinfected.
>
> A small, controlled amount of chlorine is the most effective method, and provides essential customer protection.

They are careful and what they dose is necessary to produce good drinking water quality. Often it is stated why the chemicals are necessary, whereas it is not explained why something counts as being impure. Carbon dioxide is soluble in water and is used for recarbonation of the water. The chlorine starts to disinfect the water, but also oxidises iron and manganese. The water then goes into holding tanks before it moves on to the sand filters. These can be regarded as obligatory point of passage number three, after the mesh screens and coagulation/dissolved air flotation. The sand filters are tanks with silicon sand of a certain grain size. It allows the water molecules to pass through but no dirt particles. Some sites use slow sand filters which is regarded as good and simple treatment, but it is very labour intensive and requires a lot of land. On this site rapid gravity filters are used and there are forty tanks. The rapid gravity filters work as follows: the force of gravity, together with a combination of 'positive head and suction from underneath' moves the water downwards through the media that collect the floc and particles. Every six hours or when the flow reduces too much a backwash is done, using compressed air. This is blown up the sand and loosens the dirt particles that are then washed away. The chlorination and filtration is a step that cannot be placed anywhere in the system. Coagulation and dissolved air flotation had to precede to control the turbidity:

[4] For reasons of anonymity of the companies, I cannot reference the reports. The reports have been published and are publicly accessible, yet WaterCo suggested leaving out the names of

> Destruction of bacteria and viruses depends on satisfactory turbidity control to enhance the efficiency of chlorination. (Viessman, 1985: 324)

After the filtration, the water goes into two contact tanks where free chlorine is added. The treatment process is so designed that organics have been removed at this stage to prevent the formation of chlorine by-products. The water stays in the tanks for about 45 minutes, depending on the flow through the works and the chlorine has time to react with bacteria in the water. This is obligatory passage point number four and will help the water to comply with the bacteriological standards. Some chlorine will be used up, some free residual will be left over. If the free residual is greater than what needs to go to the customer, sodium thiosulphate ($Na_2S_2O_3$) is added. This dechlorinates the water. Like pH, the amount of chlorine is easy to control as well and varies at different points during the treatment. In the contact tanks also phosphoric acid is added. This lowers the pH and is for plumbosolvency. A chemical reaction takes place and the pipes are coated, so no lead can get into the water. This is the newest part of the treatment plant and leads to complex negotiations with regulators as we saw in chapter 5 and to discussions about whose responsibility what water is, as we will see in section 6.4:

> That was December last year. It was to comply with the old standard, lead is going down to ten, so it is to comply with the, what the DWI do, is: they come along and say: 'oh, you are breaking the lead standard. You have two years to get there'. So, we have to put a plant in to get to that, otherwise you get prosecuted, we don't need that. So, the company as a whole has put in plumbosolvency plants all around the company. I'm not quite sure the company's [procedure] long term. They may go to the regulator and say: we need 50 million to remove all the customers' lead pipes. [WaterCo] have removed theirs. But the customer hasn't, it's measured at the customer's tap.

Phosphoric acid is not regarded as a substance that forms a risk to human health: it can also be found in coca cola. However, that is not the case for all added substances. Sometimes added substances can have unwanted effects. We have seen in chapter 5 that this was the case for the by-products (trihalomethanes) of chlorine. The European 1998 directive has incorporated this. Similar things can happen with other

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these companies.

parameters that need to be controlled, for example bromite. At some plants sodium hypochlorite (NaClO) is dosed. This is used for disinfection. However, it contains high bromite. There is a substitute which is low in bromite, but that is two or three times the cost. The company then has to decide whether the level of bromite is still far enough under the regulatory standard, whether they want to pay more or will look for an alternative way of disinfecting the water.

After the contact tank the water goes in the mixing and pump section tank. Either it is pumped to the customer directly or it overflows into pure water storage tanks. 40% of the water is pumped to the customers, for 60% gravity is used.

We have seen a few regulatory standards cropping up (colour, turbidity, and bacteria). These substances are (to a certain degree) removed from the water at specific points in the treatment plant. I called these points obligatory points of passage. Some parameters that can be found in the regulations are not relevant here, because they do not occur in the raw water or in a very limited amount. The treatment plant demonstrates this, since the special treatment technologies needed to remove certain parameters has not been installed. For instance, many companies that use surface water installed Granular Activated Carbon (GAC) stages at treatment plants to remove pesticides when the English 1989 regulations came in.

But where are all the other parameters that were not allocated a specific obligatory point of passage? Many parameters do not have a specific passage point. They are believed to be removed throughout the treatment process as a whole. We can thus see that the treatment process focuses on a few key parameters, whether these are regulatory or operational or both. The enemies of drinking water are only partly determined by regulatory standards in a treatment plant. Operational standards play a crucial role too.

The whole process is subject to broader quality assurance in several ways. The plant is large, but normally only operated by six or seven people. The number of people has been reduced over the last twenty years because the technologies have become more reliable and many of the technologies have been renewed and therefore need less maintenance (Peter/14042003). Most of the treatment process is automatic: water moves from one place to another, sludge blankets are removed, backwashes are done, and substances are added to the water. Sodium thiosulphate is an example:

> The issuer reads the chlorine, sends a signal to the pump and it increases or decreases the amount of chemical (Jack)

Sampling of the water is one means of quality assurance. Like most of the treatment process, this is primarily an automatic process. Automatic –and operational, not regulatory– sampling takes place at several points during the treatment process: at the raw water, dissolved air flotation, pre-filtration, post-filtration, pre contact tank, post contact tank and at the final water. The instruments sample every ten or fifteen minutes and the results come in at the computer in the manager's office: 'this just takes all the reagents and turns them into a graphical format' (Jack). The manager can look for an overview of all parameters or trends for specific parameters. In the past many tests were done manually, but that is not regarded as necessary anymore:

> The frequency has reduced in terms of the manual checks, cause the actual online monitors have got more reliable, so that the monitors, the information we are getting now from looking back on historic data, the information is a lot more reliable, so now we do fewer on-site tests unless it's a real, critical part of the process. And then you go through a risk assessment side of the frequency. So, you don't just think: oh, I won't do that anymore, you follow a documented procedure to determine the risks and the reliability of the instrument and then that determines whether we do an on-site test or rely on the instrument. (Jack)

The instruments have not replaced or changed the parameters that are monitored according to Jack:

> It still measures the same things, it's just it's more reliable. It's, you can depend on it a lot more.

The reliability of the instruments was an issue that was often referred to. At the treatment site, the instruments are checked up on their reliability and backed up by both other instruments and manual checks:

> Some of the equipment will be, what is called [validating], so you'll have three instruments measuring one sample. So, if one of those instruments fail,

> you still have two other. So, the reaction for that one failure isn't as crucial or critical if all three failed. If all three failed, then you are not measuring that process 24 hours a day. If one or part of it fails, you are still measuring it. Depending on the instrument is the criticality of what part of the instrument fails or isn't correct, is how you respond. Basically, if the whole instrument failed, you would go back to do more frequent on-site tests. (Jack)

The people working on the site check whether the instruments are working correctly by taking manual samples. They do this once a day or once a shift, depending on how critical the process is.

> All you do is go and take a manual sample, get a reading, compare to the monitor and then the rest of the time the monitor just ticks away. (Jack)

Chlorine and pH were particularly mentioned as crucial steps in the process. Chlorine is seen as crucial because it disinfects the water. The fluoride monitor at the end of the treatment process is also considered important. As we have seen earlier, pH is crucial because if that is not correct at the beginning the final water could contain high soluble irons that are not taken away by the rest of the treatment process. Also the pH on the final water is seen as vital, but also here this is not for regulatory reasons.

> The final water pH or pre-contact pH is crucial to make sure that we'll put in the correct pH out to the customer, so that it's not as acidic or not too alkaline, so we don't basically destroy all the fittings or deposit too much scale on the pipelines. (Jack)

The operational samples, unlike the regulatory samples are thus tested on the site and can send results immediately to the computer of the treatment manager. The immediacy is important and the accuracy of onsite tests is perhaps regarded as less important. The results of the sample analyses would not be accepted by the DWI for a regulatory sample, since the analyses are not subject to the same degree of quality assurance and good laboratory practice, as for instance accredited laboratories would. Yet, as Jack mentioned, the company still uses risk assessments and company protocols –that are in principle auditable– to determine the reliability of the tests and the frequency with which they have to be done. The accuracy of the tests is ensured by means of –more trusted– manual samples.

In addition to the monitoring of instruments and the checking of the reliability of the instruments by other instruments and manually, several points in the treatment process also have alarm bells. If something starts to go wrong, the alarm will signal that immediately. People then have the opportunity and the time to correct that what is wrong before the final water will fail. The alarms give pre-warnings of possible failures and therefore use standards tighter than the regulatory standards.

One way of assuring the quality of the water has always existed and is still important. In the era of automatic processes, automatic sampling, and complex and advanced treatment technologies, smelling the water is still crucial. The treatment plant I visited had an instrument called the smell-bell. In the instrument the water is heated up and sprayed and the odour magnified by a thousand times. The treatment workers are trained in how to smell and every two hours someone smells the water. Someone asked me to do the smell-bell test. He remarked that the water smelled very earthy, but that nothing seemed to be wrong with it. He did not smell any diesel or anything like that. I did not smell anything and could not even say that it smelled earthy. Just like only observing the treatment plant did not provide much information about what was happening at the site, smelling water may not provide much information to an untrained person. The smell-bell test does not look for any particular regulatory parameters. It looks for unusual smells which may or may not be related to regulatory standards.[5]

> With the taste and odour test that we do every two hours and magnified by a thousand times, you pick up most, a lot of things. (Jack)

As we have seen, a lot of back-up checks are in place to see if the treatment process works and if it indeed manages to provide a good quality water that complies with all the regulatory standards, whether or not these have a specific obligatory point of

[5] Chris explained that 'the only sort of new contaminant that's been an issue in the last few years is MTBE [methyl tertiary butyl ether]'. MTBE was used to replace lead in gasoline, but then contaminated the water. In California there were a lot of problems, but in the UK the amount of MTBE used is much lower and the UK standards for storage tanks and garages are much stricter than in the US. He argues that, in addition 'fortunately the substance can be detected by taste and odour at concentrations well below anything that's got a health effect, so you've got a safety factor in there'. The smell-bell is important to detect substances like this that are not otherwise measured.

passage. These back-up checks are not defined by national regulations or associated guidance, yet they can be considered as a support system to ensure compliance with the regulations. In the words of Lewis (WQM/181102):

> There are no regulations saying that you should measure raw water, but you cannot treat a water without knowing what is in the raw water to treat. So, we tailor our treatment requirements, analysis requirements of raw waters very much to the types of water it is.

However, what happens if something does go wrong with the treatment process or if there is an unknown substance in the water that may be harmful?

The treatment process is designed to routinely remove known elements from the water. If the raw water does not contain pesticides or *Cryptosporidium*, there is no stage in the treatment process that will remove those. In that case also the monitoring for these substances is less frequent. An unknown substance is thus not automatically picked up.

> You are hoping that it will be something that affects other parts of the process. So, if you see some dramatic changes in other parts of the process, then you start looking. But we would rely on, we don't have a raw water monitor that looks for everything. But most things will possibly have an odour to them. (Jack)

The smell-bell test is thus crucial. Although it is perhaps the least complicated and technical test, this is one of the few places where unknowns might be picked up on. Unknowns may also be detected if they affect conductivity, chlorine levels or other parts of the treatment process. In those cases, (manual) samples have to be taken and the unknown has to be traced back to where it comes from. I will give an example:

> There was a chemical that went in at the last work into the river and that gave a cabbage, a very low concentration to get a very strong cabbage odour, so you could pick it up. We didn't know what the chemical was, but we knew that that wasn't the norm, so basically you stop taking the water out of the river, get a sample, send it off to the labs and then they look for all the

> obvious things. And then the EA [carry out surveys] when they go through all the people that hold chemicals upstream and check whether they've had a spillage, check their drainage, the drainage and things like that, and then we trace it back that way. (Jack)

However, if someone spilled something in the water, this person or company has to contact the Environment Agency which will then issue a notification to the water company saying what and how much of that substance has been spilled in the water. However, Oliver, in his commentary on this text, argues that WaterCo, like other companies, cannot rely on this happening in all instances. WaterCo therefore ensures that the procedures are robust enough to cope with this eventuality. Much is done to prevent unknowns being encountered. Regular sampling will detect any trends in increasing 'natural' substances (for which one samples of course) and the environment agency will be informed about man-made contaminants. The EA also has its own sampling program to measure the quality of the raw water sources. This too may sense substances in the water that were not 'supposed' to be there. In the words of Catherine (WQM/110401): 'The more farmers you have got, the more pesticides you have'. The environment agency samples for some different substances that the individual water companies might do. In this sense, the wider environment of other agencies measuring water quality provides quality assurance as well. WaterCo together with the EA takes a more proactive approach to water pollution as well: catchment management.

> The manager up in [place of water source] keeps an eye on what is going on, he knows what farmers are there, what chemicals they use. We have a policy that's called spray-safe, so [WaterCo] go out to them in conjunction with the environmental agency and say: use this chemical if you are going in to kill weeds and dump your (sheep) here and things like that, and store all your chemicals in a safe way. (Jack)

Yet, if something that may form a risk to public health has entered the water, a company may decide to stop the intake of raw water. Stopping the intake of water is a decision the company's director has to make together with the health authorities if the decision meant that customers would be deprived of their water supply. In most cases stopping the intake for a limited period of time is sufficient to let a chemical go by; the vast majority of these intake stops can be decided locally because they have no impact on the customer. Bill explains how such a decision process works:

> If the water quality of the raw water is of a reasonable quality, then the plant controllers can take it on to the plant and then they can treat it. But if it starts to go outside the range of quality that is acceptable to them, they then have to refer the decision to their manager and then if it goes outside of range for him, he then has to refer it either to the water quality department or to his senior manager.

A few examples illustrate when companies stop the intake of raw water:

> You can have deterioration in the raw water, probably over a very short period of time. And it could well be that you would look at it and think: 'well, rather than take a risk with that, I might shut my intake at the treatment works and then reopen in six or eight hours or whatever'. You know, those sorts of things do happen. I think most of us will experience that. (...) You can have a specific incident if you like or a specific pollution of a surface water source that, yeah, you would shut the intake. (Samuel)

> We have on our treatment works at [name of place] and what we do there is we abstract from the river into a bank side storage reservoir that gives us security and then take it on to the plant. But we have done, after floods for example, when the colour and turbidity of the river water have got very high, we stopped taking it out of the river and used our bank side storage and then replenish that from the river when the quality is improved. (John, WQM/271102)[6]

> Our treatment works have actually got alarms on them which would stop water going into supply if the disinfection fails, so it shuts the plant out. (Martha, WQM/040202)

[6] John adds: 'What we'd say is that we could always treat it, but it would be a) very expensive to treat and b) we might not be able to treat it at the highest flow rate. So, I would say, it is never too bad to treat, but sometimes we would choose not to take it, because we'd rather not.'

When the company stops the intake, it has to keep sampling and as soon as the chemical has passed, the abstraction can start again. The treatment plant I visited at WaterCo had a storage of clean water that could provide the population it served with water for about a week. After this time, a risk assessment would have to be made: how harmful is the chemical as opposed to how harmful is it not to provide people with water. In some cases parts of the plant will shut down automatically, for instance if the chlorine goes out of range or when a low nitrate source fails where it is blended with a high nitrate source. The technologies will ensure that water that exceeds standards for these parameters will not be distributed to the customers. In these cases, it is a manager's decision to turn the plant back on. The manager will rely on an emergency procedures manual.

Sometimes the automatic or manual samples show that there is something wrong with the water. If the manager sees on the monitor that the final water has a high level of turbidity, he will try to find out what happened or is happening:

> Somebody might have turned the sample tap on very fast or some maintenance may be looking at that meter which it could have been carborating it. What you can do is then go look onto the computer (...) the electronic log for all events and see whether maintenance were working on turbidity. (Jack)

If a peak is noticed in one of the graphs, someone has to go and check, 'you can't just ignore it' (Jack). However, not every peak means a failure of the system or a standard. Peaks can often be explained by referring to the 'normal process' or necessary maintenance work.

> From experience you know that perhaps if a filter washes, the pH might [spike] for a while, for 30 seconds. If that 30 seconds goes on for an hour, then there's something is wrong, so they would go and look at it. (Jack)

As long as one knows what is going on at the site and can explain what is happening, a thirty-second spike does not have to worry anyone. If the peak, or an alarm for that matter, would go on for much longer than can 'normally' be expected, the treatment manager is called to have a look at it. Procedures are in place to help people to deal with this.

> The procedures might say: leave it for 30 minutes, if it's failed after, still there after 30 minutes then do A, B, C. (Jack)

Even if a peak appears during a long duration, the seriousness of the peak depends on where in the process it takes place. If there is a mid-process error, peaks in themselves may not be regarded as very serious, because the water may be blended and the failure may not appear in the final water. However, if a peak appears on the final water, the company is not complying with the regulations or may be supplying unwholesome water. The reporting procedure of the treatment plant to the water quality department of WaterCo depends on the process time. If it is found that there is high iron on the final water for ten minutes and the process time is ten minutes, no notification is necessary. If the high iron would go on for about two hours, the treatment plant would have to contact the water quality department. This department would in turn assess whether the DWI should be notified of the case. The procedures for notification to the water quality department differ per parameter. For some parameters a longer duration of 'failure' is acceptable than for others. Jack states: 'If something went wrong on the dissolved air flotation, we would want to do three plant samples to find out where the soluble aluminium has got to'. The need for notification also depends on the stage of the treatment process. In short, the importance of failure and thus the necessity of reporting within the company depends on the duration of the failure, where in the treatment process it takes place and for which parameter. If a failure is considered serious, measures will be taken to rectify that what went wrong. This may mean work in the distribution network, chlorination of reservoirs, or advising customers to boil the water.

The 'failures' are not so much identified by the UK regulations or the EU directives. Rather they are identified with help of local, company specific procedures and company standards. The company standards are stricter than the regulatory standards. This gives the company time to sort out a possible problem before the regulations are breached. The people working on the treatment site are not expected to know the regulatory water quality standards by heart. However, they get a feel for the ranges within which the different parameters are and know where to find the information that tells them what to do if something goes wrong.

> We have all the quality procedures. If the pH goes, the pH would be 6 and it goes to 7,5, there is a procedure that tells them what to do, who to report it to, it requires reporting. (Jack)

They are helped identifying when something goes wrong and thus exceeds a WaterCo standard by the monitors and alarms. Through these technologies and the many procedures that have been developed around the regulations and specific WaterCo standards, the water quality standards do not have to be remembered:

> It's all set up on the [computer], so if whatever we need to measure to comply with the standards, it's all in the system and all the procedures, so we don't need to look for arsenic when we don't look for arsenic. If arsenic was a problem, that would be in the tests and that would be the procedure, the monitoring would be there. But we don't look for, we don't need to. (Jack)

If there would be an arsenic problem, samples would have to be manually taken every half an hour until the right equipment would come in. Automatic sampling takes place only for those parameters that are expected in the water. Jack states that everything goes automatically, but 'if something has a little hiccup, then there is a bit of manual intervention to go and sort out the problem'.

A translation and in the words of Latour (1997) delegation has taken place from the national (or European) regulations to localised procedures and from written maximum standards to technologies that 'warn' when the material does not comply with these standards. This translation to localised standards and materialised policing of these local standards can go even further. The company standards become localised differently at different sites:

> A lot of the sites will have different target ranges, they still work to the same regulations, but their target ranges might be different, at some sites slightly tighter than others. (Jack)

The localised target ranges are adjusted to the materiality of the water. If the water for instance has a relatively high level of nitrate, but is below the regulatory standard, setting a target range that will never be met is considered unnecessary.

Not only the regulations are 'unstandardised' at local sites, also different treatment plants look differently. The treatment processes are similar at different plants and have not changed much over time as we saw at the beginning of this section.

> A lot of it is you float it or you sink it, you add a chemical and give it a stir, it's all very similar. (Jack)

However, the treatment processes have to be adjusted to the quality of the raw water. The items that were found in the water and the levels of these items determine what sort of treatment is needed (membrane filtration, clarification, disinfection by ozone, contact tank, activated carbon). The relations between the quality of the water and the treatment processes are summarised in a matrix, as Jack explains:

> So basically, you start off with your raw water and then the matrix says: this is [how] you need to treat it.

It is not just the raw water quality that leads to diversity in treatment plants. This diversity of plants was subject of discussion during a meeting when I visited the treatment plant. I attended this meeting which was organised to discuss how WaterCo could become one of the 'best' water companies in England. One aspect of the meeting was to try to identify problems that occurred in the company. The attendees were split up in groups and had to discuss how people could do their jobs as badly as possible. The question then was which of the problems they had identified were real problems. Two women of whom one was a secretary, about thirty treatment maintenance men in blue WaterCo uniforms, and a few managers who were wearing suits attended the meeting. One of the problems the maintenance people encountered was the lack of standardisation of treatment plants. People complained that the pumps and treatment technologies are all different.

> If you come to a plant at night, you can easily spend the first few hours trying to find things. Maybe with help of a drawing, but following a drawing is quite difficult. (One of the maintenance staff, 140403)

Even if treatment plants use exactly the same treatment processes, the actual technologies and instruments used on the site may differ.

> You go to site A and the pump is stop-start, stop-start. You might go to site B and the pump operates in a totally different of way, it's a different made of pump, nothing looks the same. (Jack)

Regulations of the European Commission have specified that a company cannot specify what make of pump it wants, only what the pump should be capable of doing. They then usually employ a main contractor that will have a small sister company that specialises in water treatment.

> [WaterCo] writes a document and says: 'this is the raw water we have, we want it to this quality, you provide the equipment with these processes involved'. And they go away and sort the equipment. And come back with the best price. (Jack)

If it is a different contractor for the different sites, one can also get different manufacturers. In this case regulations, although they apply to all companies and all EU countries, generate diversity rather than standardisation.[7] It is therefore important that the people have received sufficient training.

> There is a procedure that we follow to make sure they are trained and competent, so if something goes wrong we can prove that they were trained and they were assessed. (Jack)

The procedures and proof that people have been trained are very important with regard to the regulations. In case something would go wrong at the treatment plant, procedures and training are evidence with which the company can attempt to prove to the DWI that it has done everything possible to prevent failures. The company can then not be accused of negligence. I will come back to this in the next section.

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[7] This makes local work more difficult. The managers could not say that the principal design of the different plants would become more uniform in the future. However, they hoped that in the future, the maintenance people could plug in their laptop at any treatment plant and get information about the specific treatment plant.

I have shown that most water quality standards remain relatively invisible during the routine treatment process. The treatment process has different obligatory points of passage and identifies a few key parameters. These are mainly the substances that are added to the water, rather than the ones being taken out of the water. The order of the process is very important, because the various stages of the process and chemicals used and in the water affect each other. The standards and regulations become more visible when something goes wrong in the treatment plant. When something goes wrong in the catchment area or during the process, it becomes important what one identifies as a failure. A failure is not as straightforward as not complying with the standard, because it depends on where and when in the treatment process it occurs and which parameter it applies to. It becomes clear that the national regulations do not play a direct role in the treatment plant. The regulations have been translated into and their enforcement delegated to localised documents (procedures) and material objects that help police them (alarms, monitors).

The treatment works are well protected and quality assurance systems are in place; the biggest risks to quality is the distribution network. The drop of water that got through the treatment process unharmed (that is, not taken away by a manual or automatic sampling) and treated, is now led to the last part of its journey: the distribution pipelines. The drop can be seen as clean, but will it manage not to get contaminated in the distribution system? Will it be able to deal with main breaks, pressure problems and micro-organisms?

6.2.3 From treatment plant to customer

If everything works well, pipelines through which the water flows are invisible to us. They form an often complicated network of pipelines that are connected with each other in several ways. In *The New Yorker* of September 2003, David Grann made a trip underground to explore the water distribution system. The system evoked his admiration. Below a few fragments from the article (Grann, 2003: 88-103):

> New York City's invisible empire, an elaborate maze of tunnels that goes as deep as the Chrysler Building is high. Under construction in one form or another for more than a century, the system of waterways and pipelines spans thousands of miles and comprises nineteen reservoirs and three lakes.

> City Tunnel no. 3 has been under development since 1969, and was initially billed as "the greatest nondefense construction project in the history of Western Civilization".
>
> Over the years, the men have constructed an entire city under the city, a subterranean world as cluttered as the Manhattan skyline: it includes four hundred and thirty-eight miles of subway lines, six thousand miles of sewers, and thousands of miles of gas mains.
>
> [Men] construct the Catskill Aqueduct, a ninety-two mile conduit (…) At one point, it crosses below the Hudson River, at a depth of eleven hundred feet-an achievement that New York City's new Mayor William Gaynor, called "one of the greatest engineering feats in history".
>
> For the first time (…) I had some sense of this city under the city – of what many engineers refer to as "the eighth wonder of the world".

Like the New York distribution system, I believe that the many English water distribution systems are, although much smaller in size of pipelines, impressive as well. However, the English systems can never be viewed as a whole by going underground. Parts of pipelines can only be seen if roads or pavements are dug up and usually this happens when something has gone wrong. The pipelines are not without danger for a water drop. The drop might not reach the tap in someone's house, because of a leak in the mains of because it is taken on a different route when a sampling officer picks it up. The material of the distribution system can also provide danger. It may contain lead that can dissolve into the water drop. The new treatment for lead that was put in the treatment plant was designed for exactly this purpose. This particular part of the treatment plant was not designed to treat the raw water, because raw water does not contain lead. It was designed to make sure that the water would get through the distribution system unharmed and would not react with the materials of which some pipelines are made. Instead of treating 'existing' water, it changed the properties of the water for future purposes, to make it compatible with an existing material environment.

At some points in the pipelines colonies of bacteria may be growing and if the drop of water does not have enough chlorine to fight them off, the drop will be contaminated. The larger and older the distribution system, the more likely it is that the water will get contaminated during its transport. Which disinfectant is used in the treatment plant therefore depends on the scale and state of the distribution network. If the chlorine dosing is correct, the chlorine will protect the water from bacteria during the transport. If the system is short and the pipes are new, a company may decide to work mainly with ozone instead of chlorine. Ozone disappears and will not stay in the water until it reaches the customer's tap. Another danger is if the drop is transported through a main where the flow used to go in the opposite direction for a long time.

> Once you put a reverse flow down the main, if there are deposits in that main, it will disturb them and you can get a customer reaction to it, so [the department that controls the distribution system] will spend a lot of time doing their risk assessments and looking at how they can introduce that change and sometimes you have to do it very quickly because it's a choice of that or no water. (Oliver)

If something does go wrong and contaminated water has left the treatment plant or water has been contaminated on its way through the distribution network, WaterCo can track the contaminated water through the system with help of a computer model.

> If water is flowing at this rate, it will be this far into the distribution system, it will reach your house in six hours, or whatever. They know that if the water's gone down pipe A, it's gonna go to zone B and so they can then possibly change that zone and get the water from somewhere else. (Jack)

The operational flexibility of the system thus also helps to prevent breaches of the standards. If the water exceeds the standards and it has left the treatment works, but is not too far in the distribution network, it is still possible to change the water that supplies the area that would otherwise be supplied with the contaminated water before it reaches the customer's tap where non-compliance becomes relevant.

Samples are taken from the distribution network and customer's taps to check whether the water is not contaminated during distribution. To make sure work on the pipelines is carried out properly, occasional audits are undertaken by WaterCo. As we saw in chapter 5, audits play an important role in quality assurance in various places which may affect or investigate water quality: the laboratories, but also treatment plants and distribution networks.

WaterCo carries out its own audits in several different departments. In official documents it states that these check if the correct procedures are in place and if the departments comply with these procedures. The DWI, as we have seen, carries out similar audits. Own audits therefore give WaterCo the chance to put things right before the DWI comes along and audits. However, the process of water companies carrying out their own audits in similar fashions as the DWI supports Power's view (1996; 2003) that audits are active processes of 'making things auditable' and 'producing legitimacy'. Audits and their environments are co-produced.

I will now discuss an audit I attended in detail. This particular audit was carried out to confirm that the procedures around repairing a burst in a pipeline were applied correctly. A leak was discovered because someone had phoned WaterCo saying that water came up in the garden and on the pavement. In this case the burst in the pipe (maybe the pipe was old or a heavy lorry drove over it) was thus identified through a customer complaint. As we will see in section 6.4 this happens often. Before addressing the audit in detail, I will give an overview of how this leak is moved through the company before the audit can be carried out.

When a job like this one is identified it is given a code which refers to the problem (no supply, leakage, poor supply, and so on) and appears in a work queue in the networks department. Some jobs get priority: if someone's garden is flooded it has priority above someone who receives a poor supply of water. According to Oliver 'it is all about priority'. The tasks with priority are assigned the letters AA. The tasks under E have the lowest priority and it might therefore take a while before these are completed. The importance of the job can however increase, depending on the possible impact and on whether a customer makes further complaints (to Ofwat or the DWI) or not. Poor pressure for example has a low priority, but if it affects more than five customers it gets a higher priority. Poor pressure will not be dealt with until the priority jobs have been done. However, if a customer calls the DWI or it occurs in the media, the problem comes higher on the priority list. The image of the company is important.

The leak comes into the networks department via the customer support group. The job is then scheduled for repair after the utilities (maps and drawings of the area) are attached. Usually someone in the field will go out to investigate and make a risk assessment and from that job (just checking) another job (repair of pipes) is created (see Appendix 6 for a protocol that schedules the jobs to priority; note how detailed the protocol is). The risk assessment investigates a large number of potential risks: the risk of discoloration, the pressure of pipes, whether there is a pressure reducing valve in the DMA which would reduce the likelihood of a burst, whether there are sensitive customers in the area (surgeries, doctors, dialysis patients, schools, restaurants, and so on), whether the place is easy to find or in the middle of the road (and if so, what the road is made of), whether valves can be shut and which ones have to be shut, what the clean water delivery points are, what the flushing possibilities are, whether alternative supplies can be used, and so forth. This information is used to carry out the job. Detailed guidelines exist for carrying out the risk assessment. For the discoloration risk alone a whole protocol exists (material of the pipes, discoloration problems over the last 12 months per 10,000 properties, etc.). The person in the field will make a detailed drawing of the area and attach it to the job. Then the jobs are printed out and sorted by priority: A, B, C, D, and E go into different trays. The utilities people take ownership of a certain job and attach details of the gas, electricity, and water pipes with help of a specific software program. If there are high pressure gas pipes, oil pipes, or overhead power cables, specific risk assessments have to be carried out. The job then shows a 'U' on the computer to say that utilities have been added. The job then goes to a technician who does a risk assessment of the job taking the utilities into account: what has to be done and when. Their authority is needed before the job can be carried out. This is important because they look into –amongst others– whether the mains have to be shut off and domestic customers, industries, and people with special needs may be affected. They might try to advise for the job to be carried out during the night (or a Saturday if schools and industries are involved) when the fewest people will experience the lack of water. In fact, there is a separate protocol saying how much advance warning the different groups should have in case work is planned that requires the mains to be shut down: 48 hours for domestic customers and customers with special needs and seven days for industrial customers. The technicians also have to determine if strategic valves are involved. These are valves at places where large differences in pressure exist (a pipe might burst more easily), at places where they stop different water sources getting into contact with each other (you might not want to mix qualities; this may cause a regulatory standard –nitrate for example– to be exceeded and cause a health problem), or at places where they form the boundary for a specific supply area. This can be tracked with a computer model that shows the effects of shutting down a main at a certain place. In these cases the duty manager has to authorise the job. In a real emergency case, there may not be time to check for instance the amount of nitrate from a certain water source, and two high nitrate sources may be mixed. However, the risk assessment protocol is in place to prevent this from happening. The valves are so important that when a crew is hired to carry out the work, someone from WaterCo, who has had special training, will go out to shut the valves and make sure that that is done properly. They then allocate the job to a stream: leakage, service, design, repair, and maintenance. Scheduling will then allocate a crew and a supervisor to the job. The job is then placed on the bulletin board where information is given about the jobs that are carried out (in case more than ten properties are shut off) and the possible or likely effects they have. As we will see in section 6.4, the bulletin board is an important tool for the customer call centre in dealing with customers and in trying to reduce the number of customer complaints.

Now the job can be done and also the audit can be carried out. We arrived with steelcap boots, helmets and bright yellow coats which said 'water' on the back. These can be regarded purely as safety measures, but they also distinguished us from the people who did the work and claimed our legitimacy as auditors. Contractors who had been trained in working with water and issues around hygiene and disinfection by a separate company (not WaterCo) carried out the job. The contractors do not always specialise in water, sometimes they do gas and electricity jobs as well.

The first part of the audit was inspecting the blue cards of the contractors. Blue cards are proof that the contractors have had both a medical test and training in how to deal with hygiene issues. The medical test consists of a long questionnaire that is then screened by a local health person. If the contractors become ill, they have to report that and hand in the blue card until they are better and a stooltest has proven that they cannot infect the water anymore. This blue card is needed in all cases where the contractors are working in restricted areas and may come into contact with (partly) treated water. The audit I attended was not such a case. However, if it had been, it would have been possible to provide me with a temporary blue card which would be based on a much shorter medical form. For the training on hygiene issues, the contractors have to work through a workbook on contamination and disinfection. I had a look through this book and it gives instructions for a number of situations. It says that water in trenches needs to be pumped out, so it is always below the level of the treated water and cannot get in contact with the treated water; that household disinfectants are not chlorine-based and that they might give a bad taste to water and therefore must not be used; that chlorine treated water cannot be discharged into any water course (it can be neutralised (made harmless) but one needs permission from the EA for this); it has instructions for washing hands and for using chlorine to make sure that it does not come into contact with other chemicals because that might produce chlorine gas and that could lead to injuries. *The issues in the workbook are* easy to audit, and although I do not know the history of the workbook, I assume the workbook may have been co-produced with both internal and external auditing processes. Both contractors working on the leak had a blue card, but one of them had not had any refreshment course. He was told to better take one.

After this check, questions were asked to see if the contractors remembered the training. These were questions about how the equipment should be treated and cleaned, how long the chlorine should be left to disinfect, how much of the solution should be used, which pipes and cables have which colours, what they should do if they would hit a sewage pipe by accident, how to find water for washing hands. Unfortunately the main auditor had forgotten to bring the list of questions, she and the other person who joined, did remember most of the questions. The process of auditing itself is guided by protocols as well which in themselves could be audited and probably will be by the DWI to ensure that auditing processes are in place. While the auditors were observing the work of the contractors, they would ask some additional questions. The contractors were pumping water out of the trench and the auditors asked them where the water was going. The auditors also made some suggestions, like using a plastic sheet to put the tools on and keep them clean rather than paper. They checked the equipment to see whether it was all there, whether it was clean, and whether it was packed in plastic so that it could not come into contact with anything that could contaminate the water. Two things were written down by the auditors. Firstly, that the chlorine sprayer did not carry a label saying the content was dangerous and secondly that the contractors had not brought dry anti-bacterial cloth to clean their hands in case the water they brought would run out. Some things during the audit were regarded as more important than others. One thing that was checked on was whether the contractors had brought chlorine (instachlor) tablets. If they would not have, they would not have been allowed to carry out the job.

The job itself was to dig around the many pipes and cables under the pavement until there was enough space to clean the pipe that contained the drinking water and to apply the collar that would close the leak. The water pipes are about 1.5

meter under the ground, whereas the cables are perhaps 30 cm deep. The pipes have different colours. Little boxes on the street tell the contractors which pipes and cables are underground in the area. The burst was quite big and the contractors needed to pump the water out to make sure it would not reach the pipe and contaminate the drinking water in the pipe. The pipe was cleaned and a chlorine solution was sprayed on the pipe and the tools and collar that were to be used. After the chlorine had had the time to do its work, the contractors applied the collar. In some cases, depending on the burst, WaterCo switches off the pressure in the pipeline, for instance when renovation work takes place. In such a case, extra chlorine may need to be added upstream, because the water pressure does not prevent contamination from coming into the pipeline. In this case the pressure was only slightly reduced, but still seen as large enough to prevent contamination from coming in. Only if one thinks that there might be a contamination problem (if the pressure has been off), sampling is necessary. It takes eighteen hours to analyse a sample and in the mean time the flow of water is continuing from the treatment plant to the tap. The sample is a precaution sample and one does not expect any problems if there was not a particular problem on the site. The contractors will be given a copy of the audit.

Back in the office, I listen to two people discussing different ways of auditing. One team member seems to do the audits completely according to the rules. Two other team members are more pragmatic about their own practice:

> You do what you can in the time you have available. (Roger, LTI/160403)

A repair audit like the one I attended, does not take as long as a renovation audit which can take two days. The two team members are more pragmatic towards the contractors as well.

> If it is raining, it is windy and muddy, you can't expect their hands and tools to be entirely clean. We won't write recommendations about that. (Roger/160403)

They are satisfied if the contractors know and understand the rules and know how to apply them, even if it does not always apply completely in practice. I was told that the contractor companies are quite happy with these audits, because it gives them a chance to show that the contractors have received good training. They thus mobilise the audits to show the quality of the contractors and the training and probably arrange the training in such a way, that the contractors will 'pass' the audit successfully. All audits are collected in a database from which WaterCo can then extract which problems occur most and where and when.

6.2.4 Retracing the route

I have shown that the choice of the water source depends on scientific, economic, technical and institutional aspects. Some of them relate explicitly to the possibility of meeting regulatory standards (and thus to make the water fit for human consumption) for a reasonable price. Others concern wider environmental consequences. When the water enters the treatment plant, different regulatory and operational standards become visible at different (obligatory passage) points in the process. The process is closely monitored with the help of technical instruments, written procedures and manual samples. This, as I also argued when I talked about audits in chapter 5, is not a case of testing the water quality 'out there', but a means with which the water quality and practices around determining water quality are co-constructed. In the next section, I will look at the co-construction of materiality and regulations/procedures in the case of practices around samples. The next section will also demonstrate that despite the quality assurance (the system in place, the alarms, the many operational samples), regulatory samples have to be taken to ensure compliance with the regulations. These samples are taken manually and subject to different practices than the operational samples in the treatment plant.

6.3 *Tracking sample from beginning to end*

We have seen that regulatory standards are important within water companies, but that, at the same time, companies have their own standards for which they take (non-regulatory) samples. Regulatory samples have to live up to the international and national regulation as discussed in chapter 5. If they do not comply with the standards and the water is regarded as unfit for human consumption, the DWI might decide to prosecute the water company. Non-regulatory samples are often taken for process control or leakages. These samples support the system that produces the (quality of the) regulatory samples.[1] When following different samples, it becomes clear that, in some instances, regulatory and non-regulatory material samples are treated in different ways. In this section (6.3) I will start by looking at how, when and by whom the samples are taken. Depending on the type of sample (the reason why it is taken and what has to be analysed), the sample is then sent to the microbiology laboratory, the *Cryptosporidium* laboratory, or the chemistry laboratory. After that, when the analysis is done, the material sample is translated into one or more numbers which have to pass through several information systems. It then ends up in the monitoring department of the company. During this journey we will also encounter anomalies.

6.3.1 Taking samples: catching the material

The word 'sample' is used within the context of much natural and social science research. A sample, for instance a population sample, is taken on the presumption that it is a reliable measure of the whole population.[2] And for it to be a reliable measure it has to be comparable with other samples taken and thus standardised. A water sample is regarded as a reliable material measure of a larger material object and as we will see, this has consequences for the way in which samples are taken. In this section I will consider a water sample as a socially constructed material object. This object is made robust by, amongst others, standardisation processes. However, in practice, a sample has a number of different characteristics, the meanings of which have to be interpreted.

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[1] Some of these samples were also taken before any regulatory standards were around, but the systems were not as extensive as they are now.

Before this, I will shortly explain what type of samples I am following in this section. Samples can be taken for different reasons and by different people as Oliver explains:

> Networks will take any samples that are required to investigate a customer complaint. Any samples that are required every time the mains system is depressurised, a bacteriological sample to confirm that there's been no compromise, networks take those. The water supply group will take their own process samples. Engineering will take samples if they are doing work on the distribution system, renovation of the distribution system. We [the monitoring department] take the regulatory samples. We also take all of the samples that were generated by a failure of the standard, regardless of whether we took the first sample. So, if it is a depressurisation sample that networks has taken and it fails, we'll do the investigation, we'll take the resamples. If it's a regulatory sample that fails, we'll take… If it's any operational sample that fails the standard, we'll get involved in the investigation.

Most of the samples are taken routinely, either for regulatory or non-regulatory purposes.[3] Some samples are ad hoc, that is, they are not part of a long-term planning process. Ad hoc samples are taken if a leak or a burst in the pipelines has been identified or work on the pipelines has been executed. These samples are often meant to investigate whether any harmful substances have come free, either chemical or microbiological. In this section I will focus on samples that are taken routinely. According to the quality inspector who took me with her, 99% of the samples taken on routine routes are regulatory and not ad hoc. Samples taken non-routinely should, in theory at least, be taken exactly in the same way as samples taken routinely and

[2] Rusnock (1995) discusses the complex issues around determining how large the population is and what is regarded as the best method to do this and describes how this changed over time in the ancien regime.

[3] Oliver states, that also in WaterCo a large change took place around the period in which the 1980 directive was implemented and the companies were privatised: 'We were supposed to be doing [the sampling] weekly then, we do weekly now, but I can remember people coming in from headquarters saying: 'the recommendation is you should do weekly samples' and it was never done. I think the problem was there were no sample taps on those reservoirs. So, you know, we didn't sample them'.

should be treated in the same way as well.[4] All samples I am discussing are for drinking water supply. They can be raw water samples, samples from reservoirs, and so on. I will start with some observations I made:

> A day on sample tour. Driving 102 miles to take samples from reservoirs and customer taps. In a company van filled with bottles, a fridge, and other equipment. The fridge in the back of the van should be two to eight degrees. It says one degree at the moment, but the quality inspector tells me it says one degree because it was overnight, but the water that will be put in [the samples] will warm up the fridge. There is a container in the van which is supposed to have hot water in to wash hands etc, especially after taking raw water samples. But it hasn't worked for ages and that is the same in lots of other vans. [The QI's are provided with waterless hand cleaners for times when vehicle hand wash systems are not operational]. In the van the quality inspector is filling me in. I ask a lot of questions and find out that each bottle in the back of the car tests one thing. Most bottles are filled with a certain solution. The sample bottle for mercury has a green substance which will preserve the mercury. Pesticides and pH samples go in a bottle of amberglass, most other samples (mainly nitrates, a few for cyanide and mercury) are taken in plastic bottles. *Some bottles are empty, these are used for, for instance,* taste and odour.

This is a little extract of the fieldnotes I wrote during that day. More will follow. I just wanted to stop here to reflect on what is happening. Previously I mentioned that samples, if people want to regard them as reliable, do have to be comparable and

[4] This may not always happen, since the people who take ad hoc samples, although they have been trained in taking samples, may not have the same experience as the professional samplers. Also the circumstances under which the sample is taken may be more difficult than the circumstances under which most routine samples are taken. Lillie (MA/140503/WaterCo) told me: 'If networks people take the sample, it is more likely to be contaminated than if QI people take sample'. Oliver puts it as follows: 'What happens at the moment is you get somebody in networks who is a distribution inspector and most of his job is about valve turning and you know investigating problems sorting out leaks and things like that. And occasionally they have to take a sample. But he hasn't taken a sample for quite some time you know and he forgets or he hasn't got the right bottle with him, or he hasn't got the right label, whereas we are the experts. And if they are not supplying the samples in the right bottle or they are not filling in the paper work properly, they don't get the results they want. And whilst there are benefits for the operation guy because he is on site to take the sample while he is there, the disadvantage of that is that they are not the experts and they don't always do it right and we end up wasting more time trying to correct those mistakes.'

standardised. Yet, we have just seen that different bottles exist for different determinants. Most sample bottles are the same size, made of plastic, and have a label with a barcode the laboratory can scan to what the sample should be analysed for. However, some bottles are of amberglass to prevent (sun)light *changing the material characteristics* of the sample.[5] Each preservative in the plastic bottles brings out the *specific material characteristic* that the people in the laboratory will be looking for later on. The material characteristics are thus not a stable feature of the water and the sample can only be reliable if it is taken in the right bottle with the right preservative. The material property that one is looking for needs to be preserved. This also means that other material properties of the water will change or disappear at the same time. A bottle for a bacteriological sample for instance has as preservative a substance that neutralises the chlorine in the water. Would this substance be absent, the chlorine would kill or at least decrease the bacteria population *at the time the sample was taken* during transport. This is a crucial point. One does not simply want to know the properties of the water, because these are subject to change. One wants to know the properties of the water at the moment the sample was taken. The water thus needs to be stabilised. However, because of the interaction between different parameters/substances, the water as such cannot be stabilised. It is the specific material properties that have to be stabilised. To describe this process I can use the concepts of 'resistance' and 'accommodation' that Andrew Pickering (1995) uses. It would be time and cost saving if one sample would be sufficient to analyse the different regulatory and operational parameters. However, the material agency the water resists this and makes it impossible. In order to be able to analyse for the regulatory standards, water companies have to accommodate this resistance (to use and to the intention and expectation to use a single sample) by taking and transporting the samples in different ways. This can be regarded as the *dance of agency* or the *mangle of practice* as Pickering calls it.

According to Pickering (ibid.: 21) 'scientists are human agents in a field of material agency which they struggle to capture in machines' and in my case in sample bottles and analytical instruments in laboratories. Human and material agency are 'reciprocally and emergently intertwined in this struggle' (ibid). They take turns,

[5] The practice of sampling and the laboratory practices discussed in the next section could be very well analysed in terms of dirt 'in' and 'out of place'. The amber bottle can then be seen as preventing a contact between a clean material and the dirty world. See Mody (2001) for an interesting example of an analysis of dirt in materials science.

so to speak, in the *dance of agency*. Yet, I would argue that this 'dance of agency' would have taken place especially when the standards were introduced or companies started to measure for substances they had not measured before. Pickering argues that material agency actively manifests itself in a period of human passivity: 'Does the machine perform as intended? Has an intended capture of agency been effected?' These questions are still relevant in an environment of regulated science in which a regulatory plateau is at work, for example when a new instrument or method is developed or introduced in a laboratory or treatment plant. Pickering however seems to regard the dance of agency as a dance to establish a particular way for material and human agency to work together when this relationship is still uncertain. The dance of agency does not refer to practices in which this 'working together' has already become a routine. In fact, he (ibid: 102) suggests that the open-ended dance of agency –that is scientific practice– 'becomes effectively frozen at moments of interactive stabilization into a relatively fixed cultural *choreography*, encompassing, on the one side, captures and framings of material agency, and, on the other, regularized, routinized, standardized, disciplined human practices'. In an environment of regulated science that is not aimed at the production of new knowledge, this is exactly the case. It is this cultural choreography that perhaps better reflects the process of resistance and accommodation in regulated science. Pickering stops here and does not explore this cultural choreography; it is my starting point. Let us now explore the choreography in more detail.

The sample bottles are prepared in the laboratories. Before the bottles return to the laboratories, however, first the samples actually have to be taken. I will now give a short overview of the sample places we visited, before going into the specifics of taking a sample (see also photos 6.3, 6.4, 6.5, and 6.6).

> The first place we came to was a reservoir. The quality inspector warned me for spiders. Apparently these places have lots of spiders and you have to be careful going in. It is just a dark cement little building on the side of the reservoir. The tap is inside and directly connected to the reservoir.

> The second set of samples was taken from a tap in a box on the side of the road. The tap here was quite far away from the reservoir.

The third reservoir we went to was closed. Water came from two boreholes, but work had been done on it and the quality inspector told me that it could only go back in supply if it passes all the quality tests. That had not happened yet.

The fourth sample place was a tower reservoir. After this we took samples at a building in a village, at another tap in a box on the side of the road, and a small building on the side of the road.

Original in colour

Photo 6.3: Sample tap: buckets are part of the mixed physical culture that ensures our water quality

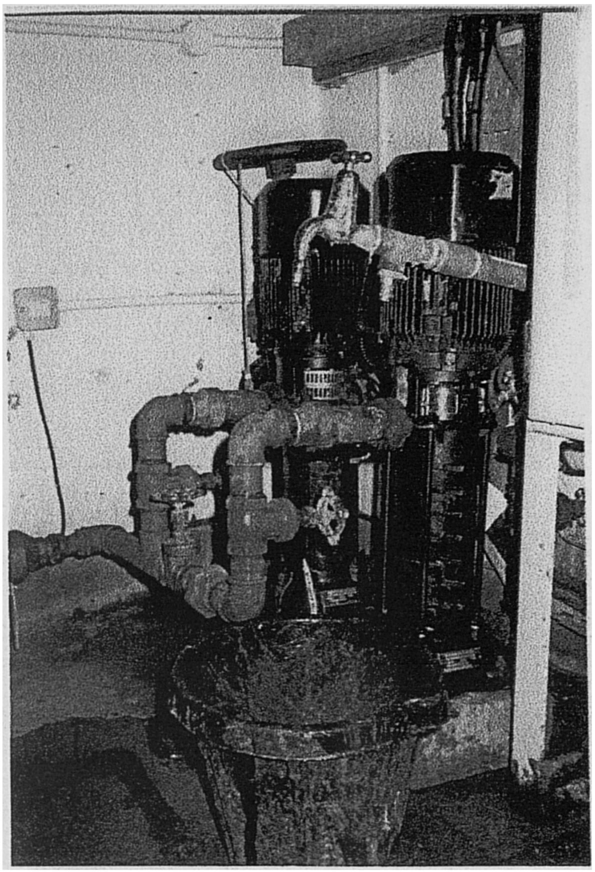
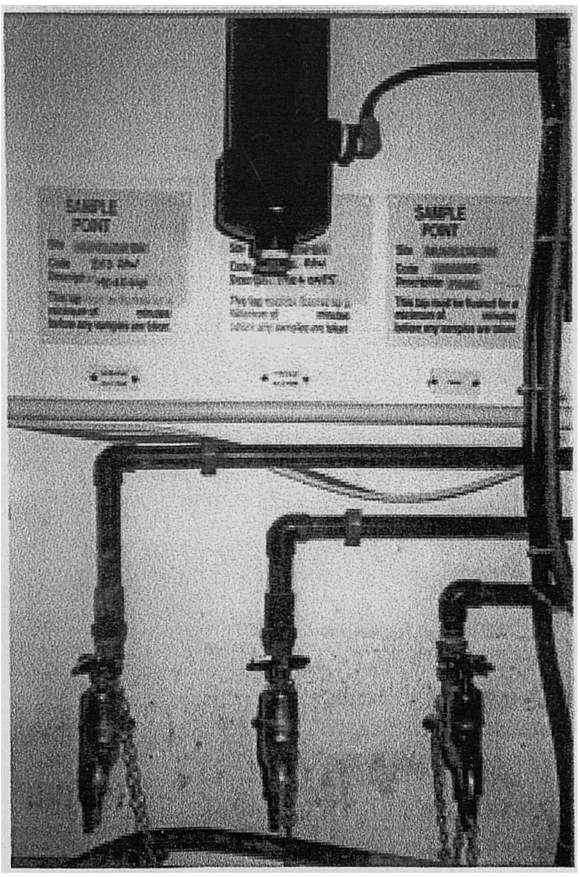


Photo 6.4: 3 sample taps: flushing time indicated to be able to obtain a 'proper' sample that represents the water



Set of samples number eight was at a customer's tap. The house where the sample has to be taken is predetermined by a computer program that meets the requirements of the DWI. The DWI wants to make sure that one does not avoid a certain house/place on purpose. Whereas in the city one may be given a road name, in the countryside it may be a specific house. We found the right house, a large house/farm on the countryside, but nobody was at home. We drove around to find another house within the DWI zone to do the samples. The quality inspector explained that finding another house can be very time-consuming. Sometimes the houses are far away from each other. If one finds a house where someone is at home, the house has to be connected to the mains (this is not always the case in the countryside), and someone will have to let the inspector in (fortunately it rarely happens that people refuse access). The company allows only one person to enter a house and take to sample, for the security of the people who live there. Therefore I could not join.

Then we took samples at another large building. Many technologies were connected to the walls of the inside of the building. There are sulphur dioxide dosing controllers and chlorine analysers. However, the chlorine is always tested by the quality inspectors as well, because their tests are more precise. If it is different from what the technology says, it is noted down in a logbook. If people from operations come around, they can test it and, if necessary, change the analyser or adjust it. They look at the logbook every time they visit, but the frequency of visits varies. They may not come for weeks. On the wall sheets with the minimum and maximum of the operating range of disinfection substances, pH, temperature and conductivity. This was not the case at the other samples places we visited.

To get to the next place, a remote reservoir, we followed a muddy track and had to open and close several gates. Inside the building one could see the mains coming straight out of the reservoir. The mains carried water from a borehole/groundwater at the moment, but this can be changed. At other times water can come through other treatment works.

We did not go to the last and eleventh place, a borehole that was switched off. It would take half an hour to switch it on before the samples could be taken and that would mean sitting around for a while. The inspector had to go to a meeting and phoned to check if it would be possible to take the samples a few days later. That was not a problem.

The built material infrastructure makes some places appropriate (where taps are built) for collection of samples and others not. How the sample is taken partly depends on where it is taken and partly (again) on what sample is taken. Samples are usually taken from a low place in the reservoir. If it is the case that the water is low and the reservoir almost empty, samples can still be taken. However it should not matter from which place you take the sample in the reservoir. It is thus assumed that the water quality (despite all the different parameters) is the same all over the reservoir, in the words of Oliver (when he read this chapter, 290704): 'Our sample points are designed to be representative of the water leaving the service reservoir'.

At most places we visited that day, the tap had to be flushed for five minutes before the samples could be taken (see photo 6.4 (page 336) for a sample point where the flushing times are/can be indicated). If the water would come straight from the main, flushing only needs to take two minutes. If the sampling point is far away from the reservoir, the flushing may take thirty minutes. These are standard times (two, five or thirty minutes) and are often written down at the place where the sample is taken. Flushing guarantees that no contamination from the tap itself or the pipelines in which the water has been for perhaps a few days gets into the sample. At some places the tap could be closed with a plug to prevent contamination going in. If contamination from the pipelines or the tap would get into the sample, it would not be a *real sample* that resembles all the water in the reservoir or borehole. The water that comes out of the tap for the first thirty minutes at a sample point where the flushing time is thirty minutes, cannot represent the water that has to be measured. The quality of the water during these thirty minutes is thought to be different from the quality of the water at any time after these thirty minutes.

This idea of the real sample, or a good sample, is illustrated by the following example. A special procedure exists for taking samples from tower and other reservoirs after they have been cleaned and before they go back into supply. In that case special equipment is needed to take a 'dip sample'. This sample is meant to investigate whether any cleaning fluids, chemicals and bacteria are still present in the reservoir. For this, sterilised bottles connected to a ten meter chain are dropped in the reservoir from above (through the roof in some cases). The metal case that surrounds the bottles is sterilised as well. The bottles must be made of glass because they are used for taste and odour checks as well and are sterilised by autoclave. Sterilisation of the bottle and metal case (both of which come in contact with the water) ensures that the water taken for investigation is/represents exactly the water in the reservoir. The sample place here resembles a carefully controlled laboratory. Taking samples at a customer's tap is sometimes considered as more 'tricky' and cannot be controlled by the quality inspector. The samples are more likely to fail and this is outside the quality inspector's control. In the countryside the supply pipes are longer and often have a low flow, because a smaller number of houses is connected to the pipes. This means that the chlorine in the pipes is more likely to disappear and the samples are more likely to fail. However, a more important and widespread 'problem' with taking samples at customers' taps is a contaminated environment as Helen (QI/130503/WaterCo) explains:

> If the tap is leaking or really dirty, chloros can't do very much. So, if that happens or people are not at home, you go next door. Sometimes the tap is frozen and you have to use an outside tap, but that is not ideal because there is more likely to be contamination and thus failures. I would try anything else first, before going to an outside tap.

Also Victor (WQM/140202) mentioned the problem of taking samples at customers' taps:

> As long as we have to sample at customers' taps, we are at the mercy of what the customer does to the tap. We can take some precautions to make sure we get a *representative sample*, but if the tap is in a filthy condition and the sampler decides to take a sample from it and it is contaminated then we get a sample that fails. We have no control about what happens at the tap.

According to the Helen the expectations for the action that needs to be taken differ according to where the sample is taken. Although the risk assessments and procedures are the same, a failure at the tap is expected to pass with resampling (the contamination is likely to come from the tap) whereas a failure at a reservoir could be more serious. Victor explains that the DWI decides on basis of the evidence presented whether a failure was or was not representative of the quality of the water that the company was supplying. As I have shown so far, expectations play an important role in the sampling process. By taking samples in different bottles, there are expectations about the way in which the material will behave. A failure at the tap is expected to be caused by one material agency (contamination at the tap) rather than by another (contamination in the water supplied by WaterCo). I will come back to the role of expectations a bit later in this chapter.

We have seen how the place partly determines how the sample is taken. The place determines the duration of flushing, the importance of sterilisation. The amount of control over the place seems to determine the seriousness of the result of the sample. However, what sample is taken also has consequences for the necessity of flushing. The order of taking samples is as follows:

1. If one needs a lead sample, it needs to be taken straight away, before any flushing, otherwise the lead from the pipes may be flushed out.
2. Flush the tap for the time it needs to be flushed
3. Take the chemical samples and then do the taste and odour test
4. Sterilise the tap and let it run for a while (two minutes) to get rid of the sterilising substance (chloros)
5. Take the bacteriological sample

Oliver illustrates, with regard to lead, that samples can be unrepresentative, depending on when they are taken:

> People ring me up and talk about that they want lead samples taken and my advice is: no point in taking a sample because it can be *completely unrepresentative*. If you've got a leaded pipe, then you may well exceed the standard. I could come round tomorrow and take a sample and it could be below the standard, but that doesn't mean that after the water stood in the pipe for 12 hours, that [it is] gonna be above. So, *taking a sample is unrepresentative*. The best thing you can do is get rid of the lead, replace it, and if you can't afford to do that in the short term, make sure you always flush the tap for ten minutes or five, it depends how long the service is before you drink it.

The materiality of the parameter determines not only whether or not the tap should be flushed or not, it also has consequences for where the sample can be taken. Some samples, like pesticides, can be taken at the source, because they do not change while being transported through the distribution system. Customers do not have to be bothered with taking these types of samples. These sample points at the sources are then called authorised supply points.[6] The materiality of the parameter influences, in addition, the instrumentation and technique of sample taking used. For instance, the bacteriological sample is taken by opening the blue bottle, which is sealed, so no contamination can enter the bottle until it is at the sampling place. When the bottle is open, the lid is held upside down, again to prevent contamination to fall in. The bottle, with a bit of sodium thiosulphate ($Na_2S_2O_3$) that makes chlorine useless and thus preserves the bacteria at the bottom, is filled. However, as opposed to other samples taken, one has to be careful to leave a bit of air in as well for the bacteria to survive. Most samples are taken and brought back to one of the laboratories for analysis. Only a few parameters are analysed at the site. Some, like taste and odour, are monitored on site because they provide valuable information that is required at the time of sampling. Others, like pH and chlorine, cannot be transported, because by the time the samples arrive in the laboratory, the material properties would have changed. These parameters have in-built time pressures and are very local parameters in the sense that their environment influences them quickly. They cannot be stabilised for a longer period of time. To analyse them as they were at the moment the sample was taken, they have to be analysed immediately. Conductivity and pH are usually done first. They are both measured with help of a probe that is put in a glass bottle. The probe that measures pH needs to be kept in a neutral solution (KCl) during transport to keep in calibration. It is very sensitive, because if it was not kept in KCl, but for instance in distilled water (it needs to be kept wet) it would go off and give the wrong results. The measuring of pH takes longer than the measuring of conductivity. The process looks exactly the same: both probes in the same glass bottle, but the pH probe needs to stay in the water until it is settled. Taste and odour are tested from the same glass bottle. The bottle is glass; plastic bottles might affect the taste. If the sample is taken from a raw water source, the inspector only smells the sample..The chlorine test measures free and total chlorine.[7] It was only when I

[6] WaterCo does not use authorised departure points at the moment.
[7] These are audited twice a year.

did the test myself that I realised the small details I had to focus on to make the test valid. These details were so normal and obvious for the quality inspector that they had not been mentioned before.[8]

> I had the water in a very small plastic bottle, the width of a test-tube, but not as long. Much smaller than the bottles for any other samples. After flushing the tap, I filled two tubes with water. I had to clean the water off the outside of one of the tubes and, at the same time, remove any fingerprints and other contamination with kitchen paper. The tube has a little white diamond sign at the front. This needs to be put to the front when entering the tube into the apparatus. The apparatus works by sending light through the bottle. By putting the diamond to the front, the light always goes through the same point and no scratches on the tube will affect the readings. One always 'reads' the result twice until one gets the same result. To measure the free chlorine, I put a tablet in the other tube and shook it until it dissolved. The water turned purple. Again I put the tube in the apparatus, which measured the difference between the 'normal', blank, water sample and the one with the tablet in. To measure residual or total chlorine, another, harder tablet was put into the same tube. This took longer to dissolve. Once again it goes into the apparatus. After the tests the purple liquid is thrown away.

When free chlorine is measured, the water goes pink if it contains a lot of chlorine. When the test for total chlorine is done, the water may turn even more pink or remain the same. This depends on the amount of organics in the water. If the water comes from a river, it is likely to turn more pink, whereas if it comes from a borehole, it probably remains the same because it has less organics in the water. It is unusual if the test result shows a huge difference between the two tests and the water comes

[8] This is a common experience for people involved in participant observation in scientific settings. Small details can be very important for carrying out a test in the right way and producing valid results. However, many of these details have become tacit knowledge and taken for granted. When an outsider tries to do the test, it is automatically assumed that he/she knows these things. In a footnote, Kleinman (2003) also discusses the craft character of science and the importance of nonformal or tacit knowledge. Kleinman (2003: 22) describes a similar experience. He tried to obtain a certain result by performing a test. However, it did not work. 'I tried a new bottle of oil. I tried all sorts of things. Then my tutor showed me a trick I had overlooked the first time she taught me how to do PCR. I needed to swirl the material in each micro-tube with a quick turn of my wrist. When I did that, I started to get results.' See also for instance Knorr Cetina (1981), Collins (1974), and Clarke and Fujimura (1992).

from a borehole. In that case this needs to be flagged. One also knows that the amount of chlorine cannot be higher than the amount of chlorine that was put in in the first place and that the amount of chlorine is usually less in summer. By looking at the results, the trained quality inspector has a fairly good idea what the source of the water is. Because they do similar routes, they are often also familiar with the reservoirs and know the sources of the water.[9] This is the same for other test results. If the conductivity test gives an 'abnormal' test result, the water may come from a borehole instead of from a river. If this is the case, the inspector will check with one of the other (eleven) quality inspectors. Another possibility is discoloration at a customer's tap. In these cases, if the inspector cannot explain why the result is off (so he/she is not aware of a change of source or work that has been done), he or she would phone the monitoring department. This often results in 'hanging around for a bit' until the department has decided what to do next. Monitoring may ask the inspector to do an extra test or take an extra sample. This shows that inspectors may know from experience what the normal results of the tests should look (smell, or taste) like and thus what they can expect. Thus, by taste, smell, knowledge of the area, and if necessary a check with other quality inspectors, the quality inspectors can judge the 'normality' of the results of the taste and odour, pH, conductivity and chlorine tests. They have another, additional way, of judging normality. At most sample places a logbook is kept in which the inspector writes down when he/she was there and what the results of the chlorine and taste and odour tests (and sometimes also the conductivity tests) were. Since every inspector does this, the logbook contains a sequence of test results and the inspector can check whether the results are very different from what was measured the last few times. To make sure that the test results are reliable, one also has to test the instrumentation itself. Everyday when the quality inspectors come back to the laboratory to deliver the samples, the chlorine and conductivity instruments are tested on water with known values to see if they give the right results. Oliver (in commentary, 290704) describes this as a 'rigorous

[9] The quality inspectors have routes in the whole area, both to make the job more interesting and to make sure they can fill in if someone is ill. The various routes remain mostly the same, except of course for the samples that need to be taken at the customer's tap. These are decided by a computer program. They get a six-week training in which another quality inspector takes them on his/her route. As they go along, they make up their own booklet with notes of the routes, etc. They do not get a standard package with all this information. During the training and of course afterwards, they get to know the area, know where the water comes from and 'get a feel' for what results are normal. The quality inspectors meet once a month to discuss things like rusty gates or perhaps trends they have noticed. Practical issues seem to be mostly discussed.

regulatory procedure known as analytical quality control (AQC)'.[10] Also Chris stresses: 'They have to follow a set-out analytical method and they will have to do analytical quality control samples at the same time. In other words, we apply the analytical control requirements in the regulations to on site tests as well as the tests in the laboratory'.

It is important to realise that the 'normality' of the results cannot be established by means of the measurement technologies alone. These instruments give a result, but do not provide the paradigm within which the result can be interpreted. The 'normal' result of a total chlorine test of borehole water is very different from a 'normal' result of the same test for surface water. Knowledge of the source of the water therefore provides the expectations that are needed to interpret the result. If the result deviates from what was expected (within the paradigm of 'normal' results), then it is time for further investigations. Without paradigm and expectations, no sense could be made of the results of the tests; their information would be useless.

So far the focus has been on the reciprocity between samples and the way samples are taken, and concepts of materiality. The diversity in regulatory and operational control parameters and the (expectations of the) materiality of the parameters, require a variety of bottles, ways of taking samples and analytical techniques. Although samples can be different and are taken differently in order to guarantee that the right material property can be checked and this property does not change during transport, these processes are very much standardised and routinised when looked at the level of the individual parameter. When asked what would be different when the inspector would go and work for another water company, she answered that the most difficult thing would be to remember the routes. The rest of the process, although the other company might have slightly different instruments, would probably be similar.

The taking of a *Cryptosporidium* sample would be an example par excellence (see photo 6.7). As we have seen in chapter 5, the process is heavily regulated and standardised and requires a great level of precision. It is so complicated that people

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[10] If the company wanted new instruments (for chlorine, turbidity, etc.), even if it is exactly the same brand as they are using already, the new instruments would have to be tested to show the DWI that the new instrument is as good and useful as the old one. The fact that the manufacturer has tested the instruments is not sufficient for the DWI. Any new instrument brings with it a large number of forms and legal documents. For this reason the company prefers to keep the old(er) instruments as long as they work. However, the company has at least once switched to new pH meters, because they had to calibrate the old ones everyday. The new ones are much better.

get special training to do this and the *Cryptosporidium* sample takers are not always the ones who take the other samples. The precision is not necessarily (only) due to the materiality; it is the regulations that prescribe exactly how what has to be done. This is also the only sample for which regulatory and non-regulatory samples are taken in different ways with regard to precision. *Cryptosporidium* is monitored continuously at the sites that have been determined through risk assessments (how many people does the place serve and how much chance on *Cryptosporidium* is there). This is done by placing a cartridge in the water that looks like dense foam or rubber. The water flows continuously through the cartridge and every twenty-four hours a quality inspector has to come, collect and replace it. The cartridge is put into a double sealed, legal evidence bag (if the sample is taken for regulatory purposes), so it cannot be opened once it has been closed. The cartridge is then placed in a box to be transported to the laboratory. The following quotation nicely details the process:

> You have to sign over the sample to the courier and the courier has to sign it over to the laboratory. So that you can trace the history of that sample back and there is no possible way that that sample could actually have been mixed up with another sample, so that no lawyer could come in and say: 'actually it doesn't apply to that, because you don't know what happened to that sample as it was driving down such and such a motorway. (...) And the information we have to, everything is tagged and sealed and has to go into bags which the police use, they are the same sorts of bags that the police use, as part of their, when they are doing investigations into murders and what have you. It is that level of detail, you know, and they've got (tamper) proof that you can see if the bag has been opened, because it has a tamper proof seal on it. (Oliver)

Original in colour

Photo 6.5: Sample tap box on the side of a road showing a stop to prevent contamination entering the tap

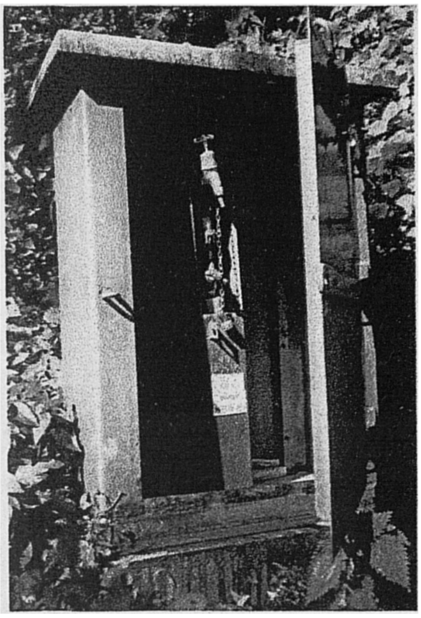


Photo 6.6: Sample tap with stop and bottle with chloros which is, together with the different preservatives, responsible for the distinction between bacteriological and other samples

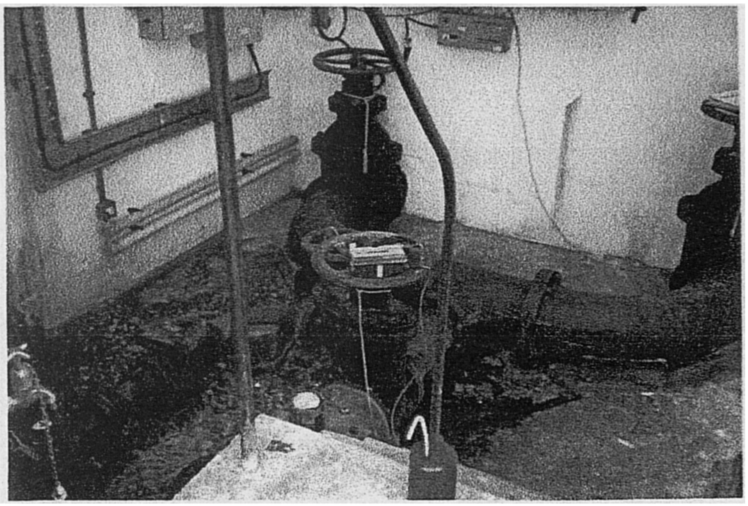
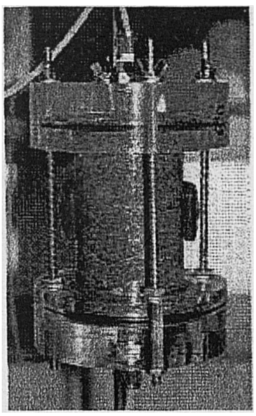


Photo 6.7: Regulatory and material de-standardisation. A *Cryptosporidium* sample looks different than a microbiological sample (see photo 4.3)



Helen told me that there are so many regulations around taking a *Cryptosporidium* sample that people made a lot of little mistakes, just in registering where, when and by whom the sample was taken, at the beginning. Robin (WQM/090603) gave an account of how he himself had experienced sampling for *Cryptosporidium*.

> At one stage, two years ago, there was going to be a strike possibly. Because of the regulations on crypto sampling it was accepted that the management could take samples, so I was trained in that and failed badly. The DWI allow you one hour to take a sample. The samplers who do it all the time take 10, 11 minutes, it had taken me 45 minutes and I made three or four mistakes in all that. It's very very complex. Definitely a different skill than you expect for [other] samples.

He also told me that they select a slightly different type of person for *Cryptosporidium* sampling. They do not have to be scientists, but need to be able do a bit of thinking and put some of the equipment together. It is important that the sampling is done well, because the DWI is very precise in checking these details. Therefore, respondents explained, two-third of the samplers, or 12 of the 33 samplers, take solely *Cryptosporidium* samples.[11] However, it has become more routine now as Helen explains:

> But now people have had time to get used to it and now it is just another sample that needs to be taken. It keeps us in our jobs. But it takes about half an hour to take a *Cryptosporidium* sample. Other samples take at most a few minutes.

At the end of the day Helen says:

> All these questions you ask, I have not been asked them for ages. Even on an audit they won't ask me these questions.

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[11] Robin explained how difficult it is to determine whether and if so, to what extent and outbreak of *Cryptosporidium* took place: 'Three different health authorities, three different levels of incidents, all with exactly the same level of water supply. Nothing to do with the actual number of illnesses I don't think, just how hard they look'.

To conclude I would like to pay attention to a chapter written by Latour (1999) in which he analyses a similar process. In his example someone collects plants that she dries and classifies. Latour tries to find out how these plants relate to the forest. In a realist discourse, the plants would directly correspond to the forest. However, Latour notes that they do not correspond to the entire forest, since that would also contain ants, worms, soil, monkeys, and so on. He explains how 'in losing the forest, we win knowledge of it' (1999: 38). Through detaching, preserving and classifying the plants, they can also be reassembled and redistributed in new ways. In this process both the botanist (she learns new things) and the plants (by being preserved and redistributed) are transformed. Also water cannot be analysed as a whole. It is –perhaps like a forest– in constant movement. The quality (and thus the water) can change within a very short period of time. Quality inspectors have to accommodate this and provide different bottles to preserve the different qualities of the water. Samples are taken to analyse a particular material property of the water which is at the same time constructed through the preservative in the sample bottle. The empty bottles (or in this case bottles with only a preservative) are in Latour's terms (49) 'set up *behind* the phenomena, *before* the phenomena manifest themselves, *in order* for them to be manifested'. As soon as the water gets in the bottle, it becomes a sample and a sign. This is the first moment of substitution, 'the very instance when the future sign is abstracted from the soil' or water in our case (ibid.: 49). This preservative can lead to the destruction of other parameters; some material properties remain, others disappear.[12] However, the parameters that are destroyed are either not important or unknown to the analyst or will become part of a different sample –in isolation from other parameters. To analyse one particular material property of the water, the total/overall water quality, if there is such a thing, is often changed. The sample, when taken, is thus only a reliable measure of the specific parameter. Latour argues that 'knowledge derives from such *movements*' and not from simply observing a forest or water in a river. In order to obtain knowledge about the water quality, the water as a whole needs to be transformed into different (materially) constructed samples.

While Latour's argument is supported by the case of water samples, his work does not take into account the ways in which the materiality of the water is

[12] This may have come about through a combination of both historical scientific developments and regulations in which water has to be tested for specific parameters. If we think back to chapter 5, these types of materiality could never have existed when water was considered as an element in itself.

accommodated by the standards-sample entity, for instance in the case of *Cryptosporidium* and not simply defined by the sampling technique itself. The sample itself is not just *materially constructed* by the preservative in the bottle, but also by being collected under particular predefined regulatory circumstances. The reciprocity between samples, the way samples are taken, and materiality are crucial. Possible contamination of the sample can disappear within five minutes of flushing the tap. Contamination of the sample does not necessarily equal contamination of the water. If a lead sample is taken and lead is found in the sample, lead was the only important parameter in the sample bottle and did not contaminate the sample. The same water not used as a sample, would be regarded as highly contaminated if the bottle was filled with water for drinking purposes; lead would have been out of place. A 'proper' sample is therefore a sample that represents the water as it was at the moment the sample was taken and if it is a sample of exactly the water (parameter) one wants to have a sample of. A 'proper' sample in which its specific characteristics come to the fore can only be taken in a particular order.

In Latour's example most analyses could not be done in the field; the soil had to be taken to a laboratory. Knorr Cetina (1995: 145-146), when stressing the reconfiguration of the natural and social order, argues that there are three features of natural objects that laboratory science does not need to accommodate. Firstly, the object *as it is*, because this can be substituted by something else or be a purified version; in my case the object *as it is* cannot even be accommodated by laboratory science although the possibility would make water analysis possibly much easier. The materiality resists this. Secondly, the object *where it is*. According to her, the natural environment does not play a role in the laboratory. However, in some cases the object where it is needs to be taken into account, because it simply cannot be brought into the laboratory as it is. The quality inspector analyses these objects (parameters like pH) and interprets the result with help of knowledge about 'normal values'. This knowledge has mainly been acquired through a paradigm of experience, knowledge and expectations of the area and the sources of the water, and if uncertainties arise, it can be checked with other quality inspectors or the logbooks that can be found at many sample points. In this case it is also important to take the purpose of the analysis into account. Perhaps, if one could analyse the material properties of the water *on the site*, they would then be able to reproduce this water in the laboratory. However, this laboratory does not practise (much) experimental science; it principally carries out regulated science. It is therefore specifically interested in the object *as it is* and *where it is*, because that is the water that is 'out there', can become contaminated, and will be drunk. Thirdly, Knorr Cetina argues that laboratory science does not need to accommodate an event *when it happens*. Also here regulated science differs from –and is much more focused on what happens 'out there' than– experimental science. Sampling officers and others need to take samples in cases of burst mains, contamination, and so forth, and the laboratory has to accommodate these samples. When the sample arrives in the laboratory, it becomes similar to the other samples in terms of analysis and turnouts, but some parameters may have to be tested *when it happens* and *where it is*.

Latour describes how the soil samples are put in a plastic bag on which the number of the hole and the depth at which the same was taken are written. During the sample tour, all sample bottles were provided with a label number which stated the date, the number of samples taken from this source (for different parameters), the zone in which the sample place is, what the sample should be analysed for, and most important in some respects a sample number. A sample will only be attached to the original context of the sample through this number. The traceability of the samples depends on this number. Latour (1999: 47) says that his sample takers are 'obliged at all costs to maintain the traceability of the data we produce with minimal deformation (while transforming them totally by ridding them of their local context)' and this is also the case of the samplers in WaterCo. During the sample tour, there was one instance where the quality inspector stuck a wrong label on a bottle. She noticed it fairly quickly and could still rectify it. We will get an idea of the consequences a wrong label might have in section 6.3.2.4.

Regulations define which samples are taken where and when. They have classified the samples before they become samples in a material sense. In the *Cryptosporidium* example regulations have a clear effect on the practices around taking a sample. The regulations may also influence which tap is chosen for taking a sample as we saw earlier. Although the sampling processes are subject to audits, the regulations do not surface often in discussions on sampling processes. Yet, we know that the sampling processes are heavily regulated and that discretion on the part of the sampling officers is subject to a regulatory risk. A history of co-construction between the regulatory regime and the sampling practice that has to accommodate materiality seems a likely explanation for the 'invisibility' of standards. The sampling processes have incorporated the regulations and become routine. In audits the DWI or WaterCo do not expect one sample to be taken with which all parameters can be analysed. The auditing process accommodates the material resistance and is co-produced with the sampling practice of using different bottles for different samples.

In the next section, I will explore what happens to these conceptions of materiality when the samples go to the different laboratories. The different routes the samples take through the company do not depend on the source of the water. The fact that different samples are transported to different laboratories means that the different samples/parameters need to be dealt with in different ways. For the chemistry and microbiology laboratory this is mainly ascribed to material characteristics of the water. Regulation is the reason for samples, which could otherwise have been analysed in a microbiology laboratory, to go to the *Cryptosporidium* laboratory.

6.3.2 Laboratories as sites of routine knowledge production: transforming the material

Science and Technology Studies have paid much attention to laboratories as sites of knowledge production. It has even become a separate field: 'laboratory studies'.[1] Laboratories were sites par excellence where science-in-the-making could be observed. Before the 1970s science was still very much an area for the scientists and historians, philosophers, and sociologists did not address the technical content and the production of knowledge itself. Although the studies are diverse, they do point to a number of similar conclusions. Kleinman (2003: 45) summarises four of them. Laboratory studies have stressed the significance of the local rather than the universal in knowledge production; they focus on the centrality of contingent factors and not on the rational in the construction of knowledge; they investigate laboratory practice as being about creating order from disorder and the transformation of nature itself in the laboratory (science is not simply the reading of nature); and they conclude that science is a process of construction rather than description.

I will not give an extensive overview of the laboratory studies literature at this point. There are other sources that can be consulted for this purpose.[2] However, a short introduction was necessary since I will engage with this literature throughout this section (6.3.2). This section cannot be called a 'laboratory study' as such. I have not spent several months or even years in a specific laboratory and it would be presumptuous to think that my days in the various laboratories could equal the detailed laboratory studies that were referred to above. My study differs from most existing laboratory studies in two other respects. This does not necessarily exclude this thesis from laboratory studies, but might instead be seen as supplementing the existing work. Firstly, most –if not all– laboratory studies have focused on experimental science. Sismondo (2004: 86), in an overview of laboratory studies, even explains the importance of these studies with the following sentence: 'laboratories are exemplary sites because experimental work is a central part of scientific activity, and experimental work is relatively visible'. Yet, a laboratory for drinking water quality analysis –as we have seen– hardly does any experimental science. Water quality analysis by water companies is very much a regulated science

[1] This refers mainly to four monographs on laboratories. Latour and Woolgar's *Laboratory Life* (1979), Knorr Cetina's *The Manufacture of Knowledge* (1981), Lynch's *Art and Artifact in Laboratory Science* (1985), and Traweek's *Beamtimes and Lifetimes* (1988).
[2] See for example Knorr Cetina (1995), Sismondo (2004), Kleinman (2003).

that operates in a different way. This will be explored throughout the chapter. Secondly, a critique of laboratory studies has been that they focus on the (scientific) practices within the laboratory, but ignore the broader societal context in which they operate. Kleinman (2003) therefore seeks to carry out an ethnography of a laboratory in which he explicitly addresses issues of power, resource dependency and institutional structures. In this thesis, I also attempt to relate the larger societal context (mainly the regulatory regime) to the practices within laboratories. Furthermore, practices within the laboratories are also explicitly linked to practices that prepare the sample for going in to the laboratory and practices that take place after the sample has been analysed in the laboratory. My explicit focus on the relations between different parts of the company and the wider waterworld, explains –apart from the practical factors discussed in chapter 3– why I spent less time in the laboratories than a 'laboratory study' would require. Not spending much time in laboratories and at the same time still acquiring sufficient understanding on what is happening in the laboratories to be able to place them in context is only possible because of the existing laboratory studies. They form a framework within which one can quickly understand science-in-the-making. Using this framework rather than 'naively' going into the laboratory does also mean that important aspects –on which the existing studies did not focus– can be missed. Yet, in my case, both because of the topic of the thesis and practical issues, it was more important to understand what was happening quickly, despite the danger of missing something. I have therefore gratefully used laboratory studies and wider STS literature to help me in my analysis.

As mentioned in the previous section, samples can be taken at different places and for different purposes and they will therefore go to different laboratories. The choice of the laboratory depends on the classification of the sample. The classification of the sample is determined in advance, either by the regulations that for example have determined that on that day and at that place a microbiological sample has to be taken, or because of operational reasons.. Keith (CML/030703/WaterCo), my key informant on this topic, explains that the networks department is more likely to ask for a microbiological sample since microbiological contamination occurs more frequently than chemical contamination when mains burst or repairs are carried out. On the other hand, the technology development department and the engineering department are often involved in the development of novel treatments where chemical parameters are more relevant. Both the regulations and the various departments within WaterCo classify the sample that needs to be taken and set the agenda for the laboratories. The laboratory itself is not perceived as setting an agenda for other departments within the company. Keith:

> I can't readily think how it can interact in that way, if you know what I mean. It's very much a service company, like any other supplier really, it's like somebody supplying pipes, are you with me? At the end of the day, the laboratory is supplying analytical information.

Other people in the company do the monitoring and take the samples. The laboratories then analyse the samples, but the interpretation of the results is left to yet another department. The results of the analysis that the laboratories produce can however result in actions by other departments. If a result does not comply with the regulatory standard, new samples may have to be taken and the failure will have to be reported to the DWI. The failure will also be investigated and if it is part of a trend or a problem with the distribution network, work will be undertaken to prevent any more failures. The organisation of a company may also influence the role of a laboratory in agenda setting. If a company owns a number of microbiological laboratories in which the analysts know the local area and the problems that are likely to occur, the analysts may have a prominent role in interpreting the results because of their detailed knowledge which the interpretation department may lack. However, if the company sends the chemistry samples to a large outsourced laboratory where the staff does not have any local knowledge and where the staff may not have any close contacts with the interpretation department, the role of the laboratory may be limited to solely carrying out the analysis.[3] The main role of the laboratory is to do the analysis and to produce a result for every sample taken. In this sense, regulated science is practised in the laboratory. In the next sections I will explore the co-construction of regulations, standardisation and practice.

After this small detour, we can return to the classification of samples. When the regulations or operational regime have determined what samples have to be taken, the bottle and preservative in which it is transported then also materially

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[3] Many companies have outsourced their chemical samples and perhaps some of their microbiological samples, but almost all of them have kept one own microbiology lab. The example is therefore based on the situation of most water companies. In the situation above, the microbiology lab is more likely to have a broader role in the company as a whole than the chemistry lab.

classify the specific sample. As we have seen in the last section, a sample can become a material bacteriological sample when the preservative sodium thiosulphate ($Na_2S_2O_3$) neutralises the chlorine in the water. When the samples have been constructed, most of them are brought to one laboratory where they are registered. The laboratories thus seldom work with objects as they occur in nature. In the words of Knorr Cetina (1995: 145): 'Rather, they work with object images or with their visual, auditory, electrical, and so on traces, with their components, their extractions, their 'purified' versions'.' Processes studied in the laboratory become independent of seasonal and weather conditions, and in this case from the water quality that is constantly changing. In the laboratory 'natural order time scales are surrendered to social order time scales – they are subject mainly to the limitations or work organization and technology' (Knorr Cetina, 1995: 145). Although I agree with Knorr Cetina that many conditions outside the laboratory do not play a role inside the laboratory, I have demonstrated in the last section that social order time scales do not totally replace natural order or material time scales, since some water quality samples need to be analysed on the site. They cannot be brought into the laboratory as they are.

When they come in, the results of the field analysis on taste, odour, conductivity, temperature and chlorine are put into the computer. The other samples are received and registered. From here the samples are distributed to the microbiology, chemistry and *Cryptosporidium* laboratory. These laboratories have different ways of dealing with the material sample; different skills are necessary and different forms of regulatory and non-regulatory control are in place. The laboratories are also physically located in different places. Judith (CA in CA+CML/020703), a chemist herself, describes her perception of the relation between chemists and microbiologists:

> Most chemists probably don't want to do micro and vice versa, I think that is your biggest sticking point. And they are very very different, I mean, I certainly view chemistry as far more scientific than the micro, but microbiologists are gonna say the complete opposite. I don't know, I think it would be very difficult to do as well, 'cause there is a different logic behind it as well, isn't there? I think chemistry to me seems very/fairly logical in the process that you use and the result you end up with. And I think micro again is probably very logical but in a different way. So, there is a different mindset

I would say. That is, having met lots of microbiologists. I don't know, I don't know. I think if you would be asking me personally I find it quite difficult to make the transition from chemistry to micro.[4]

Chris (DWC/040603) adds:

> There is always a difficulty with microbiology in comparing methods because you don't have good standards like you have in chemistry. You can make up a standard solution of arsenic that everybody can analyse and get the right result, hopefully if they've got a good method. That's not the same for microbiology, that's more of an art than a science. I hope you are not a microbiologist.

The analysts of the different laboratories need different skills and their difference in disciplinary background seems unsurpassable. Despite the differences between the laboratories, all of them are subject to a regulatory regime and standardised to a certain degree. The degree to which the regime and standardisation influence laboratory practices however differs. The *Cryptosporidium* laboratory, as we will see, operates in a very standardised and regulated way. All methods and procedures are prescribed by regulations. The *Cryptosporidium* laboratory will therefore operate in exactly the same way in every water company.[5] Within and between the microbiology laboratories and the chemistry laboratories more possibilities are open. They will be similar to laboratories of other companies, but some methods and practices may be different. When asked what would happen if an analyst from one company would visit another, Judith says that the practices will not be too different, because of the UKAS accreditation. This accounts for standardisation to a certain degree, but even more to the reliability of the laboratory. Judith:

[4] This is probably (partly) due to the way in which chemistry and microbiology are taught. They are separate disciplines in different departments. Bringing this up in an interview led people to say that the two are very different. A combined 'water discipline' would give people some insight in all aspects related to water and water quality, but disadvantages were thought to be more important. People would not specialise in anything which would make it difficult to develop new technologies and it would limit their possible work places. An analytical chemist can now work in all sorts of industries, whereas otherwise he/she would be limited to water companies. The company that I studied for this chapter used to have laboratories that did everything in the same place.

> Because there are certain standards and practices within different laboratories, you've got laboratory practice. If you are working to a UKAS accreditation, it doesn't actually dictate a method, it looks more at how you do things and make sure you follow the method more than anything else. They don't really analyse the method to make sure that the method is correct, they look at what you are doing in actual practice and make sure the analyst is doing what he said he is going to do.

The UKAS accreditation judges a laboratory on 'good laboratory practice'. This is important for the laboratory, especially if it receives samples from clients outside the water company or if the water company itself is a client because it outsources the samples. With the accreditation in place it demonstrates that it is a place that can be trusted with the samples. The accreditation standardises certain practices, but does not standardise instrumentation. Differences in instrumentation in especially chemistry laboratories can, according to Keith, be caused by economies of scale.

> If you consider some kind of laboratory doing analysis for [name of company] and (their) commercial partners, then in terms of economies of scale they can afford to invest in a machine that is capable of doing a 100 or 200 samples a day per parameter. If you go to a small water company, right, then the chances are that they are not going to be able to afford that sort of investment, indeed, they won't have the workload to support that sort of investment. Therefore, they'll be using different instruments. That instrument may have as its basis a different analytical technique and therefore, obviously, the method is different. The thing is of course, it comes back to the fact that for regulatory purposes, the regulations say you have to use the approved, you know, recognised methodologies. Now, within those blue books of course, you will find, in most of those blue books, that you've got more than one method. So, straight away there is an opportunity there for different laboratories to use different methods and therefore different procedures, different practices.

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[5] Not all water companies have a *Cryptosporidium* laboratory. Many send their samples out to other laboratories.

As we will see, economies of scale play a less important role in the case of microbiology instruments, because they are very labour intensive and much less automated. However, even though there is a bit more room for alternative instruments, there are obstacles as well. As Henry (CAM/140503/WaterCo) explained me from his own experience, if someone has improved an existing method and wants to change this existing, accepted, and prescribed method, many tests have to be done to demonstrate that the new test is as good or better than the prescribed method. I will return to this in the section on the microbiology lab. A second barrier is that, according to Keith 'it is very difficult to find alternative technologies that get you where you need to be. The room for manoeuvre is restricted'. Field tests can be regarded as cheap alternatives, but they cannot give the analyst the level of accuracy and precision to meet the regulatory style of reporting.[6] Sometimes it is for instance the low detection level of a substance that is required by the regulations that make a field test unsuitable.

After these more general remarks, I will now look in more detail at the different laboratories: what happens with the different samples, do they take different routes within the laboratories, what concepts and patterns of materiality can we distinguish and what is the role of regulatory and other standards?

Microbiology lab

When the bacteriological samples arrive in the microbiology laboratory, taste, odour and conductivity are tested if this was not done in the field, for instance when it concerns ad hoc samples. The bacteriological samples are all taken in the same way and all bottles contain the same preservative which has neutralised the chlorine.

For the first analytical task, 100 millilitre of the water from the sample bottle is poured through a filter which is placed at the bottom of a measuring funnel (see photo 6.8). On the funnel one can read when the water reaches a 100 millilitre mark. However, sometimes the funnels have become dark and it is hard to read exactly when the 100 millilitre is reached. The analysts 'get a feel' for the 100 millilitres and try to be accurate. However, if they pour a few drops more it is not a problem. During this procedure, it is important to make sure that the lid of the bottle does not touch the table and is held upside down. The water in the bottle is needed for a second analytical task and should not become contaminated in the laboratory. The

[6] See also footnotes 156 and 189 in chapter 5.

funnel is made of plastic and sterilised in an autoclave before use. When the funnels go in the autoclave they are packed in paper to keep them free from contamination when they get out. To ensure that the funnels have been in the autoclave and to prevent confusion, the paper is held together with yellow tape which has stripes that turn black when the tape is heated (see photo 5.1). The black stripes are thus a sign for the analyst that the funnel is sterile and can be used. The filter is a membrane that is put under the measuring funnel (which has a magnetic base to hold it and the membrane filter in place on the filtration apparatus) with help of a set of tweezers that was held in flames and dipped in a purple solution. The water is drained through the filter and the bacteria (anything between 0.5 and 5 μm) remain on the filter. The analyst then lifts the funnel and picks up the filter again with the (disinfected) tweezers and places it on a plate with a pre-prepared red medium (membrane lactose glucuronide agar: MLGA).

I will make a short detour to explain how MLGA came into existence. This red medium was developed by WaterCo. If a laboratory wants to use a new method, it has to go through a validation process. It needs to prove that the new methods is equivalent or better than, and thus a good alternative to, the ISO method. A protocol was developed for this method that has become a new ISO standard. The technical aspects of the EU directive on drinking water are managed by the Article 12 Committee who will accept alternative methods that have had the proper validation. Other labs that want to use new methods like MLGA need to do equivalency and validation tests themselves to prove that the method works in their lab and with their water as well, otherwise they can be taken to court for not using a proper method of analysis.[7] To prove the effectiveness of MLGA, the microbiology lab collected data from 6500 natural drinking water samples. The results had to be compared with the results of other methods. The methods for regulatory samples are checked on performance by the DWI and need approval from the DWI before they can be used. I will explain why WaterCo changed the method from MLSB (Membrane Lauryl Sulphate Agar) to MLGA to look at *E.coli*. With the old UK method of MLSB the lab used to have two membranes to look for coliform bacteria and *E.coli*, one at 37°C (for coliforms) and one at 44°C (for *E.coli*), but there were other coliforms that grew at 44°C and looked the same as *E.coli*. Therefore, 50% of these presumptive results

[7] Apart from the ISO method for coliforms and *E.coli*, there is an Enterococci ISO method and a plate count ISO method, but there is no method for Clostridium perfringens. The method developed and validated will therefore become the ISO standard. Henry has developed this method using TSC medium.

turned out not to be *E.coli*. This was 70% of the positive samples that needed confirmation and thus further work (remedial action: resampling). Henry therefore developed a method (new medium) that was more specific for *E.coli* and that uses only one membrane, a single plate and detects *E.coli* after 18 hours. 99.9% of the time it turns out indeed to be *E.coli* with this new method. This has reduced the confirmation work and time and materials the first time around. It is an example of research that can be classified as efficiency research (see chapter 5) and in which the *dance of agency* may have been at work. Other water companies and the food industry now use the method as well.

Back to the microbiology lab. MLGA identifies various species of bacteria. The red media is placed upside down to prevent condensation touching the colony of bacteria when the plate is placed in the incubator. This way, the colonies do not spread out and become merged. The plates will then be incubated at 37°C (the basis for normal coliforms) only (the old method had one at 44°C as well for *E.coli*). The MLGA plates and other plates (e.g. m-ENT medium for Enterococci) are incubated at 16:00 and checked at 8:30 the next morning. At 10:00 the final read takes place. If yellow colonies on MLGA are identified, it means that coliforms are present. Green colonies are *E.coli* colonies. Any other bacteria that can grow would be pink. Red colonies on m-ENT would identify Enterococci. Both *E.coli* and Enterococci are indicators of faecal contamination of the water. Most of the samples (99% or more), however, have negative results. The laboratory was said to be 'all about *preventative monitoring*' (Lillie, MA/140503/WaterCo). The analysts look for *indicator organisms*. If no coliform colony does develop, it is unlikely that any pathogens are present. Presence of a coliform colony may indicate a potential problem long before pathogens become a problem. Henry said that the laboratory does not usually look at the primary cause of contamination (*Salmonella*, *Campylobacter*, etc.). The microbiology lab has the methods to do so, however, these are not suitable for routine monitoring because they are very labour intensive and take a long time (some pathogens leave spores and it takes a long time for them to develop). In addition, they are unnecessary in most cases. Henry:

> [Microbiology laboratories] look for *E.coli* as an indicator, not for pathogens. This is what the industry has done for the last 100 years and the absence of *E.coli* has protected public health.

Although he sees *Cryptosporidium* as one of the few organisms that behaved differently and needs treatment management, he regards it as highly unlikely that there are more emerging pathogens (and regulatory standards with regard to them) that need different analytical methods. Henry:

> The current methods are partly historically based and there is no necessity to detect more pathogens, that would be more expensive. If one wished to use direct methods the price of water would go up. The methods have to be appropriate for what they are used for. To understand bacteria dynamics is not useful or necessary for routine purposes and regulatory monitoring. One of the big issues at the moment is how to deal with that: better methods, at molecular level, could be developed, but do we need that?

This is an example of the influence of regulations on innovation practices in laboratories.[8] Henry told me that while developing much more sensitive methods for microbiological research may be of limited usefulness; this is different for chemical methods. Chemical parameters are not zero-based, but have nominal standards. It might therefore be useful to improve them and make them more sensitive.[9]

When I visited the microbiology laboratory, a positive result was identified. The sample was positive for coliforms and came from a customer's tap after the mains had been depressurised. A contractor had taken the sample. People were now going out to resample and take samples from the next-door properties. The results of the resampling would be known the morning after. In the mean time, the analysts further analysed the initial sample, which was called '*presumptive coliform*'. Parts of the presumptive coliform colonies were taken and put onto other plates. Known coliforms, *E.coli*, and Enterococci and other bacteria (stock cultures or test organisms are bought from the national standards laboratory) were also placed on

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[8] This seems to hint at the regulatory plateau, or in this case analytical methods plateau, that was discussed in chapter 5. Yet, it does not mean that companies like WaterCo are not aware of emerging pathogens. Henry writes a column on 'emerging pathogens and drinking water' in a company newsletter and works together with the WHO which pays attention to potential and emerging pathogens. At the time I am writing this chapter, UKWIR is looking into severe acute respiratory syndrome (SARS) as a possible pathogen in drinking water. Sometimes pathogens can be discovered by accident, as was the case with *Legionella*. This was identified when someone accidentally left a sample in the incubator, longer than it should have been, and saw something unusual.

[9] As we saw in chapter 5, the WHO and the EU set the standard for pesticides on the detection limit in the 1970s and 1980s. According to Henry better detection has a positive value based on the perceived public health risk.

these media.[10] These are used for positive and negative controls and ensure that the media works and that the result of the sample can be compared with something that is known. These new plates would go into the incubator and would be checked the next morning, together with the (re)samples that would be taken that day (both before and after sterilisation of the customers' taps to determine whether it was contamination of the tap or the water causing the positive result). On the conformation medium plate the colony was spread around and tablets (testing for an enzyme called galactosidase) were put on top and incubated at 37°C.[11] If coliforms of *E.coli* are present, the colony turns yellow. Other types of bacteria do not gain colour. The colony is also tested for the presence of oxidase. Some of the colony is spread onto a second plate which is incubated at 44°C (to test for a compound called indole, which is produced by *E.coli*). If the result of the further analyses is negative, then the presence of coliforms or *E.coli* is not confirmed and the computer will show that 'we thought we had a positive, but we didn't'. If the confirmation of the presumptive result is negative, which is unusual according to Lillie, it is called a null confirmation. Even in the case of the positive result, the pathogens themselves are not tested. The analysts only look for a confirmation of the presence of the indicator organisms.

The second analytical task is not set up to look for colonies of specific indicator bacteria, but to count the total colonies of bacteria that develop. With an electronic pipettor one millilitre of water is taken from the sample bottle and put onto a plate. This plate is larger than the plate with the red media that was used for the first analytical task. In a machine the media (yellow this time and called Yeast Extract Agar or YEA) is added. This media is a non-selective agar, which means that it will grow any bacteria. After every sample in the first task the funnel was replaced and a new sterile one used for the next sample, after every sample in the second task a new pipette tip is used. The plates of YEA are then incubated at 22°C and 37°C. The incubation at 22°C lasts three days. This detects the slow growing bacteria. The incubation at 37°C lasts two days and resembles bacteria growing in an environment at body temperature. The colonies are counted by placing the plate with the colonies

[10] Kleinman discusses a few examples in which a –in his case academic- laboratory buys standardised and commercialised products. Like with the kits discussed in the previous section, these products also can have both advantages and disadvantages for the lab. See notes 156 and 189 in chapter 5.

[11] If the colonies would have been too small to be spread over different plates or to be separated, they would have been grown up on a nutrient medium so that they could be used for the final confirmation.

on an illuminated grid and a magnifying glass above it (see photo 6.11). One presses (touching the glass) all the colonies one recognises and the machine counts and bleeps every time a colony is pressed.[12]

In the 1980 EU Directive there were guidelines that indicated that drinking water should have less than 10 colonies at 37°C and less than 100 at 22°C. These guidelines are not in the new EU directive or UK Regulations, which say there should be no abnormal change. If the number of colonies is larger, there might be a built-up of bacteria which will cause a deterioration in the quality of the drinking water. The results are entered into the computer and go to the monitoring department. A summary of the results will go onto the public register.

The analysis will show how clean the distribution system is and whether any trends in bacteria growth can be identified. If the analysts find twenty colonies in the distribution network one week, fifty the next week, and a hundred the following week, they know something is happening. This may result in action by other departments within the company: resampling or perhaps flushing of the system. This second analysis however does not distinguish the different species of bacteria.

In both processes, one can see that the materiality that is bacteria is treated in very specific ways. The samples were taken in a certain way to make sure that the bacteria would reach the laboratory alive and had not changed since the sample was taken. The analysts are very careful to preserve the bacteria that were sampled and those bacteria only. By washing hands every time one enters the laboratory, keeping the lid of the bottle upside down, sterilising the tubes and set of tweezers, and so on, great care is taken in making sure that no contamination (other bacteria) is added to the sample.

The media are made up in advance, often a week before they are needed, because they can only be used after they have been through a quality control. The quality control is done a day after the media are made. A few plates are selected, some are negative and are not supposed to have grown colonies, to others known coliforms and *E.coli* are added. This shows whether the agar grows what it was made for. The media have an expiry date (a week for MLGA and TSC (Trypose Sulfite Cycloserine Agar); a month for most others) and have to be used before that or thrown away. The media are sterilised in the autoclaves in which also the funnels and

[12] Until recently the analyst did count the specific number of colonies above 300. 300 was the limit. Whether the count was 301, 302 or 30.000 (which can easily happen during a summer period) did not matter. However, the regulations about plate counts have changed and the analyst now has to be more specific on larger plate counts.

bottles are sterilised. The autoclaves work with pressure and steam. One has to be careful to set the right temperature. If the temperature is too low, sterilisation does not take place. If the temperature is too high the media would be destroyed. The idea is to sterilise the bottles, funnels and media, so that any bacteria growth must have come from the samples.

Original in colour

Photo 6.8: Microbiological sample analysis; labour intensive

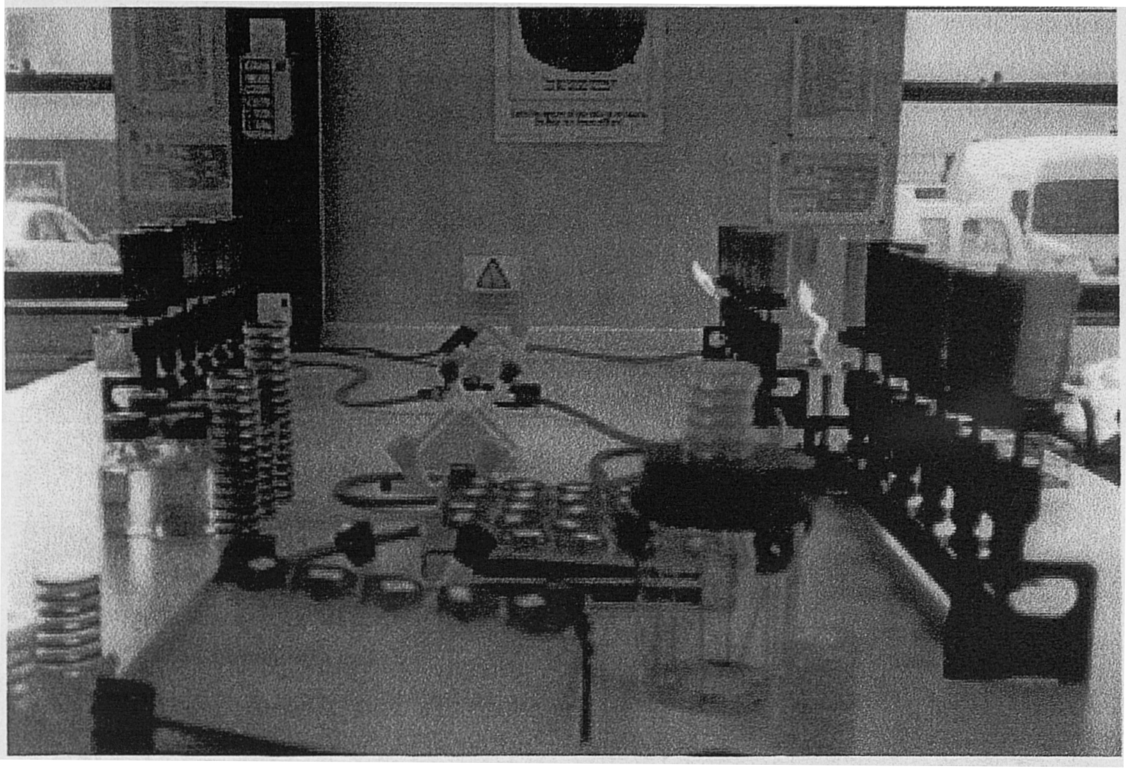
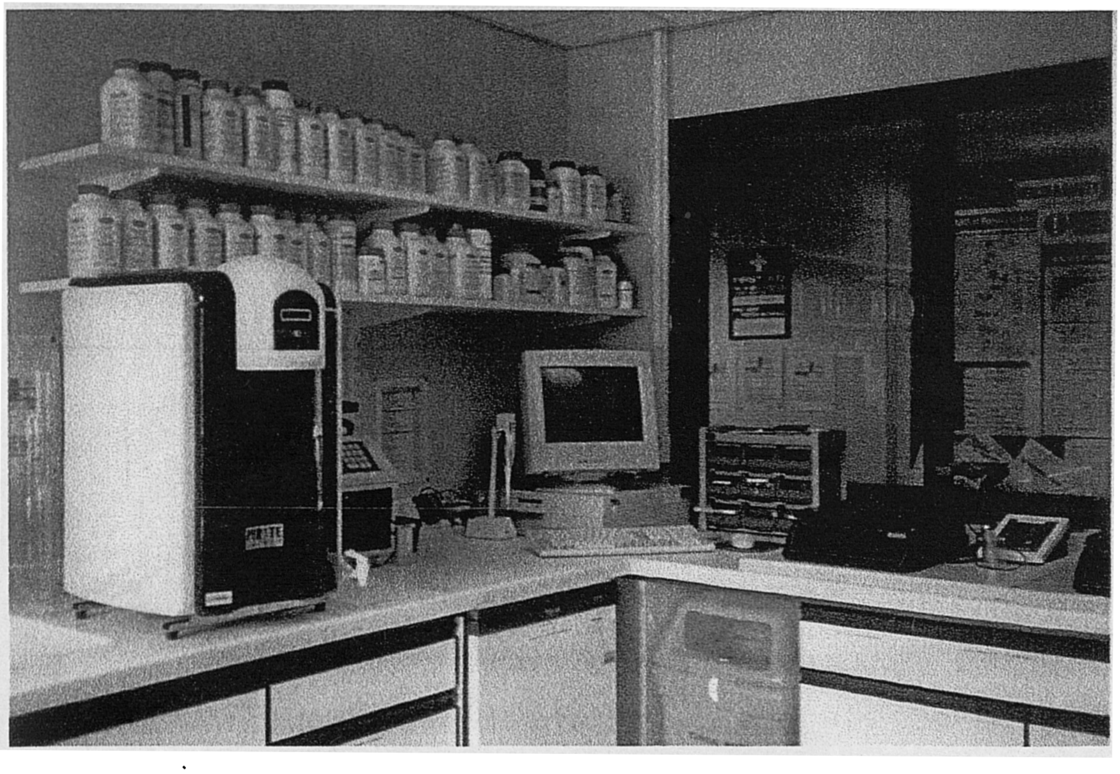


Photo 6.9: Room for media preparation in microbiology lab; the centrality of the computer also here



Original in colour

Photo 6.10: Automatic media preparator in the microbiology lab

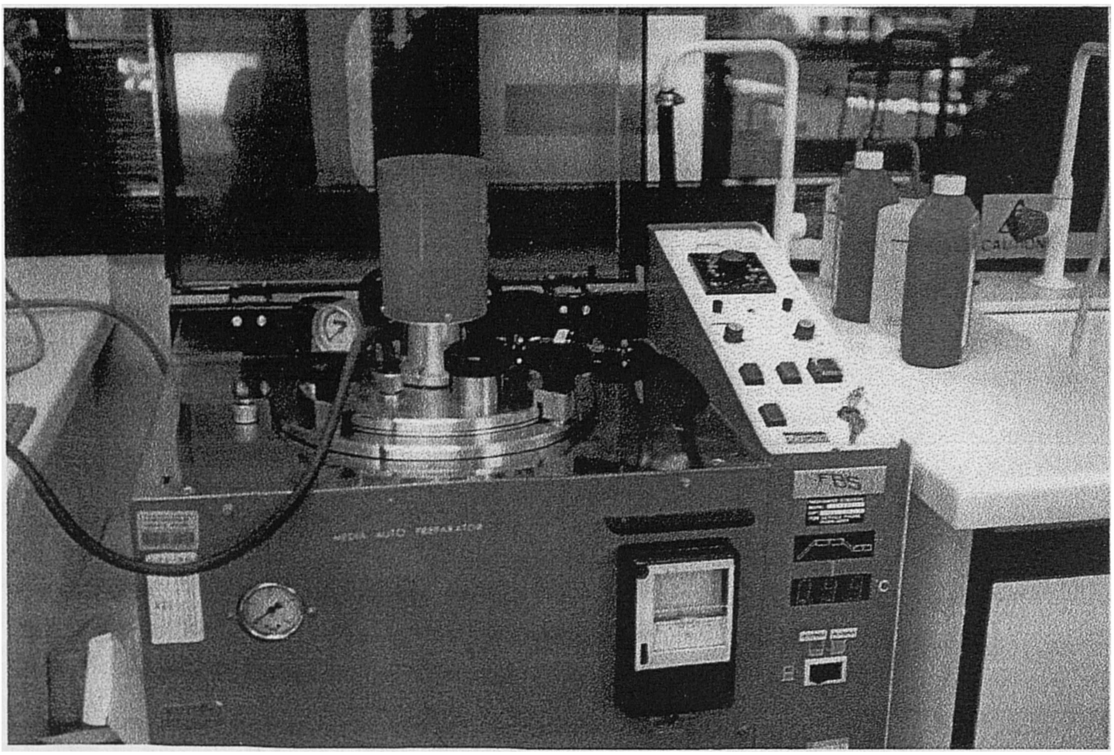


Photo 6.11: Plate count in the microbiology lab; only possible after colonies of bacteria have grown (material time)

The autoclaves and media preparators produce graphs that are checked regularly to make sure that they have done exactly the right time-span and at the right temperature. The temperature and time can also be read off the machine immediately. Although possibilities of contamination are a concern for everyone who analyses drinking water quality samples, this great care to reduce possibilities of contamination may be regarded as more specific for the microbiology laboratory than for analysis in the chemistry laboratory (depending on the substance to be analysed). The risk that bacteria in the microbiology laboratory contaminate a sample is higher than the risk of pesticides in a chemistry laboratory contaminating a pesticides sample. Pesticides are less likely to 'just be around' in a chemistry laboratory than bacteria in a microbiology laboratory. Wastewater samples, if they would come into the microbiology laboratory, would be analysed in a separate space. The laboratory is set up in such a way that if there is a contamination issue (something that, I was assured, never happens) the contamination can be isolated and backtracked until the point of origin is found. The label on the sample bottle is of great importance to this process. This label follows the sample to the different plates onto which the samples are transferred. The plastic sample bottles are thrown away after the sample has been analysed, but they are kept for one day in case one of the samples turns out to be positive and the label has to be checked.

Like other analysts, the microbiology analysts do not want to contaminate the sample with something that was not in the sample originally. However, unlike the analysis of samples in other laboratories, microbiology analysts detect bacteria by increasing the amount of the "substance" under analysis.[13] Both the media and incubation help the growth of certain bacteria into colonies which can be seen and counted. The colonies were already there, but too small to be seen. Only by growing them on different media into larger colonies can one analyse which bacteria and how many of them are present.

In this analytical process, time is a very important factor. And not just social order time scales as Knorr Cetina suggests. Microbiological samples have to be transported to the laboratory and analysed fairly quickly, otherwise the bacteria may die or the material may deteriorate. Keith:

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[13] Lillie, who worked in a dairy laboratory before she came to this laboratory, explained that water is quite a hostile environment that can have few nutrients present and chemicals, such as chlorine, which will injure the bacteria. This is completely different for something like cheese. For cheese the plate counts used to be much higher.

> The previous microbiology guidance, called Report 71, referred to the fact that (with) microbiological samples, the analysis should commence within six hours of the sample being taken. The wording has been changed to some extent in the latest regs, but nevertheless it is recognised that you don't want to be keeping microbiological samples for any length of time, even in the necessarily ideal storage condition. Because the bacteriological population will die out. And if you want to be able to reflect the quality of the water at the time you took the sample, you really need to do the analysis as quickly as possible.

Oliver also mentioned the change in guidelines. Now samples have to be analysed within 24 hours. One may want to do the analysis fast to get the results as soon as possible, but the timing has to be good: one has to wait until the bacteria and colonies have grown.[14] If one would check the result too early, not all colonies may have formed and one may miss important information. After a certain time, the analysts know from experience that no new colonies will grow. The process of growing colonies is very hard to speed up, because it is determined by the material developments of the colonies. Keith:

> I think there is certainly some reluctance in terms of trying to reduce the incubation time. The sort of things that we would look at is trying to reduce the time between taking the sample and getting it into the incubator (...) you do the (content) preparation on the site and it's been incubated as you transport it to the laboratory.

An earlier result cannot really be achieved. However, one can try to anticipate what the result will be. Keith:

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[14] Six years ago, WaterCo had a trial of starting the incubation already in the van. Helen had not taken part in the trial, but three other quality inspectors did and Helen told me the trial had caused some problems. In the lab, since all samples are analysed in a short time-span, analysts can read the results off at the same time. In the van the incubation starts at different times for every sample and the readings will have to be done at different times as well. WaterCo has not yet continued the trial. Oliver also mentioned this: 'Henry has been doing some research, on site, where, starting the incubation process in the van and having mini-filtration and incubation systems in the vehicles to shorten [the period of analysis] and to look at using different media that would give you a more rapid growth [of bacteria], but we haven't come up with a solution on that as yet.'

> Coliform/*E.coli* is a 24 hour test in terms of getting a presumptive result. We speed that up by getting them to actually look at the plates a few hours prior to the end of incubation anyway. And (that attempt) gives us an opportunity to put in place any operational activity that we need to do. But having got the presumptive result, we respond generally fast unless our risk assessment or other information suggests otherwise. (...) If you actually get a confirmed result out of that, (it is in time and on top of things).

If one can already identify a positive before it is fully grown, then that is not going to change by letting it grow a few more hours and action can be undertaken. The quote above also suggests something about the way in which results are interpreted and the way in which action is undertaken as a consequence of the result. The analysts look very much for a presence or an absence of indicator organisms. To count the organisms is important for trend analysis, but one count at one particular day is unlikely to result in action by other departments. Counts over several days or weeks, which show a particular trend, may have such consequences. However, a result in which an indicator organism is positively identified will often, if not always, have immediate consequences. This will start with resampling, but may lead to advising people to boil their water, and an investigation of the problem, which may in turn lead to work on the distribution system.

To make sure that the analytical instruments in the microbiology lab work, they are, like the instruments in the field, tested every so often. One example is the pH of the microbiological media. Bacteria grow best in a pH of seven or seven and a half. If the media are below or above this pH value, they need to be adjusted before they go into the autoclave. Once a week the pH probe is checked against known solutions with a pH of four, seven and ten to see if it indeed gives an acceptable pH range. A second example is that after every ten samples a blank sample (sterilised water) is going through the analytical process to check that everything is working properly. These blank samples are taken in glass bottles and can be differentiated on that basis. This proves that the method works and no contamination has occurred. Chris explains:

> Tests will be done by the water company on *typical samples* to determine the performance of the method. Even if a water company moves an instrument

from one part of the laboratory to another, it will be expected not to do the full suite of tests, but it would be expected to carry out some checks to ensure that the values won't change. And all of this is inspected by DWI from time to time.

Other examples are the check to see if the media grow what the analysts want them to grow and an alarm system that is related to the temperature of the incubators. Both the fridges and incubators have tolerance levels that are set by the national guidance. Incubators over 40°C have a tolerance level of 0,5°C, otherwise one could put the incubator at 60°C and 'prove' that the sample is negative by killing the bacteria. The temperatures of the incubators are monitored on a computer and logged in archive files. If there is a fluctuation in temperature an alarm shows at the computer screen. This can just be because someone opened a door of an incubator to check on the samples. However, the person who does this, has to write his/her initials down and a comment to explain what happened. A minor fluctuation is acceptable as long as it can be explained. The archive files on the computer are all part of DWI audits and the laboratory often has its own checks that are stricter than the ones by the DWI: 'it is safer to overdo things'. The laboratory is not accredited. According to Henry, accreditation would only be useful if it was a commercial laboratory. However, he stated that this laboratory was as good as or better than many accredited laboratories.

The analysts can generally interpret the significance of the test results.[15] If a tiny coliform colony is growing for instance, it is likely to come from a biofilm, whereas if it is a large colony it is more likely to have come from surface water or soil. The bacteriological standards for drinking water are set at zero, so the analysts

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[15] Analysts who know the area are better able to interpret the results and can, in this way, be proactive. This is more likely the case in a smaller company and/or in company laboratories. Keith: They potentially know what a result might be. And therefore they are perhaps more proactive in making sure that the information gets to the right people at the right time. Because a centralised laboratory doesn't necessarily have that level, if you want them to be proactive, you've got to really specify what you want them to do, every time. You know, you've got to give them clear guidelines, clear parameters, for doing extra work and that becomes very difficult, becomes very bureaucratic, very difficult to capture.' Rosa (WQM/270502) adds: 'A small company has the advantage that it knows its area a lot better. In a large company you are only gonna know a small part of the area, so you would be less likely to know the whole picture.' Yet, no company told me that having their samples analysed in a non-company laboratory had disadvantages. Rosa: 'We don't have our own laboratory, we use other company's laboratories but that is just using them as contractors really, no difference from that point of view.' In fact, sometimes contractors' laboratories were regarded as more independent. On the other hand for Lewis (WQM/181102) having an own laboratory means independence, since then samples can be analysed at any time of the day or night, if necessary.

will know immediately when the sample does not comply with the regulations. Most of the samples that come to the microbiology laboratory are regulatory samples. Some samples can also be analysed for operational reasons. The laboratory can do non-regulatory analysis and investigations on specific issues. One example is the analysis of algae, a biological analysis that has been brought into the microbiology laboratory. Algae can cause taste and odour problems, can block filters at treatment works, and make the water toxic, so it cannot be used for swimming. The type of problem they cause partly depends on the type of algae. Diatoms (Baccilariophyta, e.g. *Asterionella*) for instance can cause a taste like geraniums and contain a substance that is like glass/silica in the cell wall. The algae will die off in the treatment works, but the silica is very hard and does not break down. Excessive amounts of these algae can block some types of sand filters. If one knows there is a problem, one can take water from a reservoir or river at another depth where the problem is less. The samples are usually taken at run off points, not at different depths, but of course it is possible to investigate this. Algae are mainly analysed from April to October when there is most sunlight and the algae grow. Samples are only taken in portions of 5 millilitre, otherwise there are too many to count. On a sunny day, the number of algae can double in a few hours. To identify the algae, the cells of the algae have to be counted and this can be difficult (the algae can be folded for instance). Experience, books and an identification guide will do the trick.

In the analysis of a sample, different sorts of times play a role. There is a material time in the sense that the bacteria only grow so fast. There is also a regulatory time: the sample has to be analysed within 24 hours. Moreover, one can speak of an organisational time. If the samples would all be brought to the same laboratory (instead of to three different ones), the longer routes and rush hour would mean that some samples would arrive late and the results would only be known later the next day. If a result would be positive, there would not be enough time to react. Oliver:

> If there's *E.coli* there, we might want to chlorinate the main. And we might want to issue boiled water notes. If you are starting that process after two or three o'clock in the afternoon, then the chlorination of the main isn't gonna be complete until ten o'clock, midnight, well, then we've got to go and take samples from customer's houses to confirm. Can we do that at that time of the

night? No, not really. And then those samples are gonna be really late off the next day.

The last time that can be distinguished is the company's acceptable response time. WaterCo tries to provide a full response the next working day to any microbiological failures. The company even wants to try to shorten the analytical window and get microbiological analysis done within six hours.[16] This combination of times impacts on the practices of the microbiology laboratories. They are one of the reasons for the existence of three microbiology laboratories in the company and help to keep working hours reasonable for the analysts in the laboratory. WaterCo used to have a large number of microbiology laboratories which all used their own methods. Now they have been reduced to three laboratories which have been standardised and now use the same methods. The times also influence that the sort of innovation that can be seen in laboratories is organisational innovation (reduce the time between taking the sample and getting it into the incubator) and innovation in making instruments and analytical methods faster to reduce the material time. Regulatory samples and operational samples can be subject to different times. Oliver:

> Operational samples, we will fridge them at the depot and analyse them the next day within the 24 hours. For regulatory samples we will analyse them on the same day they are taken.

The regulatory time thus does not necessarily influence operational samples.

In conclusion, quality assurance plays an important role in the microbiology lab. The media, fridges, analytical methods, and incubators are all subject to a regime of quality control. The different types of time, especially material and regulatory time, point to the co-construction between materiality and standards. Both have to take the other into account. The regulatory time, it is assumed, is partly set to ensure public health. However, bacteria only grow so fast and this process cannot really be speeded

[16] It was noted that the response time of local authorities, who sample for water and food at factories, is much longer. They may occasionally find *E.coli* in a factory, or restaurant and then ring the water company to ask whether it is the plumbing on the site or the water: 'where is the *E.coli*?' The water company then takes some samples to ensure that it is not the water that causes the problem. But, as Oliver says: 'Quite often those sample results are five days old when we get a call from the environmental department'.

up. They grow under carefully controlled circumstances that are subject to a strict regulatory regime. The regulatory zero standard for (certain) bacteria in the water and the use of indicator organisms then makes it easier for the analysts to identify a non-compliance as soon as it shows.[17]

[17] Lillie states, in line with chapter 5, that the standards for food and bottled water are less strict and a certain level of bacteria is allowed.

Chemistry lab

Whereas the microbiological samples enter the microbiology laboratory in the afternoon and are then immediately prepared for analysis, the samples for the chemistry laboratory arrive at the laboratory at four o'clock in the morning. The chemistry laboratory is an independent laboratory that has a contract with WaterCo. The number of samples can vary from 250 to 700 a day. The samples do not just arrive in plastic bottles as in the microbiology laboratory, but in plastic, glass, and amberglass bottles. The laboratory has its own label system and the sample bottles therefore get a label from the laboratory in addition to the WaterCo label they already carry. The samples then go to a central room from where they are picked up by the analysts. The analysts are generally specialised in one group of parameters. The laboratory is organised into work units per group of parameters. I will now give a short overview of the laboratory, which cannot be as detailed as the overview of the (practices in the) microbiology laboratory because of the large variety of samples and of instruments with which the samples are analysed.

Firstly, there is a taste and odour work unit with its own enclosed laboratory area. The people who work here have been trained in and selected on their ability to smell and taste. When they work they cannot smoke or wear perfumes. The human senses are used for screening. If a sample has an unusual taste, additional tests will be carried out. Other than regulatory samples, the majority of the remaining samples come in because of taste and odour complaints. Before the samples can be tasted, the chlorine needs to be removed. If the sample is a raw water sample, microbiological analysis has to prove it safe to drink first. Over the last ten years the taste and odour check has been developed into a formal test.

Secondly, there is a work unit for nutrients like ammonia, phosphate, nitrate and nitrite. The analysis undertaken in this unit is mostly automated and can produce several hundred results each day. The colorimetry instrument is a multi-channel machine (see also photo 6.12) and uses a pipette to take a small amount of the sample and to add the reagents appropriate to the various channels. This is heated and produces coloured complexes. The results are measured and cross-checked against standards (which are of a known quantity) and are then updated in the computer when the worksheet is full. This happens a few times a day.

Thirdly, pH, conductivity, colour and turbidity are measured as another separate work unit. The conductivity is analysed first. Conductivity used to be analysed first, because electrolyte would come from the probes and that would influence the result of the conductivity test. The person who guided me around the laboratory was not sure whether it was still the same method, but conductivity was still analysed first. There is a specific length of time for each test to come to a stable reading.[1]

Fourthly, there is a laboratory area for the organic analyses work unit. I was told that it was convenient that this unit was separated from the rest, because that would reduce the chance at cross-contamination from volatile organic chemicals utilised within the main laboratory. With help of gas chromatography different parameters are separated. The different compounds in the sample go along a plastic coated thin glass column in the form of a spiral at different times. When the instrument detects something, a peak appears at the screen. This is then measured against the standard. Also mass spectrometry is used. Apparently, this gives a higher degree of confirmation. The sample molecules are here differentiated into fragments. This is a particularly useful technique because iron fragments can be checked specifically and there is less chance of interfering compounds (one can check specifically which iron it is). It is like a fingerprint. If one is looking for unknowns, one can check the found compounds against a huge spectral library. This instrument cannot do as many samples as the one in the nutrients unit, because it is limited by the possibility to separate peaks. The whole process can take twenty to sixty minutes.

[1] The person who guided me around thought that different time lengths may exist for different waters, but the analyst said there is a set time that applies to all.

Original in colour

Photo 6.12: Multi channel technology in chemistry lab; organisational time is important (wait for enough samples to come in and be analysed at the same time to fully use the machine's capacity)

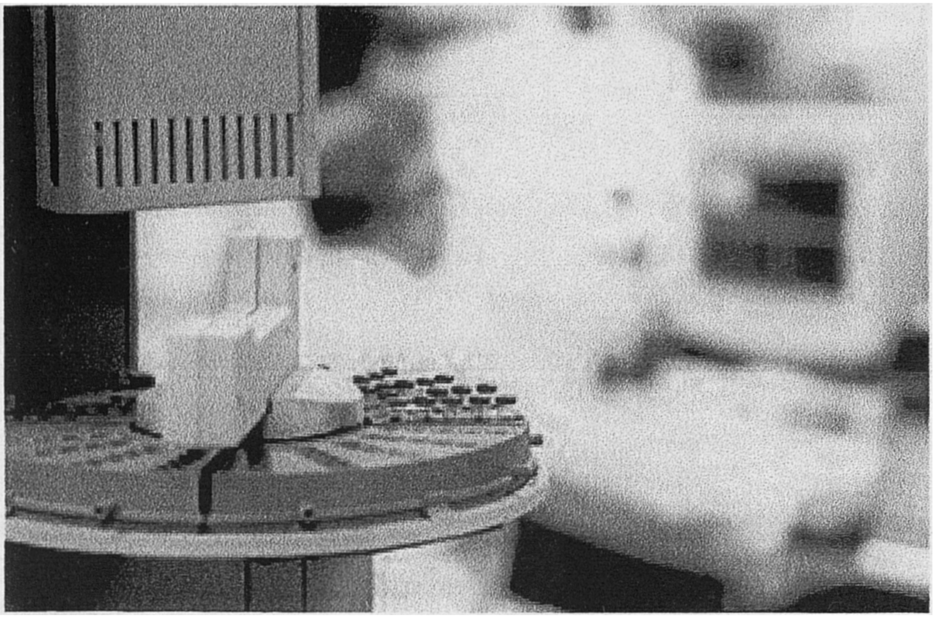
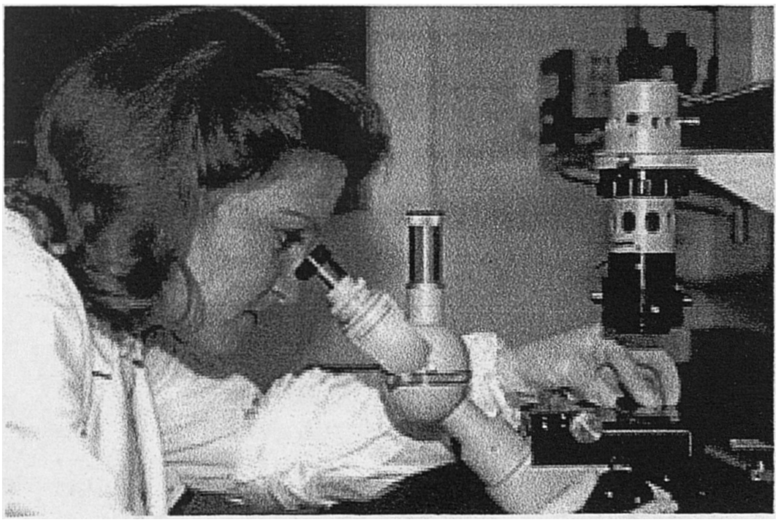


Photo 6.13: Technology for investigating material properties; 'out of place' in the chemistry lab, but 'in place' in the microbiology and *Cryptosporidium* lab



A different instrument analyses disinfection by-products against known concentrations. For all instruments, quality controls are in place. I was shown a chart indicating the capability of the instrument based on a particular validation method which is accompanied by strict rules. The chart shows a normal level and warning levels. The analysed quality control samples should fall around the normal level, in between the warning levels. When I looked at the chart, I could see that the sample results had been fine for the last few months, but that recently a bias towards the lower warning levels had emerged. It was likely that the instrument –and not the samples- was the cause and had to be fine-tuned. In this unit I was also told that occasionally the DWI quality standards contradict UKAS audits. This makes decisions on 'good laboratory practice' sometimes difficult.

Fifthly, there is a central space. The samples are organised here and people's worksheets tell them which samples they have to analyse next. They will have to collect this sample from the trolley in the central space and take them to their unit. This space is also used as a preparation area where acid is added to metals, which are then heated up. Cyanide and total organic carbon (TOC), which does not have a set prescribed concentration or value (pcv), are analysed here too.

In the sixth and last room some metals (lead, cadmium, mercury, arsenic, manganese, etc.) are analysed. They used to analyse these with help of flame methods where one measures the light absorbency. However, because of explosion danger they could not be left overnight. Now ICP-MS techniques is used. ICP-MS is a relatively new technique for the determination of trace elements in solution and stands for inductively coupled plasma mass spectrometry. Because of its superior sensitivity, ICP-MS is a brilliant method for most determinations of trace elements. Yet for mercury a different method is needed, since often losses are found due to both volatilisation as well as adsorption to the container walls. For organics (especially chlorine pesticides) a different technology is used; the GC-MS (gas chromatography mass spectrometry) technique is the most used for these kinds of organic compounds.

Going from a microbiology laboratory to a chemistry laboratory, a number of things struck me. Compared to the microbiology laboratory there is a huge variety of bottles, substances to be analysed and instruments. This comes back to the point made in the section on sampling: the overall water quality can only be composed of an analysis of different sub-samples with different methods, all of which represent one small part, one parameter, of water quality. Whereas taste and odour samples have to be taken in a glass bottle, low-level metal would stick to the side in a glass bottle and the result would not be accurate. Metal therefore has to be taken in a plastic bottle.

The way the samples are analysed here is different from the way they are analysed in the microbiology laboratory. Instead of looking for a presence or an absence of a particular parameter, chemical analysis focuses on how much of a particular parameter is present. *Precision* becomes important. Precision is important in the microbiology laboratory in the sense that the process has to be carried out precisely. In terms of the result of the analysis, precision has a different meaning in chemistry analysis. In the words of Wise (1995: 3) 'Precision is everything that ambiguity, uncertainty, messiness, and unreliability are not. It is responsible, nonemotional, objective, and scientific. It shows quality.' According to Wise, precision cannot exist without standardisation. If one wants to establish the reliability of a measurement, one has to agree on what this reliability is and thus 'precision requires standardization' (Wise, 1995: 8). In other words:

> [W]e need only observe that claims to precision have minimally required that successive measurements should yield very nearly the same value. (...) [Measurement has to be consistent] with results obtained by others, typically under different circumstances and with different concerns. Precision thus requires agreement about standards of comparison. This point is important because it shows that precision is never the product simply of an individual using a carefully constructed instrument. It is always the accomplishment of an extended network of people. Precision within the laboratory requires an extensive set of agreements about materials, instruments, methods, and values that reach out into the larger culture. (...) Seen from a somewhat different perspective, reliability is never a matter simply of a reliable instrument. It is also a matter of people judged to be reliable using methods that display their reliability. Establishing precision is also a matter of establishing credibility and trust.[2] (Wise, 1995: 8-9)

[2] This is a similar argument to Latour's comment (1983, 1988) that in order to make (experimental) claims valid in other laboratories in other parts of the world, the laboratories had to be equipped in the same way as the original laboratory (and thus standardised) and the scientists have to agree on the methods of analysis, etc.

In the laboratory, the reliability emerges in the relationship and trust amongst analysts; between analysts and instruments; between instruments, analysts and the objects of analysis; and sometimes between instruments and other instruments. During a little tour in a wastewater laboratory, an instrument produced a result that was 'abnormal' and not within the regulatory margins. The person who showed me around did not 'blame' the wastewater itself, or the instrument that had done most of the analysis, but the analyst who was new and had probably done something wrong. The relationship of the analyst with the instrument and/or with the water sample was not yet regarded as trustworthy. However, had the instrument been new and the analyst very experienced, the lack of trust would probably have been ascribed to the instrument and perhaps its relationship with the water sample. A result of an analysis is only looked at twice if it does not fall within the boundaries of what is normal. If it is an 'abnormal' result, it does not automatically lead to the conclusion that it is the water quality that is off. In every case it is decided who and what is trustworthy and who and what is not.

In the chemistry laboratory, one can see all these elements come back. The training the analysts have had, is put up on the walls of the laboratory. This shows the reliability and experience of the analyst. Keith:

> Within the whole concept of regulatory analysis and in the, I suppose to some extent accreditation, laboratories have to be able to demonstrate that the analysts are competent. I mean in that respect they've got quite an extensive system within (the name of the company). You'll see every analyst has progress charts on the wall where it demonstrates their individual level of training in a particular method and where further development is required. And that is very powerful in terms of demonstrating competence in various methodologies. And of course all those training records are part of auditing. So, I could come in, DWI could come in, any other client could come in, ultimately UKAS would come in.

However, the training of the analysts is not only important in order to demonstrate the trustworthiness of the laboratory to the outside world, it is also meant to reconfigure the scientists in the words of Knorr Cetina (1995: 146):

> If we see laboratory processes as processes that 'align' the natural order with the social order by creating reconfigured, 'workable' objects in relation to agents of a given time and place, we also have to see how laboratories install 'reconfigured' scientists who become 'workable' (feasible) in relation to these objects.

The reliability of the instruments develops through validation tests and quality control, like entering blank samples into the process. If a blank sample has a high result, contamination may have slipped in and the whole process of analysis needs to be scrutinised. Some compounds or contaminations are easier to backtrack than others. Pesticides are not a problem, because DDT is not lying around the laboratory. But metals and dust are everywhere. The reliability is audited both internally (WaterCo) and externally (DWI, UKAS). As we have seen in the example about the organics laboratory above, most samples analysed by a specific instrument should be in between the warning levels on a chart and on the normal level. If the results of many samples happen to be on the low or high side, it is mostly assumed that the technology needs to be adjusted, not that there is something seriously wrong with the water. This also shows that there are certain expectations of the water. The water is usually reasonable stable and often one expects certain outcomes. The samples will have been taken properly, so no other contamination could have entered the bottle.

Agreements on what constitutes a reliable method and precision are to some extent laid down in the regulations that partly prescribe what methods should be used. However, the methods are not entirely prescribed as we have seen in the introduction to this section. Keith said that often more methods are recognised and which ones a laboratory chooses depends, amongst others, on economies of scale. One can also choose a new method as long as one can prove that the results are of the same or better quality as the results of the approved methods. Yet, there seems very little need for innovation of chemical analysis methods. Keith:

> Some of the current methods are thirty years old, although there will have been enhancements. Take a multi-channel analyser, in fact, if you look at the actual methods of each stream, they are merely the methods that were used thirty years ago. I say thirty years ago, even longer than that, when I worked in the industry. If you go back, you'll find that some of these blue books go

back to the mid-seventies or so. The only thing that has changed is the sophistication of some of the detection systems.

Judith adds that enhancements have often been in the form of automation. Automation is often just taking standard chemistry to an automated form that is more efficient.

> Take BOD [biochemical oxygen demand], we used to do it standing there and putting a probe into each bottle. And now you've got a robot that does that for you, so it's a little bit quicker for the analyst, because they can go and do something else while it's being done. So, it's no real change of the method, but we've got a robot now doing what a person was standing doing. So, it's an enhancement, especially if you are the analyst.

Samuel phrases it this way:

> Things change and 25 years ago I was doing the analysis with the test tube. And now I wouldn't find a test tube if I walked into the company's laboratory. So, it will change. I think that the basic principles probably haven't, but you know the way in which we do things has, and the chemicals that are available, the better controller the processes, but the basic principles are no different than they ever were, although probably we've added some.

The colorimetry instrument mentioned above has developed in a similar way. It is an instrument that came from hospitals where it was (and still is) used to analyse haemoglobin. It is an instrument that just automates standard chemistry. At the moment the chemistry laboratory is thinking about buying an even larger machine that will be quicker.

The changes that have been made to instruments thus mainly have to do with the detection system. Real innovations are costly and are mainly left to research organisations and universities. Water companies read what new methods are being developed and sometimes take existing technologies a step further, by automating it, changing the level of detection, or transforming it from an instrument in one environment to an instrument that works in another environment (like the colorimetry instrument). It is mainly efficiency that is improved.

The need for precision in analytical chemistry can be regulatory or non-regulatory. The regulations require any methodology to be able to measure a certain quality to one-tenth of the prescribed concentration or value (pcv). This means that presumptive results that are so important in microbiology do not really exist in analytical chemistry. Keith:

> If the results have not been subject to standardisation or quality control, then it is effectively a semi-quantitative result. And often that can be good enough for an initial response. But often we are in the position that ultimately, if it's an event of any significance, DWI wants to know. And if DWI want to know, they want to know accurate results, so we are almost forced to ask the lab to get down the route of proper analysis. Simply because somebody wants the results and wants to know that those results are correct.

It is the regulatory regime that determines what sort of tests are done and determines that most samples must be analysed in a 'proper' way. The regulatory standards also affect innovation processes. However, the limits of detection of several technologies have lead to a situation in which the overall performance of instruments 'far exceeds the general requirements of the regulations'. (Keith) These limits of detection do not only have a regulatory task; they are also used for operational control. Keith: 'In terms of the expectations that we have of [the chemistry laboratory], we expect them to have a method that is better than the DWI requirement, because operationally we want them to regularly get down to those lower levels'. Getting down to those lower levels seems to be of particular importance with regard to those parameters that are used for operational control. Turbidity is regarded as important in this respect, because turbidity monitoring is required on sites where *Cryptosporidium* filters are at work. Reaching the lower levels proves more difficult for some parameters than for others. According to Keith, the level of detection of metals is now much better than it was thirty years ago. Not all metals however have the same limit of detection.[3] Keith:

[3] According to Keith also bromate 'historically was a challenge'. There was one supplier of equipment and when the instruments aged, the technology was not very good anymore. 'But now, I think, we've got back to a position where ok, it is still a bit of a challenge. We are down at the bottom end again now in terms of bromate. I mean if they were to push the bromate level down any lower in terms of regulations, then that might be a bit of a challenge, because you are looking at something (...). Yes, I mean bromate was a bit of a challenge and perhaps, I think we are there.'

> It may be that you've not necessarily chosen the lowest sensitive line for instance for a metal, because there is a risk of potential interference. So, you may have selected a less sensitive line for nickel for instance than you have for (another metal). On the other hand, something like iron for instance, the analytical range for iron is largely, I suspect, broader, longer, wider than it will be for lead and the reason being of course is the in terms of the sample that we provide (the chemistry laboratory), the range of iron values can be quite large. With iron you can get discoloration and this can reach quite high levels.

The analysis of organics is very complex because there is a broad range of organic materials and the analytical methods are quite weak at the low detection levels. If one tries to analyse a lower level, the level of noise goes up. For this reason organics currently do not have to be analysed below 25% of the pcv.

In the previous chapter we have seen that most negotiations around standards take place around nominal standards. This can be because everyone agrees that microbiology standards are so important that they have to have a zero standard. It can also be that nominal standards leave more room for negotiations of the boundaries. Analytical chemistry faces a similar question: how low do we want the technologies to detect certain parameters? At some point, there is no reason to spend more money on developing instruments with lower detection limits, if this is not necessary.[4]

In addition to regulatory and material reasons, also economical reasons play a role in what the laboratory looks like. In the microbiology lab we have seen how important time can be. There it was principally *material time* that determined the analytical process. Time is essential also in the chemistry laboratory, but in a (partly) different way than in the microbiology laboratory. Analysis of some parameters are slower because of digestion time. Digestion time means time to release the metals, dissolve them, add something and heat them up. In principle they can do the samples in the morning and have the results at the end of the day, but usually it takes about two or three days. Time is not as essential in terms of health risks in the chemistry laboratory. Keith: 'Chemistry analysis is definitely useful, but does not give speedy security information in terms of health like microbiology does'. For some parameters time is important in the sense that they need to be analysed soon to *keep their*

[4] See footnote 26, chapter 5.

'material properties'. Samples that need to be tested for other parameters can, under the right conditions, be stored for quite a while without anything happening to the 'material substance'. Keith:

> Things like phosphate or nitrate or sulphate or nickels are not going to change over several days, provided you have exactly the right sunlight, and at 28 degrees. As long as it is reasonable storage and control and it is taken in the appropriate container, then much of the chemical (parameters) remain fairly stable. So, there is a few that are like microbiology which need to be processed fairly quickly, but there are others which [are] quite able to [be] processed at a much later date, if we can do it that way.

In theory one could analyse some samples long before some other samples on the basis of their *material priority*. However, there are other types of priority. Samples taken for operational control reasons would often have priority above samples taken for regulatory control (Keith: 'some of it is of course just gathering data for the regulations'). Perhaps these can be called *functional priority*. And there is *economical priority*. An example by Keith:

> In a batch of analysis of fluorides for instance, there will be fluorides there which are operational control check samples to make sure that the fluoridation (works) are working correctly, but there will be some which are just for the regulations and don't need to be on the public register technically for 28 days. But we've got a two or three day term in time for fluoride, because some of the (results) we want fairly quickly. So, they are all covered by that two or three day term.

At the moment these fluoride samples are analysed together for two reasons. The electronic system does not allow the laboratory to separate the different functional samples and it is economically cheaper to do them all in one go. This can be called *economical time* instead of material time. It may be cheaper and perhaps more efficient to analyse 100 samples at the same time and to the same detection limit, even if this detection limit is not needed for all the samples. In this case, the laboratory may sometimes also have to wait until the 100 samples are collected. Keith:

> There's a cost you see in terms of running more than one instrument or having to switch methods or run samples separately. The methods machines, the carrousels are capable of taking 200 samples a day. If you are only sending in 50 regulatory, you are not using the efficiency of the machine. Run most 50 and then retune it to a different limited detection to run another 150. It is far better to just broadband and run everything together.[5]

Whereas material and functional priorities would probably cause individualisation in terms of analysis of the sample, the economic priorities cause standardisation. Keith himself says: 'we analyse it altogether and therefore all the time-scales are condensed together'. Prioritisation of sample type has however been considered within the company. Economic reasons will probably decide on this. Keith:

> We don't say, these are operational, we must put these ahead of the queue. It can only work that way if we actually let [name of chemistry laboratory] know specific sample numbers and identify them and say, can you pull these out of the process, put these ahead of the queue? And that creates noise in the process of course. There are some powerful arguments for that, because ultimately if you can do it by prioritisation of sample type, then [name of chemistry laboratory] could maximise perhaps some of the efficiencies of stable things like methods in terms of the equipment capability and batch them into batches of a 100 or whatever and just run them once a month. And there might be potential savings, and then again, there might not. It just depends on the overall balance.

If prioritisation would take place, samples for operational control would gain a more important status than regulatory samples. Parameters like lead that gives information on how the quality of water might cause lead pipes to dissolve and other metals that are used for process control and to treat water would become more prominent within

[5] Keith argues that this is easier on the clean water than on the wastewater side: 'And largely, I mean, it's probably easier for water supply, because generally even with raw waters and potable waters, the actual range of results that you are likely to get or require is relatively quite small when you compare it to the waste side where instruments have to deal with trade wastes, which can be in 1000s of milligrams per litre concentrations down to effluents which might be down to microgram per litre. And there is more of a challenge there'.

the chemistry laboratory. At the moment, although lead is regarded as very important because the pcv for lead is coming down, lead is treated like every other parameter and regulatory standard within the chemistry laboratory. The regulatory standards are more complicated here (they are numerical) than in the microbiology laboratory. Analysts often work with one particular set of compounds and were trained in the pcv's for these compounds. However, there is no need for them to remember all pcv's for all parameters. Keith:

> Within the business I would suspect that everybody is appreciative of what a pcv breach means, cause ultimately it affects the company's compliance. And that is a public thing. And I would suspect that the laboratory services would appreciate that as well. Whether that is fully thought through down to the bench level within the analysts within the laboratory is difficult to say. I think it comes back to the professional approach of the individual. I mean there are people and I am not knocking them at all, there are people who are just interested in 9 to 5, aren't they? You know, this is a job, 9 to 5. And as long as they are doing the job correctly and give no cause for complaint, they are happy.

The analysts in the laboratory are focused on analysing the result in terms of the analyst-instrument-sample triangle. However, they do not have any knowledge of the area where the sample comes from (like the quality inspectors and partly the microbiologists). This makes it more difficult to analyse where something went wrong if the result is off. If one knows a source has just been switched, it is easier to assume that it is probably the sample that is off, rather than a contamination issue or someone who made a mistake. We will see this in the next section.

In conclusion, samples can be said to have within them different temporalities, in-built time pressures of what the samples are of. These are important in where which samples are analysed. However, when the samples arrive in the chemistry laboratory, this is not anymore the main concern. It is economic efficiency that standardises all samples and takes care that all samples are analysed at the same time. The *material time* becomes irrelevant (at least as long as they can manage to analyse all samples before they go off). The material is however still analysed in different ways, no instrument fits all, but at the same time and to the same detection level. The focus on precision and numerical standards has a number of consequences.

Cryptosporidium *laboratory*

In some ways, the *Cryptosporidium* laboratory is very different from both the microbiology and the chemistry laboratory. It is a very strictly regulated laboratory and as a visitor, I did get that impression immediately. As in the microbiology and the chemistry laboratory I had to sign in when I entered the laboratory. However, unlike the other two laboratories, here an alarm went off as soon as the door was opened. The alarm makes sure that everyone in the laboratory is aware that someone enters or leaves the laboratory. I had to be supervised during my stay in the laboratory. The laboratory is separate from other laboratories and only concentrates on *Cryptosporidium* to avoid any cross-contamination. The individual sites where samples are taken also have their own equipment to avoid cross-contamination between sites. But it is not only the visitors and contamination that are strictly regulated. The sample data and the analytical process and methods are also subjected to strict rules. When the samples come in, they are registered. Each separate site has its own logbook. The evidence bags in which the regulatory samples are collected are scanned into the computer and stored for one year in a fireproof container. In total they have to be stored for five years. Some changes or new rules in the regulations are relatively small. At some point during the analytical process, it was written that 'no considerable drop of pressure' was allowed. This has changed into a numerical value and now no '0.1 drop in pressure' is accepted. Analysts had to measure the light of the microscope before they started the analysis. Now a requirement exists that the light should also be measured after the analysis to make sure that the light did not fade during the analysis. The DWI can say that the analysis was not good if the analyst did not measure the light after the analysis.

The *Cryptosporidium* laboratory is more heavily regulated than the other laboratories.[6] It is therefore also standardised: all *Cryptosporidium* laboratories should operate in exactly the same way. The company I studied brought in a few additions to the regulations in ways of dealing with the samples. They developed for instance coloured transport boxes, one colour for each site. Keith:

[6] Despite this, it is a dying industry according to the analyst I spoke to. He believed that soon *Cryptosporidium* analysis will be unnecessary, because the treatment plants will remove any present ouses.

> With regulatory Crypto, it is that prescriptive, that is the method. And everybody used that method. There were two written things at the front end that are slightly different for us, because we have chosen to do that. So, the transport boxes for instance, that's [name of the company]. The DWI are happy with that, but not all of them use transport boxes. That is just a system we developed internally.

The *Cryptosporidium* laboratory is also the only laboratory that distinguishes between regulatory and non-regulatory samples. As we have seen, regulatory and non-regulatory samples are treated in the same way by quality inspectors, microbiologists and chemists. Although chemists are thinking about ways of prioritising operational control samples and the microbiologists sometimes give temporal priority to regulatory samples, the sampling, transport, and analysis of both operational and regulatory samples are the same. In the case of *Cryptosporidium* analysis, the non-regulatory samples are dealt with in a slightly different way. For example, the worksheet for non-regulatory samples contains less information than what has to be written down in the logbook: site description, concentration, volume. Keith explains further:

> There is a lot of costs associated with the prescriptive crypto methodology in terms of the forensic trail that we don't want for ordinary operational type samples. That is why you end up with different, to some extent, different methodologies. There is a fair bit that is the same. With chemistry of course it doesn't matter whether it's a leak, whether it's a regulatory sample, whether it's a process control sample. If you want to know an iron result, then you use the iron method. Because, unless it happens to be an extremely dirty sample that is likely to damage the detectors on sophisticated instrumentation, then the majority of samples (would be clean in the first instance and go swept through), a sample is a sample is a sample.

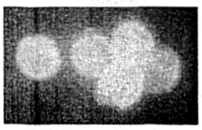
Is a *Cryptosporidium* sample not a sample? Non regulatory samples are collected in different ways (as we have seen in 6.3.1). No evidence bags are used and the worksheets used during the analysis are less detailed than the ones for the regulatory samples. In the laboratory the regulatory and non-regulatory samples are analysed by different people. The regulatory samples are analysed in the morning before twelve o'clock. They are taken the day before and arrive at the laboratory at eight o'clock in the morning. For the analysis there is a three-day turn around. Most of the analysis is done the same day, but the analysts obtain the result the following day. If necessary, they could do the counting at ten or eleven o'clock at night. After twelve o'clock the non-regulatory samples are analysed. Analysing both regulatory and non-regulatory samples would be too much for an analyst who then may not be able to maintain the turn around time. Whereas the chemistry laboratory is set up according to sets of parameters (metals, organics, etc.), the microbiology laboratory has no particular set up (everyone does everything and all samples are treated in the same way), the *Cryptosporidium* laboratory is set up (divided morning and afternoon) according to regulatory and non-regulatory samples. The time that is important seems to be a regulatory time.

I will briefly describe the analytical process (see also DWI, 2000: *Standard Operating Protocol*). The dirt, bacteria and *Cryptosporidium* in the filter are washed out with some cleaning liquid (an aqueous buffered salt and detergent solution) and collected in a 30 ml tube. This is then centrifuged, so that potential oocysts and cysts, amongst which *Cryptosporidium*, sink to the bottom. One scrapes off the material at the top of the tube and aspirates the rest of the fluid. The oocysts and cysts are magnetised by attachment of magnetic beads conjugated to anti-*Cryptosporidium* and anti-*Giardia* antibodies.

The magnetised oocysts and cysts are separated from the extraneous materials using a magnet, and the extraneous materials are discarded. This method is called immunomagnetic separation (IMS). At the IMS stage the sample that originally contained a 1000 ml is brought back to 50 microlitre. The magnetic bead complex is then detached from the oocysts and cysts. Then stained fluorescent antibody is added to the oocysts and cysts; the stain procedure takes 60-90 minutes. The slides go in boxes and in the incubator at 37°C. Then the excess stain is aspirated off. The slide is screened the next day.

Despite the regulatory regime to which the detailed analysis is subject, it seems that interpretation of the result is not straightforward and depends largely on the expertise of the analyst. Even the *Standard Operating Protocol* (DWI, 2000) states: 'Identification of oocysts cannot be adequately described in text as it is necessarily somewhat subjective and dependent on experience'. The screening of the ouses takes place in a dark room with microscopes and a TV monitor. The analyst explained me that he was looking for something green with a light-green circle around it. It would be between four and six micrometers. However, other species or bacteria can be similar and round as well. There are different species of *Cryptosporidium*. They are not all infectious, but look similar. The regulations do not discriminate between them. Whether they have an impact depends on whether people are healthy or not. It is possible to use UV light to see the DNA in the form of the nucleae. *Cryptosporidium* is an oocyst with three or four nucleae. These are not always easy to identify. Sometimes they overlap which may make some of them invisible. There can also be a hole in the wall of the oocyst and the nucleae can be outside the oocyst.[7] If this is the case, they cannot be screened (they can just be bacteria); an empty oocyst could be anything.

Photo 6.14: Making Visible: *Cryptosporidium* after fluorescent antibody is added



[7] An oocyst is just a vehicle for nucleae to survive, it dissolves in the body, leaving the rest free to infect.

When the analyst showed me *Cryptosporidium*, I saw something under the microscope and on the screen when he enlarged it, but I could not have identified it as *Cryptosporidium*. The analyst showed me the textbook next to it. Still, to me they could have been different organisms. According to Sismondo (2004: 87), this is one of the first lessons of laboratory studies: 'experts have somehow learned how to read their material in a way that novices cannot'. The analysts have learned to read the material in a certain way and in this sense the material and the analyst can be said to be co-constructed.

Latour (1999: 59-60) provides a similar example. A soil sample has to be compared to a colour sheet on which each colour is assigned a number, the Munsell code.

> It takes some skill to insert the soil sample into the Munsell code. In order for the soil sample to qualify as a number, René must in fact be able to match, superpose, and align the local clod of earth, which he holds in his hand, with the standardized color chosen as a reference. To accomplish this, he passes the soil sample beneath the openings made in the notebook and, by successive approximations, selects the color closest to that of the sample.

According to Latour (60) this is one other transformation or translation of the 'original' sample: 'it is a transmutation of local earth into universal code'. Also in this transformation we loose the earth but win knowledge of it. Latour points out that by focusing on the colour, René ignores the volume and texture of the lump of earth. After he identified the colour, this is than replaced by a reference number. René, like the analyst in the *Cryptosporidium* laboratory, is trained in facilitating these transitions. Non-experts would have more difficulties. This is one of the reasons why, when they present their results to the outside world, the information is 'sanitised' and it becomes 'a nice arty picture' in the words of Keith.

The analyst has to weigh the pros and cons of what he/she is looking at. The analyst checks the size, shape, brightness of the outer circle, counts the nucleae and checks gates in the wall of the oocyst. They only focus on oocysts, because anything else they see can also be anything else. Usually what *Cryptosporidium* is becomes quite clear to the experienced analyst. If the analyst is not sure and has reasonable doubt, he/she can compare what is to be seen under the microscope with other examples of *Cryptosporidium*. The analyst can also ask someone else to have a look at it or even another laboratory. The slides are analysed blind, but if necessary the analyst can see in the logbook where the sample came from. The analyst also knows that more cases of *Cryptosporidium* can be found after a night of heavy rainfall. All this information can be involved in making a case for or against the question whether *Cryptosporidium* has been found. In general, an analyst explained me, if one is unsure, it is probably nothing. There is no procedure that recognises presumptive results as there is in the microbiology laboratory. The only thing that is important is whether *Cryptosporidium* is there or not, that is what it says in the protocol. Therefore, no mention is made of potential *Cryptosporidium* to the monitoring department or the customer until one is positive. In the laboratory itself, they talk about *Cryptosporidium*-like bodies. Trust in the reliability of the analysts is thus essential here. Keith:

> We (have confidence) in the information that the laboratory provide, because of the training of the analysts, their experience and expertise and the fact that that is continually assessed. Not only through the various schemes in the protocol of the DWI where they have to send off (plates) to other laboratories to double-check what they have read. But also by the fact that [the name of the company] employ an external consultant to come here and (check) as well.

However, it is not just the training that is part of the audit trail of the DWI and experience that is important. There is something else. Keith:

> I think, to my mind I was thinking in terms of a professional approach from within the individual, it is something you bring to the job, isn't it, really? It is your morality in terms of not cutting corners or failings, it is openness and honesty in everything you are doing really.

There is still a lot of development in the Cryptosporidum laboratory. Although WaterCo did analyse for *Cryptosporidium* before the regulations and much of the expertise was there, it remains a relatively new test (it was developed in the late 1980s, early 1990s). The growth in knowledge progresses along methods enhancements. Since also the regulations are relatively new and the DWI keeps updating them, the analysts have to update their knowledge of the regulations by checking the DWI website and information letters regularly. Such a large engagement with the regulations is rare in the microbiology and chemistry laboratories and supports the idea that development in analytical methods and techniques is largely standard-driven.

The unknown sample: standards and material properties up for debate

In the previous sections we have seen that results cannot be interpreted without knowledge about the origin of the sample and the material properties of the sample. In this section I would like to give an example of a case in which material properties are not assumed and worked with in that particular way, but in which the *material properties themselves are up for debate*. During the day I spent in the chemistry laboratory, I had some time to interview the contract manager who co-ordinates the relationship between the laboratory and the water company. We sat in a separate room. Halfway through the interview two men came in to discuss an 'anomaly' with the contract manager, who has a background in chemistry himself. They apologised for disturbing us and after they had left, also the contract manager apologised for the disturbance. They could not have known that these 'spontaneous' and accidental events sometimes turn out to be the more important ones. My tape had been on and recorded everything that was said. Below I will give a rough transcription of the conversation that took place. I have had to shorten the conversation. Some parts of the conversation were not entirely clear, both because there was much overlap (different people were talking at the same time) and because the two men remained standing in the door opening which was quite far away from the tape recorder. However, the overall idea that was expressed in the conversation has been recorded very clearly. Before I give the transcript, it is important to note that the two men (in the conversation A and B; C is the contract manager) brought the two samples they talk about with them. One sample looked very yellowish, the other had a darker brownish-yellow colour.

A + B: Knock, knock, sorry to interrupt.

C: That is all right.

A: We've seen [name] and he said we should come to you. We brought some samples we've been getting in a lot.

C: Oh, he mentioned that this morning. That is drinkable (pointing at two sample jars with yellowish/brownish water).

A + B: Haha. You think that's ok? (ironic)

C: Sure, that is drinkable. Nothing wrong with that. (ironic)

After this they started speculating about what the sample could be. They suspected it might be a leak. B explained that the water might cause problems with the instruments and block the filters if they are analysed in the water supply laboratory. They had started getting a few more samples like this.[8]

C: So, are you saying, you see them more than normal these days?

A: Probably a little bit more, yeah, I would say. We are getting say ten a week… on average. Couple a day, sometimes we get more in a day, sometimes we get none. But about ten a week is about right. And some as well smell like effluent as well in all.

The nature of the sample is not clear. The analysts want to know whether they can send these sorts of samples to the wastewater laboratory, since the technologies there deal with more polluted water. They could be certain that the sample would not damage the instruments. The contract manager understands why the analysts are asking this.

> I understand what you are dealing with here. I mean, they almost fall in between two worlds, don't they?

He acknowledges that they have to be careful not to overload the technology and damage it or to contaminate the instruments that could lead to contamination of other samples analysed by these instruments. However, he is reluctant to send these samples to the wastewater laboratory. He expects people to recognise a sewage sample if they take it and in that case it would not have been sent to the water supply laboratory. Since the samples have arrived here, the contract manager practically eliminates the idea that the sample is a wastewater sample although he is aware that occasionally a mistake can happen. It is most likely that the sample comes from a leak. However, it could be a discoloration sample as well. The sample raises a question about what the sample is a sample of and the contract manager tries to identify the sample by looking at what analysis has to be done.

> I mean, it raises the question for instance, if it is a leak, why asking for metals? These are the sorts of things that are going through my mind. [Metals are not what you would be interested in]. So, why one would ask for metals, I don't know. But people don't very often know what they are asking for.

Suddenly the sample taker is perhaps not so trustworthy. If it were a leak, it would be perfectly acceptable to filter out the mud. However, if the sample turns out to be taken to test discoloration, filtering the sample would be unacceptable.

> When I look at that I wonder what is the point of analysing you see, why don't you analyse them [filtered]. If it is a leak then that is an important thing. We are not interested in mud, we are interested in parameters to marry with the incoming supply. On the other hand, if that's not the case, with discoloration the DWI might want to know.

They still don't know what sort of samples these are. Whether they are leakage samples or discoloration samples will have different consequences for the way in which they will be analysed. As we saw in the first section, the sample has to be (materially) constructed, for example by filtering out the mud or not. This is only possible if the sample was classified beforehand.

The contract manager suggests that most parameters will probably still fall within the water supply range and will therefore have to be analysed in the water supply laboratory. Analysing a water supply sample in a wastewater laboratory, although it may prevent instruments in the water supply laboratory from being damaged, has complicated consequences. It would mean that the sample would be analysed with different methods which also have different detection limits than the ones in the water supply laboratory. As a consequence, the results that appear on the database could not be interpreted in the same way, as I will explain in the next section. To identify the sample and be able to analyse it in the appropriate way, the

[8] The contract manager did remark that these were only two samples out of 30.000 and that that is a very small percentage.

analysts now have to phone a contact person who can find out where, when, and why it was taken.

In this case, the laboratory has a piece of unknown materiality (I refer to both samples as one). It came into the laboratory as any other sample. However, the colour and the smell identified it as something that may not be an ordinary water supply sample. At first sight, it was not regarded as a 'proper' sample for this laboratory. It looked like a sample out of place. This example shows that the status of the raw material is not given by the physical appearance; the physical appearance in this case has resulted in a situation in which the material properties of the sample are up for debate. It demonstrates that samples do not exist in themselves; they are always samples of something. They link into paradigms of water, whether these are drinking water or wastewater. The number of possible classifications is limited and the analysts try to relate the sample to one of these two paradigms, even though the sample seems to fall 'in between two worlds'.[9] By doing this, assumptions of the paradigm, which are usually as good as invisible, are revealed. If they would not succeed to fit the sample either into the clean water or the wastewater paradigm, the analysts would not be able to make sense of the sample and would not know *what standards to employ*. Without a paradigm, interpretations of samples become impossible.

Perhaps one could argue that the unknown materiality that entered the lab is not actually a sample, rather, it can be regarded as a specimen or materiality that is in danger of becoming and remaining a specimen and therefore an anomaly. Samples are related to paradigms in which it is defined what one needs to know. The unknown materiality only gets the status of a sample by finding out where it came from and what it is meant to represent. Until then it is a specimen of an unknown body of water.

The analysts have to make a risk assessment. Latour describes how objects may perform before we know what it is. In this case, the analysts do not know what the object does but assume it may harm their instruments or be dangerous for human health if it turns out to be a drinking water sample. However, if the latter is the case,

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[9] There could have been three laboratories: a clean water laboratory, a wastewater laboratory and a middle category. However, the Keith doubted whether that would be a good development in terms of costs. 'I suspect that because the laboratory systems can handle a lot of raw waters with low levels of (pollutants) it just is not economic to develop a middle

they hope they can figure out what the sample is before it starts performing, so they will be able to warn the people in the area where the sample came from. However, they do not (yet) know what this water may do. Latour (1999: 120), who observed a similar thing when Pasteur identify yeast by looking at what it did in the fermentation process, concludes:

> Before the entity is safely underwritten by a fixed ontological substance, (one) has to add precautions (...). Not yet knowing what it is, he has to fumble, investigating all sides of the vague boundaries he has sketched around the entity in order to determine its precise contours.

If the sample 'is' wastewater, but analysed in a clean water laboratory and considered as drinking water, instruments may get damaged and samples following this one may get contaminated as well. In this case the results of the analysis will come as a shock because they far exceed the regulatory (or operational) standards and emergency measures will have to be taken to prevent people from drinking this water. However, if the same results would be obtained in the wastewater laboratory on a wastewater sample –provided the instruments of the two laboratories would allow the results to be the same– no action would have to be taken because the sample result is regarded as normal within the regulatory regime. As was also shown in section 6.3.1, paradigms define the normality of the result of the analysis. If the wastewater sample 'is' (later identified as) a clean water sample but has been analysed in the wastewater laboratory with different instruments and at different levels, the outcomes will be noted down in different ways and appear on the information system differently. This will make interpretation of the result very difficult.

In order to identify the paradigm to which this sample belongs, the sample has to be traced back to its source. An important instrument for this is the sample number on the label that is goes with the sample through the laboratory. In the microbiology laboratory, the label comes in on the sample bottle and is then copied to the different plates on which the bacteria of the sample grow. With the sample number a contact person of WaterCo would be able to check where and when the sample was taken after which the department that took the sample can be contacted

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analytical stream for things, the odd parameter might be in the milligram per litre range but the majority is still gonna be in the microgram per litre range.'

for further information about the sample. We can now see that if the quality inspector would have provided a wrong label for the sample bottle (even though she would probably not have had a label for wastewater), the traceability would have become difficult and the analysis and interpretation might have had dangerous consequences. Even if the mix-up was not between clean and wastewater, a mix-up with the label might have resulted in the confusion about the metal analysis if the sample was probably a leak or in damage of the instruments with which the sample would be analysed.

The traceability of samples and thus their sample numbers is essential. Without these numbers there would not be a way to make sense of the unknown sample: *reverse engineering is impossible.* Analysts could probably measure what is inside the unknown sample, although they have to be careful not to destroy the instruments. However, if they know how many metals and how much of the metals the sample contains, they can say 'this looks like wastewater' or 'we are not quite sure'. They cannot answer the question whether it may be wastewater leaking into clean water or a particular contaminated source of clean water. The material characteristics of the sample do not determine whether the sample 'is' wastewater or clean water. This can only be determined by knowledge of where, when, how, and why the sample was taken. The local circumstances remain important for interpreting the sample. Only if this is known (say a sample comes from a drinking water supply), it can be combined with the material characteristics of the sample as found in the laboratory (heavily contaminated) and one can conclude that there is a problem. The material characteristics of a sample as established by a laboratory only make sense within a particular paradigm.

As we have seen, the traceability works through a number of transformations of the initial sample: the 'cascade depends mainly on the conservation of traces that establish a reversible route that makes it possible to retrace one's footsteps as needed. (…) When each stage is *aligned* with the ones that precede and follow it, then beginning with the last stage, one will be able to return to the first. (…) The succession of stages must be traceable, allowing for travel in both directions.' (Latour 1999: 60, 64, 69) However, unlike the plants or soil samples in Latour's case, the particular water or sample cannot be retraced or kept for future reference. Some samples can be kept a little longer than others, but after the analysis is done, the 'original' sample is gone and all that is left is the reference number. The traceability which is so important when something goes wrong and in audits relies on the trust that this sample number indeed once referred to a real sample and that there has not been a mix-up of labels.

6.3.3 The end product: delocalised and dewatered numbers

The sample number that was attached to the sample when it was first taken could be referred to without the presence of the 'original' sample later on in the process. During another series of transformations (amongst others by means of laboratory instruments) the samples themselves and the processes of analysis have disappeared and numbers on a computer screen indicating the presence, absence, or value of a parameter have replaced the material samples. As we have seen in the example of the unknown sample, these numbers are not sufficient to be able to trace back the 'original' sample. They do not have any meaning if they are not attached to the sample numbers which can provide information about where, when, and why the samples were taken and thus whether they are clean or wastewater. On the computer the analytical values and samples numbers are therefore linked.

Yet the numbers on the computer screens in the laboratories are not the end of the story. Three different information systems are used. The first system came into existence ten years before the regulations came into place. On this system samples were recorded. We have already seen that every sample has a sample number that is used to trace the sample through the laboratory. However, in this database the samples are also connected to a point code that relates specifically to the place where the sample was taken, to the date and the time at which the sample was taken and the number of samples taken a day, a week, or a year. All sample points have been assigned an acceptance officer whose job is exactly to make sure that it is possible to trace the samples. Keith:

> All of these sample points have an owner, which is called an acceptance officer. And technically, that acceptance officer is responsible for the quality of the data against that sample point. So, really, he should be looking at all of the data that come in through our lab sample point codes to make sure that he is happy with what the laboratory results are saying.

Every sample is also connected to a sample type, which tells one whether the sample is raw water, borehole water, surface water, final water, tap water, and so on.[10] Then the sample is connected to a sample reason, which explains why the sample was taken. It can for instance be a routine sample, a process control sample, a sample related to a customer complaint, a leakage control sample, and so forth. If it is a routine sample, it can be either regulatory or non-regulatory. Keith:

> It is (slightly) complicated because within routine are all the regulatory and non-regulatory which are taken routine. It is the way it's grown up really over the years, bearing in mind of course that this system was in place about ten years before regulation came along. So, to accommodate the regulations, you just sort of use the data system that we had in place in the first place.

Regulatory samples only occupy a small place in the database. Some sample reasons are more specific. For instance the parameter fluoride alone forms a sample reason. Keith:

> Fluorides is information we have to share with the health authorities. So, fluorides have their own sample reason, 78, so straight away the operational people can (zoom in on) all samples taken from this point. They can put into their query: I want to look at all samples 78. And the database has got with it associated a lot of reporting tools, which allow people to access any of the data using these combinations of date, time, either, or, or several combinations of this.

As the quotes demonstrate, the database is extensive and contains a lot of information. This information has to be collected in a specific way. I will show this by discussing the case of the unknown sample. If this sample would be analysed by the wastewater laboratory, the result against a particular sample point code would have been obtained by different methods. Then there are data on the database which are actually beyond the level of detection of the 'normal' instruments of analysis. This raises questions when –in the words of Keith– somebody down the road is

[10] These are only on water supply. There are dozens of different types for wastewater, soil, etc. Under process control one can also find things that apply to wastewater. Both clean and wastewater fall under this database. The numbers can be on the same database, the samples cannot be in the same laboratory.

looking back at the date. How can these data be interpreted? The way in which the database is organised only allows for data that are obtained in a specific way, otherwise the interpretation of these data becomes complicated or even impossible.

The chemistry laboratory cannot access this database. It uses a different information system that does not recognise the data from the other system. This is why they cannot track themselves where a particular sample comes from or what the reasons for sampling were. The laboratory would have to rewrite their software. This is subject to discussion. If the two systems would connect better, the laboratory could see which samples should be analysed before other samples. It would be possible to prioritise operational control samples, samples taken because of customer complaints and samples taken because of leaks where water is flowing down the road. Keith regards this as important for the company, because 'that's what we are measured on and it is our public face'.

The third database is –unlike the first one– a scheduling tool for the regulatory samples. It tells the quality inspectors where and when which sample has to be taken. The samples are registered on this information system before they go to the laboratory. This database makes it possible to prioritise samples and ensure fast-track analysis of some samples. However, not everyone in the company has access to this database. The first and the third database have to talk to each other, because, although there is overlap, they do not transmit all the same things. In the third database for instance, there is always just one single reason for the taking of the sample. In this sense, also this database restricts the sort of data that can be entered. A sample could be a regulatory sample, but one might want to add a lead analysis to the sample. However, lead may not be a routine regulatory parameter, but an investigation. This could perhaps be accommodated in the first database, but not in the third. This makes the working between the systems complicated. Keith expresses that they are working towards a single database:

> In the long term, we would like a single database. And obviously, what we are hoping is that this current rewrite of [the third database] which has to be rewritten to accommodate the new regs (...) but in addition to accommodating the new regs it's been made more functional. And we are hoping that the increased functionality of it, will allow all departments to use it, and do away with ... altogether and then that can become the single

> database. And it will be a more powerful tool, but that's a few years down the road, I think.

The different databases all allow for specific data to be entered and if these data are different or obtained in different ways, the interpretation of the data and the traceability of the sample becomes very complicated. The use of one database, although it would favour one way of organising over another, would make this process easier. The databases are important in another respect. They make the numbers obtained from a particular sample comparable and compatible with numbers obtained from other samples. In Latour's example of the soil sample, the different soil samples could be compared with each other with help of diagrams. In my case, the different samples taken during one sampling tour cannot be compared to each other, partly because they are sampling different parameters and partly because, if these parameters are the same, they are from different sources. Comparison over space does not make sense, since the locality of the sources is so important in interpreting the result of the analysis. However, the databases make it possible to compare samples to samples from the same source over time and use this for trend analysis. Trend analysis is easier for some parameters than for others. Dick (LTI/160403/WaterCo):

> Bacteriological failures/risks are very difficult to predict. If there is a problem at the treatment plant with iron and manganese for instance, they can make a prediction on how many failures they expect, what action to take and what possible solutions there are

More important than trend analysis is that since the regulatory and company standards have been programmed into the databases, the numbers can also automatically be compared to the ideal, regulatory standard. When the numbers are entered in the computer and when a number 'fails' the standard, this is flagged up on the screen. In Oliver's words: 'All parameters have global and/or site specific limits set up on the quality archive which generate exception reports. This is our primary mechanism for detecting unusual results'. The databases thus provide us with information we could never have obtained by looking at the water -the information would have been invisible. In Latour's words (1999: 55) –we just have to replace 'soil' by 'water'– 'what we lose in matter through successive reductions of the soil, we regain a hundredfold in the branching off to other forms that such reductions –written, calculated, and archival– make possible'. By losing locality, particularity, and materiality, Latour argues, we have won compatibility, standardisation, calculation, and relative universality.

Samples (or sample results) take different routes from here, depending on whether they comply with the regulatory or operational standards. If they do comply with regulatory standards, they will be compiled and sent off to the DWI in monthly reports. If they do not comply, protocols help to identify the next step. The quality procedures manuals gives guidance in what data should be gathered to do the risk assessment. Depending on the outcome of the risk assessment, there are recommendations in terms of what one should do. Oliver:

> It [the manual] gives them support in terms of knowing how serious things are and what sort of actions are expected, it gives us some standardisation to make sure that one individual won't go and do, ignore something while another one will go completely over the top and waste resources. So, it gives us that standardisation in terms of response.

When I visited WaterCo I was shown this quality procedures manual on the computer. It is extensive. If there is a bacteriological failure one has to judge how bad the result is. The manual helps you with a number of questions: is there any supporting information that goes alongside the result? Was there any chlorine in the water? Why was the sample taken in the first place? Were there any problems on the site? Is this the first time it has failed? And so on. One would then look at the environment of the place where the sample was taken. Where is the water coming from? What is downstream? Are there problems with surface water reservoirs upstream? Has there been activity in the distribution system? Whether action would be taken depends on the outcome of the risk assessment. Oliver:

> For any coliform we would, if it was non-coliforms or high plate counts we would have debates as to whether we needed to resample or not. If it's high non-coliforms and it's at a customer's tap, we probably won't resample that, because we see them periodically. If we saw non-coliform bacteria on the final water, we would resample and investigate, because that's not usual, (we don't normally see that). On a reservoir we would probably resample and see

> what happened, and then if it was still there the next day, we would investigate why it was there, a customer tap we probably wouldn't. Unless it was something, perhaps if it was a health complaint, we might do. But if it was a routine one, we probably wouldn't.

This quote shows that if action is taken, resampling is mostly the first step. In order to do this one has to trace back the other sample to see where it was taken. The interpretation of the sample –as we have seen earlier– heavily depends on the possibility to trace the sample, because the 'origin' of the sample often determines what sort of action will be taken. In the example above, the same high plate count of non-coliforms would result in no action if it was at a customer's tap; in resampling if it was at a customer's tap and a complaint was made (which will show in the database); in resampling if it was on a reservoir; in resampling and investigation on a final water. Again, the result of the analysis as such does not determine whether it is a good or a bad result and what action has to be taken. The action is also shaped by the material substance of which the analysis has provided a result. If the high plate count did not consider non-coliforms, but *E.Coli* a lot more sampling would be done, the company would speak to the health authorities and may give out a boiled water notice. Another, interesting, way to formulate this is:

> When the results come from the lab, they look at the question: is that real? Is there a need to react? They need a reality check. (Roger)

It seems that if the parameter for non-coliforms (which are not a high risk to human health) fails, the failure is more likely considered as a failure with the tap itself or a failure with taking the sample. However, as Roger says,

> If the failure is likely to be serious, if it is *E.Coli* rather than just coliforms and people did dig up a main in bad weather, more sampling and investigation is needed, more samples downstream and upstream and perhaps analysed for more.

After an interview, Robin (WQM/090603) took me back in his car and told me how difficult it sometimes can be to know the cause of a failure. If there is a bacteriological failure at the customer's tap and one resamples and does not find anything, it is assumed that it was a problem with the tap or with the sampling. However, in theory it could have been a temporary failure of the water that the company provided. It can happen that it is only after a year or so that one sees that these incidental failures at this customer's tap actually show a pattern, which can be seasonal or depending on the source and pipelines that supply the property in a particular period. The result remains the same, but the interpretation is different.

6.3.4 Conclusion

In this section, I have followed a water quality sample from when it was taken until it ended up on a computer screen, was interpreted and may have resulted in taking another water quality sample. As Latour (1999) showed with a soil sample, I showed that also the water quality sample develops into a number through a series of transformations during which the local and material may be lost, but comparability and universality are gained. For both the soil sample and the water quality sample the traceability of the sample is of the utmost importance. My story also differs from Latour's in a number of ways. I have shown that water samples cannot always be analysed in the laboratory. Sometimes they need to be analysed on the spot. Unlike tracing a soil sample, the material water sample cannot be traced back all the way. In this process the sample number is essential, because without that number *reverse engineering* is impossible. Latour did not address the complications of the loss of reversability in his example. Yet, the sample number is crucial, since the material properties of the sample as such do not have a meaning outside the particular paradigm in which they operate. To show this, I gave an example where the chain of transformations (temporarily) is not reversible.

I have encountered very few instances when the material resisted particular expectations or ways of organisation. This can be due to the fact that my fieldwork was short, but also to the fact that water companies have worked in similar ways, with similar instruments, and under a similar regulatory regime for decades now as chapter 5 illustrated. In order words, companies have worked in a paradigm of regulated science in which also a regulatory plateau is at work. Latour (1999: 30) describes how the 'known world and the knowing world are always performing in concert with each other'. Material agency and regularised, routinised human practices, in Pickering's words, work together according to a cultural choreography. The regulations and human practices have to take materiality, the speed with which bacteria grow, into account, and materiality is organised and classified in such a way that it helps to make sense of the regulations –think of the taking of a particular sample. Yet, it does not mean that materiality and regulations are at all points regarded as equally important. The section on the laboratories, which could be called 'normal labs', demonstrates that in some situations regulatory time can become more significant than material or organisational time and regulatory and non-regulatory samples can be treated in different ways.

In the by now routinised co-construction (no longer co-production which is what Pickering talks about) of the material, the scientists, and their (regulatory) environment seems to have led to a situation in which few disagreements are left. However, according to Kuhn (1996 [1962]: 59, 65):

> The decision to employ a particular piece of apparatus and to use it in a particular way carries an assumption that only certain sorts of circumstances will arise. There are instrumental as well as theoretical expectations, and they have often played a decisive role in scientific development. (...) Without the special apparatus that is constructed mainly for anticipated functions, the results that lead ultimately to novelty could not occur. And even when the apparatus exists, novelty ordinarily emerges only for the man who, knowing with precision what he should expect, is able to recognize that something has gone wrong. Anomaly appears only against the background provided by the paradigm.

Although the analytical instruments in WaterCo's laboratories have developed over time and become more precise, I have not heard of the discovery of anomalies that then led to novelty. Kuhn writes about experimental research science that is designed to be innovative. Regulated science seems to work differently and can consequently be said to encounter a different type of anomaly than one could encounter when practising experimental science.[11] Regulated science is designed to close down uncertainty, rather than to open it up; it regulates instead of innovates. An anomaly, which is basically something that was unexpected on the basis of a particular

[11] Faulkner and Senter (1995) explore the knowledge contribution to innovation by comparing in-house R&D and Public Sector Research (PSR). In a review of the literature they show the complexity of attributing innovation to a particular type of research, yet argue that the contribution to innovation of research by academic and government laboratories is limited compared to that of R&D.

paradigm or theory, can emerge when there is a failure in closing down this uncertainty. However, when an anomaly is 'discovered' in regulated science, it is not the scientific theory on that is questioned. The problem is not the way we think about the world, but the water, the treatment technologies, the specific analytical apparatus, or a combination of these. The anomaly is thus regarded as explicable and expected to fit in one of the existing paradigms and, because of the regulatory regime and possible health risks, has to be explored immediately. It is not possible or allowed to ignore the anomalies or put them to one side until there are so many of them that one has to investigate them, even though, as we have seen, sometimes an explanation for an anomaly can only be given when more of them have been found.

It is in the paradigm of regulated science that the interpretation of results takes place. The interpretation of the results and the judgement about whether action should be undertaken or not, cannot depend on the results of the analysis alone. I have shown that, in some cases, it is unclear who should be 'blamed' for a wrong result (in a laboratory it can be the analyst, the instrument, or the water; a failure of the final result can be ascribed to the water, the place where it was taken, the sampler, the flow in the pipelines, and so on). It would be interesting to explore which actor is blamed under what circumstances, but unfortunately I cannot go into that. However, if there is confusion about who or what is to be blamed, it is unclear also who should be sanctioned and which standard should be enforced and how.

The paradigm of regulated science therefore has consequences for what standards mean and how they work in practice. They only work when there is a reciprocal relationship between them and the materiality they try to govern. In addition, they operate in a specific paradigm. If, for a moment the paradigm is unclear (when the origin of a sample if unclear for instance), what standard to employ becomes subject to debate. Materiality 'out of place' can lead to such confusion about standards.

6.4 Tracking customer complaints

A customer complaint usually emerges after the water has been treated and transported through the pipeline and after many operational and regulatory samples have been taken to ensure the quality of the water. It might therefore be that something has gone wrong during the process that has taken place before the water arrived at the customer's tap. It might also be that other factors have influenced the customer complaint; the tap may have been contaminated or an illness may have been caused by food rather than the water from the tap. In 6.3.3 we have seen how difficult it sometimes is to establish the cause of the failure of the water: if it is indeed the water that fails the regulatory standard and under what circumstances the failure is taken seriously and action is undertaken. The situation becomes even more complex when the customers develop their own individual and non-formalised water quality standards and a situation emerges in which the customers do not seem to trust the scientific and regulatory standards. In this section I will give an overview of the route customer complaints take through WaterCo. Many complaints come into the call centre and –after an explanation to the customer about what is happening– they are considered as dealt with and require no further action. Calls about a few subjects are dealt with more thoroughly and more time is taken to talk with the customer. These are calls that are more likely to result in action by the networks department (fixing a burst main for instance as we have seen in 6.2) and in taking samples, the process discussed in section 6.3.

Customer complaints can arrive in two forms, in letters and in phone calls. Although for our purpose the phone calls are the most interesting form since they more often deal with water quality issues, I also want to give a short overview of the route a complaint letter takes. This route is slightly different from the route a phone call takes and will provide us with an even better insight into how WaterCo is organised.

Every day WaterCo's mail centre receives 3000 to 5000 pieces of mail. This is all the mail that is not addressed to specific departments of WaterCo. A few people open the mail and do the very first sorting. After this, the mail is quickly read and scanned into the computer. The original documents are filed and stored for twenty days in case someone needs the original files. Customer complaints have priority over other mail, because they need to be responded to within five days according to WaterCo's own targets; Ofwat requires a response within ten days. The speed at this part of the process is important, because the longer the letters stay here, the less time someone else will have to actually deal with the letters. The scanned letters then move through the computer system into work queues. The people dealing with the work queues do the second reading of the letters. I was surprised about how quiet this department was; hardly any phone calls were made. Customer complaints have priority and automatically pop up first in the computer. The complaints that come in are usually about the company that has done something to upset the customers. They can be about sewer floodings, about situations where a hole in the ground was left behind after work on a pipeline, about the scheduling of appointments (not being able to keep them), about network development (water pressure, discoloration), about water supply, etc. Mostly these issues are longer term and not urgent, otherwise the customer would have phoned WaterCo.

This department can access information systems or contact other departments to check things. Most of the contacts are with the Networks department. As in the previous section, the Networks department has a different information system than this department, therefore the scanned letters need to be printed out and sent by fax. When Networks send an email back in which they explain what happened, this department will then reply to the customer. In complicated cases, Networks may add a paragraph with information which will make it easier to reply to the complaint letter. It might happen that they do not get an immediate response from the department that is asked for information: 'sometimes people from other departments simply do not think about the customer on the receiving end'. That is why they have developed an escalation mechanism: after three days they will send a reminder; on day four they can contact the middle managers, senior managers and heads of departments, so that the pressure on the involved person will also come from his or her own department.

Audits are important within this department, both carried out by Ofwat as by the department themselves. The fewer complaints a company gets, the more money they receive and the more they can charge the customer. Bringing the complaints and the time to deal with complaints down is therefore crucial. If customers are not happy with the quality of the water, they sometimes refuse to pay their bill. However, in emergency situations like a burst main or no water, no good will payments will be paid out. If discoloured water is the case, the customer can take the meter reading of the running water until it returns to normal and the company will pay the amount of running water. This is usually not more than one pound. However, in most cases where the water will be switched off for a while or the customers receive discoloured water because of works on the distribution network, the customers have received a warning letter, one of the tasks of this department as well. Advance warning is a proactive mechanism to reduce the number of customer complaints. If a new treatment plant is installed or a water source is changed, one tells the customer in advance what problems may arise (these problems have been investigated by another department), because, as someone said, 'you don't want them to phone in'.

Customer complaints can also lead to problems being discovered. The billing department received a letter on the day I was there from a woman who received a high water bill while she had not even been in the country. The computer shows the woman's address, the kind of property she has (detached, semi-detached; old or new; whether it is likely to have a meter or no) and former correspondences with and phone calls to the company. Her bill is compared with her normal consumption rate. An inspector was sent out to check if it was an incorrect meter reading or if there was a leak. He discovered indeed a leak and the bill was adjusted. The information was then sent to Networks which would repair the leak. In section 6.2 we have seen how this works. The letter to the woman said:

> The water meter is not installed as a leakage device but a useful tool in the detection of leakages and changes in consumption at an early opportunity. A leak in the network can be detected by a spinning water meter when it is not used.

In emergency situations –many of which invoke water quality issues– customers would rather phone up than send a letter. In the customer call centre the most important and urgent complaints and issues come in. Calls from hospitals and prisons and calls to the separate smell-line have priority. In contrast to the 'letter department', the call centre was very noisy and busy and staffed 24 hours.

When people phone up, they will first hear an answer machine which tells them in which areas there are known problems and when these will be over. This is information the call centre receives from the bulletin board of the networks department (see section 6.2) or when many calls from the same area and with the same problem come in. This reduces the number of calls which –as I explained above- is good news for the company. If an incident happens –that is five phone calls in three minutes from one area- the duty manager makes sure that a screen above the call centre starts flashing to make everyone aware of it. When I was there, the answer phone played a message about three areas that did not receive water. There was a high call alarm, so the call centre informed networks (the bulletin board did not mention that any work was being done) and Networks said the problem would be solved by 2 p.m. which in turn became a message on the answer machine.

When a customer phones in –I was allowed to listen to six phone calls that were made that day– the street name or area can be checked on the computer to see if someone else has called about a similar problem. Unfortunately none of the phone calls I heard were about water quality. They were about a house that did not receive water; about flooding from the sewer; about damage on a water main which was hit by a drill; about a query that someone had two weeks before; another one about sewage problems that were not solved when the crew just drove off (the man who phoned owned a night club and was worried he would not be able to use the toilets that evening); and one about a woman who wanted to buy a property but needed a place for the animals to drink and wondered if she could tap into the water supply for that. The calls were diverse, but I did have to collect my information about what happens to a customer complaint about water quality by asking people and looking around.

The people on the phone have a guideline on their computer. If someone calls about a certain problem, they can click on the guideline which tells them what questions they should ask. Like the guidelines used in the treatment works and the guidelines that are used to determine what action should be taken after a sample has failed, also these guidelines were extensive, far too extensive to print out.

This is similar to clinical assessment software (CAS) elsewhere. Protocols are used to deal with enquiries and to give advice. They are designed to deliver a standardised service regardless of time, space, staff, or caller. Yet, research has shown, in line with other investigations of the use of technology, that the call-takers re-order, conflate, and decline to ask and supplement protocol questions (Hanlon et al., 2003). Although complaint protocols may differ from advice protocols, both involve co-construction and making sense of 'the problem'. Let us have a closer look at the complaint protocol used in WaterCo.

Under the heading 'water supply quality', one can find the subheadings of smell, discoloration, taste, bits in the water, chlorine, fluoride, lead, air, wider smell/taste, and animals. These guidelines are organised in a different way than the guidelines used when a sample has failed the regulatory standard. They are organised by the sorts of things the customers will notice in the water. It is interesting to see that chlorine, fluoride, and lead are the parameters that are singled out from all the parameters water companies analyse. Whereas operational parameters play an important role in the treatment process and distribution system and both operational and regulatory parameters are important in the laboratories, in this context parameters that the customer finds important are essential. A separate subheading in the guidelines dealt with illness. According to the duty manager that day not many people call in with complaints about illness. However, if they do, the guideline will go through questions about the nature of the illness, about how many people are affected and so forth. She also told me that questions about fluoride usually come up after people have read about fluoride in a newspaper or magazine. Questions (usually complaints) about chlorine come to the fore when people move houses, when something happened to the pipes and chlorine was added, or when they get a different water supply. When it comes to hardness, like with chlorine, it is a change in water people notice.

Some calls are referred to the so-called second line; these calls mainly refer to the quality of the water. If a customer says the water tastes peculiar, has discoloration or looks unusual otherwise, or contends that the water made him or her ill, the second line will deal with the call. The people who work here have more knowledge and can contact other departments and call the customer back if that is necessary. Whereas the first line gets 1500-2500 calls a day, the second line technical team that deals with the water quality issues gets 300 a week. They have a bit more time to talk and do not have the six-minute limit on a call as the people working on the first line have. According to Goode et al. (2004) the integrated telephone and computer system that the first line team works with, 'allows the measurement, monitoring and management of work flow' in order to enhance the speed with which problems are dealt with.

If calls about discoloration are referred to the second line, the call-takers there will advise the customer to run the tap and will call back after twenty minutes to two hours. In most cases the water will have cleared by then, and otherwise they will contact networks to see what can be done about it. Networks often discovers this way that a problem has occurred. In some cases the problem may be long term. If there is a long term problem with discoloration and for example the treatment works are not good enough to remove iron and manganese in a particular place, 'you can't advise customers to run the tap for 25 years' (someone at the customer call centre). In fact, in this case, if the customer calls four times, networks can install a regular flush or a filter and monitor the filter. The result of this is that individual complaints go down. The flushing can thus be a proactive activity by networks that will help to reduce complaints. Networks used to be much more maintenance than customer driven, but co-operation between the call centre and networks may reduce the number of complaints and result in more money for the company. Audits can be seen as a proactive activity for this reason as well. Every week the second line do their own audits in which they ring ten customers in each of the fourteen districts and ask them about the service WaterCo provides. Apparently patterns are changing and also here fewer complaints come in. On the second line there is also a special team –they get 450 calls a week- that deals with escalated complaints that have come through Ofwat, the DWI, or the headquarters of WaterCo. It is important to keep customers informed and to prevent them from stepping up to the DWI or Ofwat.

When a call comes in about the taste of the water, it usually is about chlorine ('the water has a chemical taste'). The second line then explains to the customer why he or she can suddenly notice the taste and that the company uses chlorine to disinfect the water. Bill stresses that companies do not want to receive any customer complaints at all if possible. By 'punishing' water companies for large numbers of complaints, the regulatory agencies indirectly control the dosing of chlorine: 'If we did put lots of chlorine in to make sure we've got a residual held through the network, we would generate hundreds of complaints' (Bill). In this way non-regulatory standards are mobilised. As Thomas says: 'We don't intend to go to zero chlorine, that's very difficult because of the nature of our water. But certainly we and a lot of other companies are pushing to get the chlorine much lower than we used to and that is driven by purely customer acceptability issues'. These standards are not mobilised through regulatory networks, but in different ways.

The second line often deals with things the Networks department cannot do much about: discoloration, chlorine, and air. For fluoride and lead information folders are available which will be sent to the customer. Phone calls on these subjects occasionally result in actions by networks or in sampling activities.

A complaint about animals will always result in an inspector required to go out and check. Also here the interpretation about whether the animal came from the treated water or not is complex. Sometimes animals (often small insects) are found in the sink or when someone turns the tap on, fills a bottle or a bucket. If an animal is found in the bucket, the customer might think that it came out of the tap. The customer needs to capture the animal which is then taken to a biologist who will assess whether it is an aquatic animal or not. If it is not an aquatic animal, it will not have come out of the tap. If it is, chances are that it has come out of the mains system. However, one cannot be sure and has to ask further questions (did the water come from a tank and so on) to try and determine where the animal came from and thus whether the company should take further actions. Depending on the interpretation, the finding may result in contacting the health authority, the local authority, the DWI, and networks to make sure that it does not reoccur in the short term and that, after an investigation, long term solutions will be found if necessary. There is not a standard for animals: 'I am using the word standards very loosely because there aren't any standards as such. You don't say you have a standard for the number of bits that come out of your tap' (Lewis). This is something that is totally driven by customer complaints:

> We don't have a routine program for looking at animals, because they are not normally there, this tends to be complaint-proven. Customers will complain, most, 95% of these come in from complaints. (Oliver)

Customers can thus play an important role in identifying water quality problems which otherwise might not be discovered.

If a customer says he or she has become ill from the water, an inspector goes out to the property within two hours and smells and/or tastes the water as well. Illness clearly has a priority to a complaint about chlorine, fluoride, or discoloration. This is due to a few reasons: a company cannot do much about the fact that some people do not like the taste of chlorine except by explaining why chlorine is used; a company cannot decide whether to use fluoride or not[12]; discoloration can be a nuisance, but is often temporary and seldom harmful for human health; illness, if indeed caused by the water, could potentially be harmful for a large number of people and a reason for the DWI to prosecute the company. In some cases it is very difficult to interpret the result of a sample as section 6.3.3 demonstrated. It can also be complex to determine whether someone became ill by drinking water and not by eating something. The quote below is an example.

> I had a lovely call from a lady the other day who said that she had an eye complaint, her eyelids were puffed up and weeping and it must be the water and basically, her doctor had sent her to us. And I tried to explain to her that we are not a medical facility, and I think she felt I was being very unsympathetic which of course, I wasn't, but you know, there are some things that we cannot do. (Sarah, WQM/230502)

[12] This is a decision made by the health authorities. The water companies have to add fluoride to the water if the health authorities decide so. At the time the thesis was written, this was debated.

Apart from the fact that the water company could not provide medical care, it would under some circumstances be hard for both the company and the doctor to make a direct link between the water and the illness.[13] Despite this uncertainty, actions are taken quickly since the possible public health *and* regulatory risk may be extensive.

If the person has really become ill and the likely cause is the water I can refer to Latour (1999: 119) who mentions that there are situations when: 'we do not know what *it is*, but we know what *it does*'. Finding out what *it is* has then the first priority. An unusual smell can for instance be fish or petrol. The inspector usually tests for what the customer thinks is wrong with the water and what he thinks himself. In most cases this results in a bacteriological sample. Sarah remarked that in the past people were asked to go to a doctor, but that under the current regulatory regime the company cannot take the risk that something is actually wrong but has not been investigated. The *regulatory risk* is too large. The customer gets the results in ten to fourteen days. It happens that customers contend that they have *E.coli*, but that the sample shows them wrong. The company will then give the customer more information to reassure the customer. However, the reassurance does not always work. Sometimes the customer simply does not believe the company. As one respondent nicely said: 'scientific truth is not the same as public truth'.

> As scientists it is quite easy to produce lots of complicated procedures to say: we can prove your water quality is good. But quite often is our expectation dealing with customers is that they still need reassurance, you know, how many scientists you put against the wall, they wouldn't quite believe us. It is actually an interesting issue, which is the way scientist communicate or the quality people communicate which still doesn't buy the trust of the people to whom we are providing the service. (Thomas, HQD/181102/WaterCo)

It seems that the role of a water company is not only to produce good water, but under the current regulatory, and partly privatised, regime also to do this in a way that has the trust of the public. There is a sense amongst water companies that the customer lacks trust in the companies. Kinnersley (1994: 159):

[13] See for difficulties in relating water to disease also the account of John Snow's struggle to explain cholera in chapter 4.

> In October 1991, the chairman of the Severn-Trent company told a conference that the industry would be spending £12 billion by the end of the century on improving the quality of the very few samples that fail to meet standards but that are still judged safe. This may well represent over-investment relative to the risks remaining, but it reflects the chairman's deeper worry that, while drinking water, bathing water and sewage treatment had all improved, public satisfaction with them seemed to have fallen.

Often water companies do not understand why the customer does not accept the logical and scientific explanation of the company. Customers often complain that there is too much calcium in the water. But 'there isn't as much calcium in probably a whole days worth of water than you'll find in an ounce of cheese. But they don't sort of make this relation' (Sarah). When a customer finds bottled water 'with extra calcium' in the supermarket, the calcium is suddenly seen as a plus. In a presentation Thomas compared the phrases 'natural minerals' and 'artificial chemicals'. These can refer to the same parameters, but will have a different impact. He acknowledges that discourse plays an important role. Companies often try to win the trust of the customers with fact sheets and water quality reports and especially by demonstrating that the water quality complies with the regulatory standards:

> We stress how we meet the standards, we stress how acceptability is important, we stress how we work with health authorities as the professional health guardians, we sell ourselves as your health is important to us. (Thomas)

In this context, the regulatory standards are mobilised as health standards. Customers however have their own standards:

> It is subjective because what is acceptable to one person is not going to be accepted by others; some people will be able to taste .1 mg chlorine per litre of water and other people won't be able to taste .3. When you ask a hundred individuals whether the water is ok in the UK, you get a hundred different answers (Harry, WQM/261102).

Regulatory standards apply to all European Union countries, or at least all water companies in England, operational standards can be set for a specific treatment plant, and customer's standards are even more individual and not formalised at all. It can be difficult to convince customers of the good quality of the water by means of a set of regulatory standards that are outside the direct experience of the customer:

> I get calls in from customers and sometimes they say: 'I am not drinking your water, it is crap'. And then my sort of defence is: 'well, that may be your individual perceptions, however, according to the standards laid down, we are not contravening whatever parameter it is that they feel that is substandard' and then of course you get: 'I don't care about your regulations, I am paying for it. It is what I want.' Chlorine, typical sort of example: taste is a very individual thing. Some people are more tolerant to it than others. (Sarah)

Companies can be upset about customers who do not trust the water companies or find their individual standards more significant than the company and regulatory standards:

> I think people should be more aware of what we have to do, personally, to maintain the standards. I think a common comment from a lot of customers is: it falls out of the sky, you know, why do you charge so much for it? I mean, obviously charging is a big issue in a lot of people's lives. But they don't appreciate that a lot of it requires treatment. (Sarah)

> A substantial number of the complaints we get from customers regard the disinfectant because they don't like the smell or the taste of it. And when you try to explain to them, it's actually there for your own benefit, they don't necessarily agree. But then, that's customers for you. (Lewis, WQM/181102)

The experienced lack of trust, although I cannot discuss this into detail, is partly due to the different 'realities' of companies and customers. In the words of Yearley et al. (2001: 349):

> In case after case it has been found that "expert" accounts of physical reality have conflicted with local people's knowledge and that rather than local

knowledge being routinely inferior and defective, it has commonly proven more sensitive to local "realities".

Distrust occurs when the local knowledge departs from the expert knowledge. 'Lay' people may have different ideas about how problems should be solved. In Yearley et al. (2001: 357) a participant on a focus group on air pollution and quality suggests that the expensive monitoring scientists work on may not be the best solution to reducing air pollution:

> So in a way forget the standards, just try and move in a direction of improving air quality by whatever means... we know that there's a connection between, you know, traffic and air quality so let's reduce the volume of traffic, you know, let's – why bother trying to determine whether it's sulphur dioxide that causes, you know.

This study suggests that standards may indeed not be important for the customer. Many in the water industry believe that customer's expectations have risen as well; higher expectations are more difficult to fulfil. Their bills became higher and they want good service and good water quality in return. A few examples:

> Their expectations have changed. They've seen their bills go up, they've seen a lot of money being spent and well I think all customers with all products have changed and they've just become more entitled to a good service and they want plenty of it. And they want it top-quality. (Samuel)

> I think to be honest people expect more these days than they used to. I mean in the 1980s before the drinking water inspectorate came into being and before the industry was privatised, I think people just accepted the fact that they turned the tap on and then the water came out and it was ok. I only think that since privatisation and regulation and prices going up, that people now expect more, but then that's typical of people in general, people expect a service whether it's about a washing machine or a meal in a restaurant. I think it's just a shift in social climate these days. (Bill)

> Customers' expectations have increased in leaks and bounds. (Lewis)

Although Ofwat represents the customer, it cannot encompass the different individual requirements of the many customers. The regulatory regime to which a water company is subject therefore does not only consist of regulatory and operational standards, but also of standards set by the customers which water companies have to take into account. Some water companies may say that they treat the water and not the customer (Fred, WQM/150202), in the words of Rosa (WQM/270502):

> We are not supplying water for animal consumption, for goldfish or tropical fish, or anything else, nor are we specifically supplying water that is good for heating pipes, so we don't soften it. I am not quite sure to say wedon't take the customer into account, but it is the water that is the important factor.

Yet, many companies have started to pay more attention to aesthetic standards. As Harry explains: 'In terms of water quality regulations, we have to meet the basic, but we'll also be looking to actually meet our customer expectation in terms of complaints on taste'. He distinguishes the 'actual' quality which is determined by the regulatory standards from the 'perceived' quality as determined by the customers. Customers' standards become increasingly part of the formal regulatory regime, since some have been added to the 2000 regulations and Ofwat sets standards for aesthetic parameters as well. In some cases the different regulatory regimes may conflict with each other as we saw in the case of section 19 and in the case where customers may not find scientific information sufficient or do not trust this information.

6.5 Conclusion

Chapter 5 introduced the notion of regulated science. This chapter further investigated the ways in which a specific water company operates under a regime of regulated science. The chapter has shown that the regulatory standards and the associated guidance are accompanied by many and detailed co-constructed protocols which help companies to deal with everyday situations. There is a further system of both quality and regulatory assurance that consists of alarms and automatic and operational sampling at the treatment plant, blank samples and validation tests in the laboratories, and audits throughout the company. This chapter has identified yet another notion of assurance: customer assurance. Customer complaints can have consequences for the company; they can lead to the identification of incidents and the number of complaints has consequences for the amount of money a company receives. A company will therefore organise its practices so that also customer assurance becomes important; it will try to reduce the number of complaints.

The regulatory parameters are not equally important in all places and at all times. In the treatment plant, some parameters are removed with treatment technologies that have been built on the site with treatment especially for them. Others are expected to be removed by the treatment as a whole. Some, like pH, play a more significant role than others because they can help the compliance of other parameters. Some parameters need to be analysed on the site because their material properties cannot be stabilised until they end up in a laboratory. During the sampling and analyses process it becomes clear how standards and materiality are co-produced with help of a cultural choreography in which both material and human agency figure. Yet, in the choreography, as we have seen, sometimes the operational, sometimes the regulatory, and sometimes the customers' standards surface. In some places regulatory time dominates organisational and material time, whereas this is different in other places.

In the laboratories, during the sampling, and when samples are interpreted, the co-construction of materiality and standards has been demonstrated. Neither of them can operate on its own; they need each other. Materiality cannot be interpreted without the standards and wider paradigm of norms, expectations, and 'normal' results; yet, it can act and that has to be taken into account by the regulations. This will be further explored in the conclusion to which I now turn.

7 The Last Drops

In chapter 3 I quoted Latour (1999: 74) who argues: 'To know is not simply to explore, but rather is to be able to make your way back over your own footsteps, following the path you have just marked out.' That is what I intend to do in this last chapter. I will make my way back and, by drawing together some material from the previous chapters, come to a few final conclusions and ideas for further exploration.

Standards and standardisation processes have, for a number of decades, been subject to debate in STS. Yet, the literature has neglected, or perhaps purposely avoided, the relation between standards and materiality. Since every standard is set to govern or even standardise something, it is important to understand the relation between the standard and the 'something'. My first research question was therefore: What is the relationship (are the relationships) between standards, standardisation processes and materiality and how can this (best) be addressed? Chapter 2 has shown that this is a complex question, since the status of that something and how it can be investigated is heavily contested. *Ideal type* realists would argue that we can get to know the world out there with help of scientific research, whereas *ideal type* constructivists would say that we can never get to know the world as it is since it is always subject to interpretation. I argued that realists do not give enough credit to the social and radical constructivists ignore the material in their investigations. The world, in my eyes, does not consist of either the social or the material; instead, these are co-constructed. Although some radical constructivists may agree with this statement, they argue that the co-construction cannot be explored as such since one would presume to know the material as it is. Rappert (2003: 571), as we saw in chapter 2, puts it this way: 'Trying to adopt a middle ground between relativist and realist positions (...) is tension-ridden because one must struggle against making definitive statements while taking certain things for granted'. Still, researchers have attempted to do exactly this. Actor-Network Theory was developed, not to adopt a middle ground, but to find a way around the dilemma of either the social or the material. It claims that how we define the social and the technical, objective and subjective, human and nonhuman, are consequences of negotiation processes that take place in networks. The Mangle of Practice approach argues that human and nonhuman (or material) agency, cannot be reduced to each other as in ANT, but operate together in a network where both material and human agency can become temporally emergent in a 'dance of agency'.

In chapter 4, I argued that water could be seen as both matter and custom that cannot be distinguished from each other. Water, and specifically water purity, has had a variety of meanings in different periods of time and in different places. The different relationships between people and water are not defined by material properties of water; instead the material properties (or affordances) are configured in these relationships. When parts of Britain became industrialised, the water in and near the towns became regarded as polluted. The need was felt to manage the material in a different way. Perhaps for the first time the physical properties and supply of water became a matter of both government and governance: the industrial and urban development required state interaction to manage and discipline the provision and use of water. Drinking water quality became determined by analyses of the chemical and bacteriological composition of the water rather than by the source where the water came from and its medicinal properties. Yet, exactly how the water had to be analysed has long been subject to debate. Hamlin (1990) showed that water analysis is not purely a scientific matter. Different systems of analysis are based on dissimilar and sometimes incompatible conceptions of for example whose responsibility water purity is. However, some controversies were closed, chemical and bacteriological scientists were educated in similar ways and a singularisation of drinking water quality, or at least tap water quality, took place in which the variety of meanings and interpretations of the water in previous centuries diminished. In the West, drinking water quality became governed by standards.

Approaches like ANT and the Mangle, despite their valuable contributions to understanding science and the world without ignoring the material, have rarely taken into account how science works and scientific facts are produced in a wider setting than in a laboratory. Kleinman (2003) provides a study that explores structural constraints to scientists' action. He discusses Knorr Cetina's *The Manufacture of Knowledge* (1981) as one of the few examples that focuses on how rules can shape action, but argues that her attention on the ways in which people involved in a negotiation process actively manipulate the rules ignores the important constraining role of rules. Both Kleinman and Knorr Cetina seem to have focused on one particular aspect of the relation between rules and human and organisational behaviour. Yet, chapter 2 raised the role rules, or standards in this case, play as something that needs to be empirically explored. Salter (1988) maintained that voluntary standards can be accepted by regulatory agencies and that standards developed by regulatory agencies can in turn be used as guidelines. The role standards play is thus not an inherent property. In this dissertation I have therefore empirically studied the 'waterworld' as a whole with particular attention to the co-construction of materiality (whatever its expression) and standards.

We have seen that drinking water quality has become increasingly governed by standards and associated regulations over the last few decades. Before the 1980s a few guidelines existed, but whether and how these were used was left to the chief chemist and chief microbiologist of a water company. Also the first European drinking water directive (1980) did not have much impact. People knew about its existence, but it was not enforced and people carried on with their routine practices. Only when the English 1989 regulations came into place and the Drinking Water Inspectorate was established and started to enforce the standards, practices started to change. Companies set up departments to deal with and understand the regulations and to tell other parts of the company how they could comply with the regulations. Water could no longer be judged by ordinary people with common sense; the increasing dependence of people on water supply systems, the progress in laboratory science and engineering of treatment plants led to a system that was led by experts and that had to be trusted by 'the public'.

The standards and associated guidance are extensive and complicated and largely influenced by how the waterworld operates. Others, Jasanoff (1990) and Irwin et al. (1998), have written about the relation between standards and the production of scientific knowledge. Jasanoff coined the notion of 'regulatory science' to refer to scientific knowledge that is produced to aid policy-making. As opposed to research science that is undertaken in for example academic laboratories, regulatory science is subject to strict time constraints, is more sensitive to political factors and leads more often to disputes over scientific evidence since the scientific uncertainty is much larger. In the waterworld regulations and standards do not only require new scientific knowledge to construct standards; moreover, the standards largely regulate and standardise scientific knowledge. It is the operation and mobilisation of standards in what I call 'regulated science' that the dissertation has paid attention to. I have attempted to compare the notions of research science, regulatory science, and regulated science in Table 7.1 below. Naturally, these are idealised views. As Irwin et al. (1997) argue the variety of regulatory science in different countries already undermines a clear distinction between regulatory and research science.

Table 7.1: Comparing research science, regulatory science, and regulated science

	Research science	Regulatory science	Regulated science
Aim of research	Knowledge production	Knowledge production to aid policy making and manage future uncertainty and risk	Regulatory compliance testing with help of existing knowledge
Role of time	Relatively unrestricted by time	Strict time limitations set by policy making process	Time limitations set by regulatory regime
Content of research/ relevance of context	Unrestricted by material as it is, where it is, and when it happens; context can be excluded	Relatively unrestricted by material as it is, where it is, and when it happens; context can be excluded from research although it helps to define areas for research	Material as it is, where it is, and when it happens; context 'determines' research
Interpretation of results	A paradigm needs to be formed, anomalies can be set aside for the time being and may change scientific theories, yet results are often interpreted from a *common disciplinary* background	Is complex, since this is different in the different disciplinary backgrounds involved	A stable paradigm has been established and is used to interpret results. Anomalies are ascribed to the water, instruments, or analysts, not to the scientific theories; they *need to be dealt with* immediately
Role of uncertainty and quality assurance	There is uncertainty about the 'correctness' of the result, but the quality assurance in place and the common disciplinary background reduce uncertainty	Uncertainty comes about through the variety of disciplinary background involved (disputes over what scientific evidence is) in creating knowledge and the therefore fluid standards for assessing quality; there are also disputes about what degree of risk can be tolerated	There is very little uncertainty; strong systems of quality and regulatory assurance are in place; disciplines are strictly separated and have their own tasks
Role of material agency (according to Mangle-like interpretations)	Resistance and accommodation lead to a 'dance' of human and material agency in which new knowledge is established	Resistance and accommodation lead to a 'dance' of human and material agency in which new knowledge is established	Processes of resistance and accommodation have become invisible and routine; yet they still exist in a more stable 'cultural choreography'
Role of the future	Irrelevant	Regulatory science is focused on managing future uncertainties and risks	Absent; regulated science follows regulations

Regulated science thus differs in a number of respects from both research and regulatory science. This has consequences for the way in which standards operate and are mobilised. An important part of regulated science is 'regulatory assurance'. Companies need to ensure that they are always in a position to make a 'regulatory response' in regard to meeting standards. Quality assurance supplements regulatory assurance. Although standards feed in and make sense of quality and its meaning, how the assurance is secured relates more broadly to the practices and culture within the water companies as a whole. Quality assurance and regulatory assurance have become intimately linked. Before the establishment of the strict regulatory regime no regulatory samples were taken. The samples taken were to ensure water quality and were part of quality assurance. Now this form of quality assurance is wider than the direct regulatory assurance, but is (partly) in place to support the system that produces regulatory assurance. Also quality assurance is therefore likely to have changed with the emergence of regulatory requirements. In fact, the customer plays a particular and perhaps unintended role in the process of quality assurance. Many problems with the water quality are discovered through customer complaints; these are the problems that can result in incidents for which the company can be prosecuted. Depending on the complaint and the parameter it concerns, action is undertaken to investigate the complaint and if necessary to solve the water quality problem. The funding of the company is partly dependent on the number of customer complaints: the more complaints the less the funding. The company will therefore try to prevent water quality problems because this will help to reduce customer complaints. However, although companies try to reduce the number of complaints, the complaints that come in are taken seriously. The regulatory risk of not investigating a complaint is large. If the complaint turns out to be serious and concerned what could later become an incident, the company can be prosecuted. The seriousness of the complaint is not only judged on the subject matter (illness versus discoloration), but also on where the complaint comes in. If a customer phones directly to the DWI the consequences for the company can be much greater than if the customer phones to the company's call centre. In this sense the company does not only seek quality and regulatory assurance, but also customer assurance. These three are of course intimately related and the boundaries between the three are not always clear.

This complicated system of quality assurance, regulatory assurance, and customer assurance that has become part of practices like auditing and operating treatment plants and laboratories and has 'enrolled' documents, extensive and detailed protocols, internal standards, alarms, blank samples, inspections of customers' taps that would otherwise be regarded as unnecessary, automatic dosing installations, and so on, also influences the specific standards-materiality relationships that are defined within this system. These different elements do not help to test the quality of the water 'out there'; instead they are a means with which the water quality and the practices around determining water quality are co-constructed. Systems of quality and regulatory assurance therefore also blur the boundaries between what is often considered 'macro' and 'micro', 'context' and 'content', and 'voluntary' and 'enforced' to point to the third research question identified in chapter 2. Both ANT and the Mangle concentrate on the construction of scientific knowledge in experimental science rather than on routinised science that focuses on ensuring compliance with particular standards. Yet, material-social and the more specific materiality-standards relationships are also at work in these routine situations.

Material-standards relationships are constructed through negotiations and mobilisations of standards in which they are co-constructed. We have seen examples in which standards were or were not set because of the perceived material characteristics and agency of certain parameters. Negotiators agreed on a standard for lead, since it is generally accepted that the parameter lead is harmful for public health. Other parameters were not regarded as harmful and were left out of the directive. The standards were set in a way that did not differ much from the way in which standards were set in nineteenth century Britain according to Hamlin (1990). The common basis of negotiators was larger, yet there were still differences about the scientific knowledge that should be 'in' or 'out' of place and that reflected different ideas about what a drinking water quality directive should be and how drinking water quality is best protected. Yet, at the same time the negotiations constructed specific material-standards relationships. Often, once set, the negotiations of this relationship became invisible and the material (the parameter) and the standards converged. The standards came to represent good water quality. The relationships were also constructed through specific mobilisations of the standards once these were set.[1] I will return to a few of them in Table 7.2 below, which at the same time answers the fourth research question raised in chapter 4.

Table 7.2: Mobilisations of standards (and therewith materiality)

	Through/by	To achieve
Mobilisation	Issuing Information letters (defining new or tighter criteria, analytical methods, proof)	♦ Compliance with the standard ♦ Specification of what the standard and water quality mean
	Auditing	♦ Compliance with the standard through ensuring and encouraging companies to avoid regulatory risks and pay attention to quality assurance
	Making a case for Relaxations	♦ Acceptance of non-compliance with the original standard and avoid work and investment of money
	Making a case for Undertakings	♦ Acceptance of (temporary) non-compliance with the standard
	Making a case for allowance of standard exceedence (there is a 'real' standard within the regulatory standard, since the regulatory standard has a wide safety margin)	♦ Acceptance of non-compliance with the standard and avoid work and investment of money
	Enforcing	♦ Compliance with the standard
	Prosecution	♦ Future compliance with standards
	Contesting definitions (unfit for human consumption)	♦ The standard and or water quality to be regarded differently ♦ Avoiding prosecution ♦ Avoiding fines due to prosecution
	Setting tighter standards	♦ Avoiding regulatory risk by ensuring compliance ♦ Avoiding upsetting the DWI ♦ Building trust (with DWI and/or customers) ♦ Competition with other companies ♦ Pride
	Setting various operational standards (for example for pH)	♦ A working treatment plant; ensure compliance with other (regulatory) standards

[1] These are (mainly) strategic mobilisations. Kinchy and Kleinman (2003) suggest that –with regard to drawing boundaries between science and policy- boundary work is not only strategic but can also be done habitually, routinely, and unreflexively. This may be the case for mobilisations of standards as well.

Chapter 2 criticised the concepts of immutable and mutable mobiles (see Latour, 1997; Mol and Law, 1994; Moore and Clarke, 2001) for being explanatory concepts. In the two empirical chapters of the thesis I have attempted to develop an understanding of the question when, where, and in what way standards become mobile and can be mobilised. It suggests that the mobilisation of standards should be understood with regard to the specific socio-material circumstances and the context of expectations and practices in which the standards operate. Not all standards can be and are mobilised in the same way. We have seen that different regulatory and operational standards become visible at different (obligatory) passage points in the treatment process and that they are dealt with differently in the different laboratories, partly depending on the regulatory regime governing the laboratory and on the way standards and materiality are co-constructed (some samples have to be taken on-site). The parameter *Cryptosporidium* is dealt with in slightly different ways depending on whether it is subject to a regulatory or operational standards. I will return to this. The classification of parameters –for example whether something is an indicator or mandatory standard– can also influence the ways in which standards are mobilised. Some standards cannot be relaxed because of the toxicity of the parameter or the way in which they are classified in the regulations. In addition, the knock-on effect of some standards on other standards can also influence their mobilisation.

We have seen that neither the concept of 'immutable mobiles' nor the concept of 'mutable' mobiles does justice to the way in which standards can be mobilised; mobilisation can be multilayered within standards. The distinction between a 'real' core standard inscribed within a more broadly framed standard shows how there is not just one layer or level of immutability within a standard.

Chapter 2 also critiqued the seemingly unconstrained and endless mobilisations or translations and transformations of standards as portrayed by many works in ANT. I raised this matter in the second research question that focused on, amongst others, resistances to standardisation and mobilisation. ANT regards the world as continuously becoming, yet, as Kleinman (2003) argues, at any point in time human and organisational actors are likely to confront existing structures as external and sometimes constraining. Whereas the wider regulatory regime may not play a significant role in the practices of experimental science that were studied in *The Mangle of Practice*, it is crucial for the way in which the waterworld operates. The relationship between regulator and regulated involves some form of boundary work (Gieryn, 1983) through which the lines of permissible and risk-laden discretion and interpretative flexibility can be drawn; this also affects the way in which companies are organised and work. In other words, although discretion and interpretative flexibility necessarily exist since not all possible situations can be foreseen and noted down in protocols and guidelines, water companies are not likely to use the discretion and interpretative flexibility freely. Even the decisions water companies make within these spaces are subject to regulatory risk. Water companies are therefore likely to ask the DWI for guidance. They also make ever more detailed protocols which are then audited by the DWI. Once the protocols pass the audit and the company sticks to the protocols, the regulatory risk has become much smaller. The mobilisation of standards is in this case therefore restricted by the regulator-regulated relationship. By making the companies subject to regulatory risk at all times, the DWI mobilises the standards in order to achieve compliance. This restricts other forms of mobilisation.

Another example illustrates that mobilisation of standards is not always straightforward. Table 2 above shows that standards can be mobilised in order to ensure or win the trust of customers (which is in turn likely to lead to a smaller number of customer complaints). Yet, as we have seen this does not always work. Customers may not accept the company's 'logical and scientific' explanation of water quality that demonstrates the good quality of the water and do not seem to regard the 99% of compliance with regulatory standards as sufficient proof. Customers often have their own individual and non-formalised standards that may not be the same as the regulatory standards. To explain this 'lack of trust' as the companies see it, we may have to touch on some of the wider literature on trust and on the 'public understanding of science' (PUS). In chapter 2 we saw that standards do not automatically lead to objectivity and objectivity not automatically to trust. One could say that before the 1980 drinking water directive was implemented disciplinary objectivity was dominant; it was the chief chemist and microbiologist who judged what was good water. Mechanical objectivity, on the other hand, is concerned with the following of rules. Yet, we have seen, both in chapter 2 and in the empirical chapters, that there is no such thing as 'simply' following the rules. Expertise is needed to interpret and deal with the rules. Halffman (1998) demonstrated that standards can be regarded as a trust device; protocols and certification systems help to view test results as reliable and valid. However, the trust is not an automatic consequence of the standards and can depend on specific circumstances. When company staff complain about the lack of understanding of the public, it follows the so-called 'deficit model' in which the public simply lacks the relevant knowledge. If only the public would be educated, its concerns would disappear. Yet, many social scientists have criticised this public deficit model by arguing that 'lay' people have different knowledges that are structured by cultural and social conditions and can, in some sense, be regarded as experts with different types of expertise (see for example Irwin and Wynne, 2003; Michael, 2002; Wynne, 1989, Yearley et al (2001). In addition, 'lay' people's concerns may not disappear if they had the same scientific knowledge as the experts. They may worry about ethical and normative questions to which even the scientific experts may not have a ready answer. I have not had time to explicitly study individual members of the public or to study the calls in the call centre extensively. Therefore, I cannot make a contribution to the literature on the public understanding of science. Nevertheless, this example hints at the idea that the mobilisation of standards to gain trust from the public may not work and is complicated by the fact that the public consists of many individuals who have their own standards and preferences about what water quality should be. Not only is the role of standards as trust devices problematic; their operation in an environment of other (whether formal or non-formal) standards can complicate matters as well and constrain mobilisation. Yet, trust, although also this can have different meanings, is important in the waterworld. Not only trust between a company and its publics, but also trust between the regulated and the regulator. As we have seen, the amount of trust present can influence to what extent standards and matters of quality assurance are enforced.

These mobilisations and non-mobilisations of standards influence (and reflect) co-constructions between standards and materiality. None of them define the water quality as it is 'out there'; they construct water quality in a different way. When a case is made for the relaxing of a standard, it is claimed that the parameter, when relaxed, will not lead to a problem for public health. When a standard is set tighter than the regulatory standard, one expects the material to be able to comply with the tighter standard and so constructs water quality again differently.

So far, the co-construction of standards and materiality has focused on discussions and negotiations of human actors: actors who argue that a standard for a parameter should or should not be included in a directive, should or should not be relaxed, and compliance with it should or should not be delayed. The arguments used are mainly based on the health-relatedness of the parameter, but also for instance on whether they can be economically removed and are acceptable to the customer. Yet, so far, it can be seen as a summing up of a number of accounts, something that could have been written by Grint and Woolgar. However, there is something else, something we can call material agency. Pickering (1995) explores how human and material agency are involved in a 'dance of agency' during the construction of scientific knowledge. When one agency is passive, the other one is active. Unfortunately, Pickering does not explore this dance of agency in a situation where the working together of the agencies has become routine. He suggests (ibid.: 102), and I repeat from chapter 6, that the open-ended dance of agency –that is scientific practice– 'becomes effectively frozen at moments of interactive stabilization into a relatively fixed cultural *choreography*, encompassing, on the one side, captures and framings of material agency, and, on the other, regularized, routinized, standardized, disciplined human practices'. We have already seen that a singularisation of water took place, amongst others, due to the increasing governance and management of water by regulatory standards. One could say that specific captures and framings of material agency have become dominant. This is even more the case in a situation we seem to encounter now, a situation in which a 'regulatory plateau' is established. It seems unlikely that the number of regulatory standards and the type of standards will radically change in the future. Processes of Analysing and 'treating' the parameters therefore do not undergo any change and become routinised and standardised practices. In an environment of regulated science that is not aimed at the production of new knowledge, human and material agency become part of a relatively fixed cultural choreography. Although the routinisation makes processes of resistance and accommodation almost invisible (they have become so normal), these processes are still at work. I will revisit a few examples.

Firstly, there is the taking of a water sample. It would be time and cost saving if a company could take one water sample and, by analysing it, determine its material properties. Yet, because of the interaction between different parameters/substances, the water as such cannot be stabilised. It is the specific material properties that have to be stabilised. Different sample bottles with different preservatives and different laboratories are needed to be able to get a picture of the water quality as a whole. This is a clear example of both processes of resistance and accommodation at work in routine situations and, at the same time, of co-construction of standards and materiality. The material resists the 'simple' notion of taking a sample and human practices and regulations have to accommodate this. The regulations then prescribe ways of taking a sample that accommodate the need for different bottles and preservatives and turn these into regulatory requirements and make them part of audits. In fact, the production of samples could be said to be subject to sample documentation that records and authorises key points in the making of water quality. The regulatory standards, associated guidance, and company protocols form multiple levels of accountability that shape the production of samples. Yet, it is not a one way influence; not only the regulations have to take materiality into account, the material has to incorporate the regulations and is itself changed when preservatives are added. Samples are taken to analyse a particular material property of the water which is at the same time constructed through the preservative in the sample bottle. Standards and materiality are therefore co-constructed. Yet, it is not something people think about anymore. Every sampling officer has standard a number of different bottles with different preservatives in the van; the cultural choreography is fixed.

A second example shows that the standards-materiality relations can become fixed, but that how they become fixed is dependent on the wider environment. In the microbiological laboratory an important sense of time is material time. Bacteria grow with a certain speed. This can be speeded up by putting them on a specific medium and in an environment with the right temperature. Further manipulation is however difficult. The time it takes to analyse a sample therefore depends on this material time. The different samples, operational and regulatory, are analysed in the same way. However, in other laboratories other material-standards relationships exist. In the chemistry laboratory it is neither the materiality nor the regulations that 'determine' the way and time in which samples are analysed. The *Cryptosporidium* laboratory is so strictly regulated that the analysis of samples is not (only) determined by their materiality; instead, regulatory and non-regulatory samples are treated in slightly different ways.

A third example shows the necessity of a co-construction of standards and materiality. It is the example of the unknown sample. Neither ANT nor the Mangle pay much attention to how the results of analysis are exactly interpreted. Yet, this example shows that when a piece of unknown materiality enters a laboratory that practises regulated science, which can in some ways be regarded as 'normal science', it cannot be interpreted as such. Neither can it be set aside as an anomaly as might happen in Kuhn's world of normal (but experimental) science. The regulations require an immediate explanation. The materiality itself thus does not determine how it should be dealt with. It is part of a particular paradigm, and in this paradigm the sample and materiality can only be interpreted as 'normal' or 'abnormal' when the origin of the sample is known. If one does not know what the likely materiality is before one analyses it, it can harm the analytical techniques. In other words, we do not know what this 'something' is, but we know it can do something, it can block the filters. Even if one has managed to analyse the sample without destroying the analytical instruments, the result of the analysis is meaningless. In other words, the interpretation of the result of analysis cannot depend on the results of the analysis alone. If the sample contains a high level of heavy metals, it can be a normal wastewater sample or an abnormal drinking water sample for which immediate action needs to be undertaken. Unlike the co-construction of human and material agency in experimental research, the co-construction of materiality, human agency, and standards mean that it is necessary to interpret materiality, to know where it can be analysed, and to know what standards to employ.

The practice of regulated science thus requires materiality to be either classified as 'normal' or as 'abnormal' and it should be possible to explain the result under all circumstances. Inspectors may know from experience what a normal result looks (or smells or tastes) like and what they can expect. By taste, smell, knowledge of the area, logbooks, validation of instruments, and if necessary a check with other quality inspectors, the quality inspectors can judge the 'normality' of the results of the taste and odour, pH, conductivity and chlorine tests. The 'normal' result of a total chlorine test of borehole water is very different from a 'normal' result of the same test for surface water. Knowledge of the source therefore provides the expectations that are needed to interpret the result. If the result deviates from the paradigm of normal results, further investigations are needed. Yet, 'abnormal' results or anomalies do not lead to a change in the way we think about the world and to a questioning of the scientific theory; they are instead ascribed to the water, the measurement or treatment technologies, or the skills of the analyst. I have shown that, in some cases, it is unclear who should be 'blamed' for a wrong result. If there is confusion about who is to be blamed, it is also unclear as to which standard should be enforced and how.

In this conclusion to the thesis, I have discussed the many and complex relations between standards, materiality, and human agency and shown how these are co-constructed and cannot exist independently of each other. I have indicated where a few of the answers to the research questions identified in chapter 2 can be found and what these are. Before I really conclude, I will shortly explain the consequences of this for the notion of 'compliance'.

Drinking water quality standards are often mobilised to act as a guarantor of quality; they are used to make water waterproof. Companies state that 99% of their water complies with the standards. Yet, what does this mean? We can now give a more complex picture of what exactly the meaning of compliance is. We have seen that by means of extensive and complicated systems of quality assurance and regulatory assurance within which standards are mobilised in various ways notions like 'macro' and 'micro' and 'context' and 'content' are blurred. Standards and materiality –which together form water quality– and thus 'macro' and 'micro' and 'context' and 'content' are co-constructed. Compliance is in fact the comparison of the standard that is constructed through negotiations, with the 'actual' water quality that is (materially and socially) constructed in a process in which a water sample becomes a number on a computer screen. This comparison forms the proof for the quality of the water. I would like to raise three points that complicate the notion of compliance. First, water can still comply after standards have been mobilised and sometimes become different standards. Yet, the mobilisations and thus the different co-constructions of standards and materiality point to different water qualities. In fact, one could perhaps speak of different compliances. Second, the statement that the water quality has improved over the last decades cannot be understood without reference to the notion of co-construction. The improvement of water quality can only be explained when one takes into account that companies have become familiar with the regulatory standards which have not significantly changed (regulatory plateau) and have been able to develop treatment and measurement technologies to deal with the parameters for which the standards were set. A last point about the meaning of compliance is that the statement that 99% of the water complies with the standards seems to imply that the water is –at least 99% of the time- of the same materiality. But, as we have seen, a shower in London and a shower in Manchester remain different showers due to the 'fingerprint of the water'.

In conclusion, I would like to argue that a singularisation of drinking water (or, better, tap water) quality has taken place that is reflected in the setting of numerical standards for water quality. Yet, these standards are mobilised in various ways which all construct different water qualities. These different water qualities do not reflect the water 'out there'; they come about through different co-constructions of materiality and standards. In these co-constructions material agency plays an important role, not because we know exactly what this materiality is in a realist sense, but because it does something. However, as the notion of co-construction indicates, materiality cannot exist separately from a paradigm of regulations and expectations in which the materiality can be interpreted, at least in the specific case of the drinking water industry. This is perhaps especially true when water quality is constructed in an environment of regulated science where science is used for regulatory compliance testing and 'normal' and 'abnormal' results are clearly defined.

At the end of chapter 2 I identified a number of research questions that I could not address in this dissertation. The list of questions and topics has now become even longer. Yet, I decided to address (only) seven of them as possible future research projects and I hope to be able to carry these out or contribute to them in the (near) future.

Research project 1: a comparative study on standard-materiality co-constructions in the waterworld (expanding the current project)

Through longer periods of ethnographic fieldwork in various companies and expanding the geographic area (Scotland would already make for an interesting comparison) much more can be learned about the role of standards and the standards-materiality relationships. Few countries have an agency like the DWI that enforces the standards in the same way. The new EU countries would form very interesting case studies: they are organised differently, may not have the same level of expertise and number and quality of equipment or financial means to purchase this, and will 'suddenly' have to comply with a number of new regulatory standards. In comparative studies more attention can be paid to cultural differences and policy styles and how these influence mobilisations of standards. This project, if it concentrates on the new EU countries, can also address the question of what happens with networks (or institutional and organisational settings) when standards change and what happens with standards (i.e. the ways in which they are mobilised, the standard-materiality co-construction) when networks change.

Research project 2: the role of standards and comparisons between regulated, regulatory, and research science

This project could be a purely theoretical study in addition to research project 1. Comparisons with countries where responsibility for drinking water quality is organised in different ways and with or under different regulatory regimes would help to understand the ways in which regulated science can be manifested. In other countries regulated, regulatory, and research science may be much more blurred. This could help us to understand the role of standards better.

Research project 3: comparing standard-materiality co-constructions in the waterworld with the world of food quality and air quality

Other 'worlds' in which both material quality and regulatory standards are present could be studied in a way similar to the way in which I studied the waterworld. This would, like research project 1, provide an understanding of the particularity of specific co-constructions and standard mobilisations *and* could perhaps identify patterns of co-constructions and mobilisations.

Research project 4: exploring the standards-publics-trust relationships

Through interviews with tap water consumers (perhaps via WaterVoice that represents the water customers in England and Wales) and ethnographic fieldwork in water companies' call centres, and perhaps an analysis with help of conversation analysis, one can explore the relationships between standards (and their mobilisations), the publics (and their informal standards), and the relationships of both standards and the publics to trust. This would be an interesting subject since it further explores the problematic idea of the singularity of 'the public', the public's expertise, the idea of non-mobilisation of standards, and the relations between standards and trust. It is a project that is not only academically interesting, but would also have the interest of water companies.

Research project 5: Trust and Standardisation

A Porter –like analysis of the relation between water companies and the DWI with regard to the approach the DWI took to standardisation in different periods. When and why did the DWI feel the need to control water companies by, what can be called, 'extreme' standardisation and what were reasons for less stress on standardisation in other periods? What is the role of trust in these developments? This can perhaps be compared with other cases of standardisation in which privatisation played a significant and researchable role.

Research project 6: An exploration of relations between science, law, and definitions of water quality

In this project a number of cases would be followed and explored in which water companies have been taken to court for providing water 'unfit for human consumption'. How is water 'unfit' and 'fit' for human consumption defined by courts? What role do science and uncertainty about scientific evidence play in these cases? It would offer a possibility to compare the relation of English judges with science to the American situation as described by Jasanoff (1995) in *Science at the Bar. Law, Science, and Technology in America.*

Research project 7: Exploring regulatory plateaus

How does a regulatory plateau define what standards are in and out of place? When and how –under what circumstances– is or can this plateau be disturbed? A close case study on the relatively new *Cryptosporidium* standard might help to answer this question. Empirically we can ask how this standard found its way into the plateau, whether there was resistance against it and in what ways.

Original in colour

Appendix 1 Information About Water Companies

Table 1, Appendix 1: Summary of the key information as defined by the DWI for each of the 26 water companies. (DWI, 2004)

Company Name	Consumers Supplied	Water Supplied (Ml/d)	Proportion Surface Water	Proportion Ground Water	Number of Treatment Works	Number of Service Reservoirs	Number of Zones	Length of Mains (Km)
Albion	470	0.095	100%	0%	0	0	1	0
Anglian	4,140,000	1,318	48%	52%	142	382	190	36,000
Bournemouth & West Hants	416,982	106	88%	12%	7	21	16	2,748
Bristol	1,077,474	318	75%	25%	17	185	52	6,500
Cambridge	291,010	78	0%	100%	22	33	14	2,194
Cholderton	2,100	1.0	0%	100%	1	1	1	44
Dee Valley	259,081	69	96%	4%	7	31	18	1,953
Dwr Cymru	2,925,000	905	94%	6%	91	528	160	27,000
Essex & Suffolk	1,700,000	483	95%	5%	25	110	66	8,441
Folkestone & Dover	182,874	51	15%	85%	17	13	10	117
Hartlepool	90,000	35	0%	100%	3	6	4	518
Mid Kent	574,565	167	12%	88%	30	66	20	4,181
Northumbrian	2,550,000	757	95%	5%	35	242	111	16,789
Portsmouth	655,382	187.5	10%	90%	20	41	23	3,247
Severn Trent	7,270,000	1,958	65%	35%	161	626	284	45,676
South East	1,461,000	360	28%	72%	61	172	90	9,445
South Staffordshire	1,300,000	340	59%	41%	22	37	39	5,850
South West	1,570,000	461	90%	10%	33	327	81	15,000
Southern	2,280,000	595	29%	71%	94	210	116	13,394
Sutton & East Surrey	640,998	168	14%	86%	9	32	21	3,372
Tendring Hundred	147,130	31	20%	80%	3	9	4	910
Thames	8,000,000	2,965	76%	24%	101	368	244	31,300
Three Valleys	2,900,000	929	42%	58%	83	137	108	14,277
Wessex	1,190,000	394	22%	78%	93	311	98	10,500
Yorkshire	4,710,000	1,300	78%	22%	86	400	190	31,062
United Utilities	6,930,000	2,022	92%	8%	140	381	288	40,600
Totals	53,264,066	15,999			1,303	4,869	2,240	331,538

Company Name	Samples taken at Treatment Works	Failures for Total Coliforms	Failures for Faecal Coliforms	Samples taken at TWs for Cryptosporidium	Failures of treatment standard for Cryptosporidium	Samples taken at service Reservoirs	Failures for Total Coliforms	Failures for Faecal Coliforms	Total Samples Taken in Zones	Failures in Zones	Total Tests Taken	Total Number of Failures	% Compliance
Albion	0	0	0			0	0	0	551	0	551	0	100.00%
Anglian	29,016	2	0	1,645	0	41,122	12	1	163,586	703	235,570	718	99.70%
Bournemouth & West Hants	3,790	3	1	1,827	0	2,138	1	0	9,376	25	17,130	31	99.82%
Bristol	6,970	1	0	1,632	0	18,532	8	3	10,683	22	36,817	34	99.91%
Cambridge	2,424	1	0			3,422	1	0	4,047	26	9,893	28	99.72%
Cholderton	110	0	0			100	0	0	390	1	600	1	99.83%
Dee Valley	2,716	1	0	1,100	0	3,242	2	0	7,194	9	14,252	12	99.92%
Dwr Cymru	17,406	3	0	6,200	0	53,502	31	1	75,250	192	152,410	227	99.85%
Essex & Suffolk	8,212	7	1	1,374	0	11,044	6	0	100,847	68	121,477	82	99.93%
Folkestone & Dover	3,398	1	1			1,282	0	0	2,992	4	7,672	6	99.92%
Hartlepool	728	0	0			628	0	0	1,341	5	2,697	5	99.81%
Mid Kent	6,922	2	0			6,522	4	0	17,779	18	30,223	24	99.92%
Northumbrian	13,782	3	0	2,963	0	24,776	22	5	156,829	127	198,350	157	99.92%
Portsmouth	6,368	2	2	1,300	0	4,240	3	1	11,435	16	23,360	23	99.90%
Severn Trent	30,914	11	2	3,043	0	62,125	20	3	184,379	149	280,465	185	99.93%
South East	12,104	2	1	3,465	0	17,630	11	0	31,604	111	64,903	125	99.81%
South Staffordshire	4,843	1	0	788	0	3,842	4	0	27,753	29	37,731	34	99.91%
South West	15,375	8	0	4,618	0	34,991	18	0	110,172	101	164,957	127	99.92%
Southern	14,110	7	1	4,417	0	21,810	6	0	35,753	89	76,090	103	99.86%
Sutton & East Surrey	4,382	1	0	365	0	3,792	1	0	12,973	49	21,112	51	99.76%
Tendring Hundred	1,256	0	0			810	0	0	1,958	0	4,048	0	100.00%
Thames	29,274	8	1	6,300	0	38,584	14	0	466,736	468	541,902	491	99.91%
Three Valleys	19,468	4	2	1,658	0	13,976	1	0	40,609	75	75,711	82	99.89%
Wessex	22,434	4	0	1,656	0	32,812	22	4	107,902	80	165,320	110	99.93%
Yorkshire	19,236	2	0	2,655	0	41,380	30	7	198,845	118	262,716	157	99.94%
United Utilities	45,324	81	15	1,500	0	39,350	47	0	253,590	473	340,777	625	99.82%
Totals	321,049	156	27	47,520		482,201	243	34	2,045,473	2,959	2,896,252	3,419	99.88%

Appendix 2 Note on Interview Respondents

The job titles of the people I interviewed were as diverse as '(drinking) water quality manager', 'drinking water inspectorate liaison and sampling coordinator', 'senior treating chemist', 'laboratory analyst', 'contract manager', 'company advisor (microbiology)', 'water quality administrator', 'water quality controller', 'scientific services manager', 'policy and public health manager', 'head of water quality', 'independent drinking water consultant', 'DWI Inspector', 'Superintending Inspector DWI', and 'Assistant Technical Secretary to the Committee on Products and Processes'.

Although the job titles were often different, the work many of the respondents did was very similar. They all dealt with water quality. In large companies the work was often divided between different people: one person would liase with the drinking water inspectorate whereas another may specifically look at the company's performance on supplying drinking water. In smaller companies one person may be responsible for many different tasks. In a description of a normal day, one respondents mentioned looking after the sampling program (sometimes even doing the sampling), dealing with the general public, liasing with the DWI, pulling together the monthly, half-yearly, and annual reports, and liasing with the laboratory. Many respondents had a chemistry background or otherwise a background in microbiology or another natural science. One respondent (Sarah, WQM/230502) did not and when I asked her about her background she answered:

> My own background? Oh dear. I am afraid, this is where it gets really embarrassing. I have absolutely no scientific background at all. (...) Everybody says: 'oh really? How do you, what, how?' Basically I came here to do another job, which was basically secretarial, and due to, I mean this is ten years ago, due to the changes in the staffing at that time I started off as a secretary and three days later I was in water quality.

A natural science background was clearly the norm in this area. Many respondents had had a long career in the water industry and worked there for over 20 years.

For reasons of confidentiality I can neither mention the companies for which the respondents work nor the names of the respondents. However, in order to refer to them in the thesis, I have given the respondents fictional names that come from Graham Swift's *Waterland* and Roger Deakin's *Waterlog*. These are either male or female. The gender does not bear a relationship to the gender that particular respondent had, but does reflect the overall percentage of men and women I spoke with. The first time I mention someone I will provide the date on which the interview was held and the function of the person. After that I will just mention their name; their function can then be found by going back in the text or looking at the Table below. The abbreviations of the functions are explained in Table 1 below, however, it is important to note that I refer to all respondents who carry out work similar to that described above as 'water quality manager'. Persons who perform different functions like the contract manager, and the DWI inspector above will be referred to differently. If the respondent works for the water company where I carried out my ethnographic fieldwork, 'WaterCo' will be added when they are mentioned. In the Table below, I have added whether the person works for a small, medium, or large company. This should not be considered as essential information. Rather, it provides a little bit of the wider context: sometimes I hint at possible differences between small and large companies in how they operate. However, these have not been investigated thoroughly and should therefore literally be regarded as 'hints', perhaps for further research. Lastly, it is important to note that the text may not mention all respondents found in Table 1. As observed in chapter 4, some interviews have proven more relevant than others.

Table 1, appendix 3: Information about interview respondents

Name respondent	Function in waterworld	Size of company (if relevant)
Martha	WQM/040202	Large
Catherine	WQM/110401	Large
Robin	WQM/090603	Large
Victor	WQM/140202	Large
Oliver	WQM/120503/WaterCo Commentary on chapter, 290704	Large
Thomas	HQD/181102/WaterCo (head quality department)	Large
Helen	QI/130503/WaterCo (quality inspector; takes samples	Large
Richard	NM/150503/WaterCo (networks manager)	Large
Dick	LTI/160403/WaterCo (long term investigations)	Large
Roger	LTI/160403/WaterCo (long term investigations)	Large
Caroline	CAWQR/150403/WaterCo (company advisor water quality regulations)	Large
Marc	CAQA/150403/WaterCo (Company advisor quality assurance)	Large
Lillie	MA/140503/WaterCo (microbiology analyst)	Large
Henry	CAM/140503/WaterCo (company advisor microbiology) Commentary on chapter, 160604	Large
Keith	CML/030703/WaterCo (contract manager chemistry laboratory)	Large
Keith	CML/160503/WaterCo Commentary on chapter, 160704	Large
Keith and Judith	CML+CA/030703/WaterCo (chemistry analyst)	Large
Judith and Keith	CA+CML/020703/WaterCo	Large
Peter	MWS/140403/WaterCo (manager water supply)	Large
Jack	TPM/140403/WaterCo	Large

Name respondent	Function in waterworld	Size of company (if relevant)
Lewis	WQM/181102	Medium
Scott	WQM/031202	Medium
Bill	WQM/201102	Medium
James	WQM/280403	Medium
Samuel	WQM/251102	Medium
George and Rupert	WQMNL/250601 (water quality managers Netherlands)	Medium
Fred	WQM/150202	Medium/ Group of companies
Mary	WQM/010202	Small
William	WQM/271102	Small
Rosa	WQM/270502	Small
Sarah	WQM/230502	Small
Harry	WQM/261102	Small
John	WQM/271102	Small
Charlie	IDWI/050603 (inspector DWI) Commentary on chapter, 130904	
Chris	DWC/040603 (drinking water consultant)	
Stephen	DWICPP/050603 (DWI Committee Products and Processes)	
Michelle	DWICPP/050603 (DWI Committee Products and Processes)	
David	RWRCNL/270601 (researcher water research centre the Netherlands)	
Ned	RWRCNL/270601 (researcher water research centre the Netherlands)	
Edward	MSWC/020701 (manager spring water company)	

Table 2, appendix 3: Information about other respondents

Name respondent	Function in waterworld	Method of responding
Sam	DCIDWI/230804 (deputy chief inspector DWI)	E-mail
Rene	ADNIPH/140800 (assistant director of the section of water hygiene of the Norwegian institute for public health)	Face-to-face interview

Appendix 3 Examples interview schedules

In this appendix I give three examples of interview schedules I used. The first one was used for an interview with a water quality manager of a water company, the second for an interview with someone involved in the negotiations on the 1998 European drinking water directive, and the third for an interview with a treatment plant manager. Note that the schedules were rather used to fall back on than to follow strictly in the order in which the questions are set. The interviews were often made company specific and asked for instance to explain the specific number of incidents a company had encountered (information I had obtained through the DWI annual reports). A number of questions have been left out of the interview schedules below since they might identify the company and/or respondent.

Interview schedule water quality manager

Name
Function within water company
Number of years working in water industry
Educational background
Organisation of the company
Number of people in company working with water quality standards
Description 'normal' day

Changing role of standards in waterworld

- In what ways have setting, implementing and anticipating standards changed over time?
- How and when did people start setting water quality standards and how has that developed over time?
- What was according to you the biggest change in the water industry over the last 20 years? (short comment on each of the following)
  - Privatisation
  - Founding of DWI
  - Founding of Water UK
  - Eureau
  - Change from Regional Water Authorities to water companies (RWAs were also responsible for polluters, if responsibility in regulations change, then there will be a different way of dealing with these regulations)
- How have these changes influenced the standard setting, implementation and anticipation of standards?
- How did they influence the ways in which water companies deal with/have to deal with standards? (do standards play a role in competition between companies; have they become more/less visible?)

- Have standards become increasingly structured, i.e. have the regulations around the standards increased (the paper work etc.)? What happened to discretion of water companies to interpret the data (as complying or not complying)?

Role of standards in communications between different organisations

- What role do standards play in the communication within and between different organisations (water companies, Eureau, Water UK, DWI, Government, industry (polluters))?
- Does it happen that other organisations (environmental agencies) have different (own) water or technical standards to comply with and that they clash? If so, what happens then? Example?
- What has been and is the role of consumers and environmental organisations in the setting of standards?
- Has there been an increasing pressure from consumers and environmental organisations to promote strict standards for drinking water quality?
- If so, in what sense and can you explain this?

Regulatory plateau/changing standards/future

- What will happen with the number of standards in the future?
    - Will the number of water quality standards increase in the future infinitely?
    - If so, how are the parameters 'discovered' and how will they be related to standards?
    - If not, why has the number stabilised?
- Do you expect a shift in the type of parameters for which standards are set?
- Is it likely that there will be standards for minimum concentration of certain elements?
- If/when new standards are developed, is the process of adding them to the existing standards different from how it used to be before?
    - What happens for example with potential endocrine disrupting chemicals?
    - What happened and is happening with *Cryptosporidium*?
- Do you expect a *Cryptosporidium* standard in other countries? Why or why not?
- Other examples of parameters?
- Are different standards implemented in different ways? Can we compare the implementation of the *Cryptosporidium* standard with for example the standard for nitrite or lead?

Water company specific

- In your company, what role do standards play in the process in which water goes from being found in raw water sources to the tap? Where do they start to function?
- What role do water companies play in the standard setting process?
- Can you give examples of how the water company dealt with appearing, changing (relaxed/tightened) and disappearing standards?
    - Who are involved in this? Who are dealing with the standards and in what ways?
    - What are problems one encounters when implementing standards into day-to-day practice and how are they solved?
- Are there cases in which you measure the raw water parameters and the quality is too bad to ever make drinking water from it?

- Is there a difference in dealing with natural and man-made pollution with regard to the regulations?
- What does your water company define as good water quality?
  - Water that complies with regulations?
  - Water with specific characteristics?
  - Do you add things to the water to make it of a good quality?
- If in any, in what cases are variations/deviations from the standard acceptable and why? Are variations from certain standards more acceptable than from other standards?
  - According to the company
  - According to national regulation

Research and Development

- Does your company do any research?
  - If so, can you give examples of the kind of research and the kind of innovations and technologies that are developed?
- What are the reasons for undertaking research and for technology development? (standard-driven, efficiency, anticipation of standards)
- Who are involved in this?
- Do other water companies do that as well?
- Does the fact that you are a large/small company affect the possibility of doing research?
- Do you have your own laboratories? How does this influence the way in which the company works?
- Have there been any examples of the introduction of new regulatory standards for which no technology or way of analysis existed yet? What happened then?
- Or the opposite: have there been examples of cases where the regulatory standards were not up to date with the technical/analytical possibilities?

- How do you know what is going on in the water world? Certain journals? Which ones are essential?

Interview schedule negotiator 1998 Drinking Water Directive

Involvement in new EU directive

- Can you say a bit more about your involvement in the process? Meetings? Were there different groups working on different things that would all be part of the directive?
- How were the standards set? (Just taken from WHO? To what extent were they adjusted?)
- How much did other regulations (nitrate directives, groundwater directives, water framework directive) influence this directive? To what extent did you as a group take these other regulations into account? Harmonisation with those directives?
- To what extent did product legislation (ISO standards for pipelines; laboratory methods etc.) play a role?
- Which standards were most disputed and what were the disputes about (between countries)? About whether they should be there at all or not, or about the maximum levels?

- Why more debates about some standards rather than others?
- Did people agree that some standards were more important than others?
- How were the debates settled?
- Would you say that some parameters are more scientific and some more political? How would you make a distinction between these two? And between the old and new directive?
- What was the input of Eureau in this? And the WHO? Had DWI a role in this? And WaterUK?
- How and why was decided on parameters that were left out of new directive (potassium) and on the ones that came in or were reduced? (lead, bromate)
- In what contexts are the quality standards seen as an opportunity and when are they seen as a constraint? Examples? Would this differ per company (for instance large/small)?
- New regulations offer greater protection against Cryptos, how?
- How do national regulations differ on residual disinfection and what is the difference with the US? How did this affect (debates about) the new directive, if at all?
- To what extent and how were consequences of new standards taken into account and anticipated? Did any problems occur that weren't anticipated?
- When is the next update of the directive? What do you think will be likely changes?

Involvement in translation to UK legislation

- Have you been involved in the translation of the European directive into national legislation?
- How was this translated into the UK regulations? Why and how is Wales different?
- Were some standards rather than other standards more contested in the UK? Did companies with different water or smaller/larger companies have different ideas on what were contested standards and what were not? In other words, what were different causes for debates?
- Also here: how were the debates settled?
- In the national legislation the monitoring of copper, lead, nickel and parameters relevant to radioactivity 'shall be monitored in such a manner as the Secretary of State shall determine from time to time and shall specify by notice in writing given to each water undertaker'. Why are these parameters monitored in a different way than the others?

Radioactivity issues

- Radioactivity was not part of the 1980 directive. How did it become important for the 1998 directive?
- The water supply regulations 2000 anticipated the outcome of article 12 (amongst others on radioactivity): can you say a bit more about this process of anticipating?
- Why was anticipation necessary? Why couldn't they wait for the outcome of the discussion?
- Who decides on questions like: what should be analysed initially?
- Do you know how companies deal with this if there is a very limited capability in sampling and analysing? They need to know at what level to monitor.

- It was mentioned that the public perception might require immediate action, action well below the standard in the case of radioactivity. Can you elaborate on this?
- Does the consumer have different ideas about radioactivity than water companies and/or the DWI? Why? Do they just have less information or might they have different ideas about health and purity?

Standards/regulations general: future and anticipation

- The DWI did some work on assessing future regulatory trends and the scientific and technical justification for those trends, also surrounding specific contaminants
  - How did the DWI go about this work?
  - Did reports come out of it?
- Is it likely that more standards will develop in the future?
  - If so, what sort of standards?
  - If not, will other means be developed to deal with water contamination by other substances?
  - Is there a sense in which all materials have been discovered or will there be such a point?
  - Is adding new standards slowing down? Why?
- What will be reasons to develop new standards? Following from emergency situations? How do new problems/standards come up? Have the process and the criteria changed over time? For instance *Legionella*?
- Are new standards formulated and implemented in new ways? *Cryptosporidium* is a treatment standard, radio-activity is indicator standard.
- What about endocrine disrupters? What happens now if new issues occur, like potential endocrine disrupting chemicals? Is this different from when new issues occurred in the past?
- Will endocrine disrupters and *Cryptosporidium* become an EU standard? What does that depend on?
- Does it become more difficult to implement new standards?
- Are there specific difficulties in implementing and policing standards (as DWI does) because of materiality of the water? And technologies? For instance compared to making sure than people don't drive through red traffic lights.
- Has the role standards play changed over the years? (have been guidelines, methods to check water quality and methods to be able to prosecute companies)
- Is there a tendency to move towards different ways of dealing with water quality, rather than standards or regulations?
- Will relaxations of the standards remain in place or was it a temporary tool until all water companies complied? Are all standards now health related? Is the regulatory plateau ever finished?
- How did this regulatory plateau come into being; who developed it?
- What is it? A list of the most important and or most occurring parameters? Are there other ways to describe it?

Emergency situations

- Do existing regulations give more guidance to deal with some water contamination emergencies rather than with others?
- *Cryptosporidium*, Chernobyl and foot and mouth have all affected a number of different countries: are similar emergencies solved differently in different countries? If so, how and why?

- In negotiating a way of dealing with the emergency situation, does it make a difference whether the contamination:
  - Comes from outside the system (Chernobyl, foot and mouth and diesel)
  - Occurs in the raw water as natural rather than industrial 'pollution' (*Cryptosporidium*, 'Hungerford Incident')
  - Comes in the distribution system through inadequate water treatment?

Interview schedule treatment plant manager

Development treatment technologies

- Where do the different treatment technologies come from? Are they bought or developed by WaterCo?
- What was the reason for their development? Are there alternatived for these specific treatment technologies and if so, why is chosen for these?
- How is the development of new treatment funded? What is Ofwat's role in this? How has this changed since privatisation?
- How do you define what treatment technologies are needed or would be useful and how do you go about it?
- How have treatment plants changed over time? Can you compare it to plants 10 and 20 years ago? Can you sketch the development of this specific treatment plant?

Role of treatment technologies

- What role can/do treatment technologies play when an 'unknown' is discovered in the water?
- Is everything treatable?
- Some instruments are used as technological barriers: is everything they stop known? Do they stop substances that have no specific regulatory or operational standards? If so, will this prevent future standards from being set?
- What is removed from and what is added to the water and at which stage?
- Does the treatment plant shut down when an unknown or harmful substance is discovered? Is this an automatic shut down or is this done automatically? Does this differ per parameter?
- In what cases is relied on the treatment and in what on the people?

On-site monitoring

- When is on-site monitoring in place and when are samples brought to the laboratory? When is the sampling done manually and when automatically? Are there cases in which one cannot rely on the automatic system?
- How is the system maintained and how/how often are the sampling and analyses techniques validated?
- How does one find out that something is wrong?
- Does the (automatic) monitoring notice unknowns?
- How has what the systems monitor changed over time? When did it change for the last time and how and why did it change? Does it monitor more than regulatory and operational standards?
- Who checks and interprets the data?

Treatment system

- What is the core of the system? Are some parts more important than others?
- Is the treatment concentrated in a particular part or spread over the whole system?
- To what extent are the technologies adjusted to the specific water they treat? Is this manually or automatic?
- How much is the design of the plant as a treatment system shaped by the need to cope with water? What are the more generic and what the more (water) specific properties of the plant?
- To what extent are safety and quality standards build into the system?
- How has the system changed in relation to the water quality standards and the water that needs treatment?
- How do the different parts of the plant and the different people in the plant work together? Are there parts that work more autonomously than others?
- In case of an emergency, do you know where the water of this plant is going?

Implementing new treatment technologies

- What happened when the *Cryptosporidium* regulations came into place? What works, if any, had to be done for the nitrate parameter? And lead? Any other current parameters?
- Can you describe the process of implementing new treatment in detail? Who works on it, how is decided where to install the treatment, how to validate that it works?
- Have there been cases where the treatment technology worked differently that how you had anticipated it would work? Was this a difference between theory and practice? What were the consequences?
- Which parts of the treatment plant have followed standards and which haven't?

Standardisation

- If you would walk into another company's treatment plant, how similar would it be to this one?
- In case of an emergency (a shut down, a fire) would you be able to use another treatment plant easily for this water supply?
- Does one need to standardise technologies, analyses, and so on, in order to standardise drinking water quality? Do some parts of the treatment system need to be more flexible than others?

Training/knowledge

- How are tasks divided within the treatment plant?
- What is the background of the different people?
- How are people trained? What is the content of the training?
- Are there emergency exercises?

Contacts

- In what cases do you contact other departments within WaterCo and which departments are this?
- Do you have contacts with the DWI and Ofwat?
- Do you have contacts with other water companies? When and how?

Appendix 4 Information Letters

These are Information Letters from 2000 and 2003, selected by the DWI as letters of particular interest. They give an overview of the sorts of issues information letters deal with (and thus which standards they mobilise and in what ways) and show which issues were prominent in a certain period.

Table 1, appendix 4: Overview information letters

Date Information Letter	Subject Information Letter
	2000
5 January 2000 1/2000	Provision of Compliance Data and Preparation of Summary Tables for the Chief Inspector's Annual Report
21 January 2000 2/2000	Water Supply (Water Quality) (Amendment) Regulations 1999 : Cryptosporidium in Water Supplies: Sampling
21 January 2000 3/2000	The Water Supply (Water Quality) (Amendment) Regulations 1999 : Cryptosporidium in Water Supplies: Laboratory Analysis
21 January 2000 4/2000	Monitoring Data Reporting Under the Water Supply (Water Quality) (Amendment Regulations) 1999 : Cryptosporidium in Water Supplies
10 February 2000 5/2000	Comparison of Methods for Drinking Water Bacteriology - Cultural Techniques
11 February 2000 6/2000	Common Carriage : Guidance on Drinking Water Quality Aspects
11 February 2000 7/2000	Provision of Compliance Data and Preparation of Summary Tables for the Chief Inspector's Annual Report
3 March 2000 8/2000	Use of Geographic Information Systems
17 March 2000 9/2000	Distribution System Undertakings: Investigations, Pre- and Post-Renovation Assessment (PPRA) and New Undertakings
24 March 2000 10/2000	Reporting Results for Cryptosporidium and Associated Matters
24 March 2000 11/2000	Fluoride Concentrations in Drinking Water Supplies
24 March 2000 12/2000	Determination of Requirements to meet new Lead Standards
5 June 2000 13/2000	Water Supply (Water Quality) (Amendment) Regulation 1999: Notification of Anomalies in Sampling and Analysis for Cryptosporidium
5 June 2000 14/2000	Data return on mains renovation for S19 distribution undertakings covering the period 1 January 1995 to 31 March 2000
15 June 2000 15/2000	Implementation of the Drinking Water (Undertakings) (England and Wales) Regulations 2000
29 June 2000 16/2000	Review of procedures for operation and maintenance of the distribution network
3 July 2000	Drinking Water Quality - Comparative Measures

Date Information Letter	Subject Information Letter
17/2000	
25 August 2000 18/2000	Audit of response to the Bouchier recommendations and the Water Supply Hygiene Technical Guidance Notes
1 September 2000 19/2000	Radioactivity and Drinking Water Supplies
12 September 2000 20/2000	Sampling During the Current Fuel Supply Problem
12 September 2000 21/2000	Information Requirements - Water Quality Information
20 September 2000 22/2000	Sampling during the fuel supply problem
	Sampling during fuel supply problem
7 November 2000 23/2000	
7 November 2000 24/2000	Drinking water supply operations during a future fuel supply problem
10 November 2000 25/2000	The water supply (water quality) (England) Regulations 2000
21 November 2000 26/2000	The water supply (water quality) (Amendment) Regulations 1999: Cryptosporidium in water supplies: Laboratory Analysis
24 November 2000 27/2000	The water supply (water quality) (Amendment) Regulations 1999: Cryptosporidium in water supplies: Sampling
24 November 2000 28/2000	The water supply (water quality) (Amendment) Regulations 1999: Notification of anomalies in sampling and analysis for Cryptosporidium and associated matters
15 December 2000 29/2000	Annual data return on mains renovation for S19 distribution undertakings due on 28 February 2001
	2003
10 January 2003 1/2003	Provision of compliance data and preparation of summary tables for the Chief Inspector's annual report
23 January 2003 2/2003	Technical Audit of Water Companies under Section 86 of the Water Industry Act 1991: 2003 Inspection Programme and Provision of Associated Information
2 May 2003 3/2003	Water Supply (Water Quality) Regulations 2000 - Authorised Departures under Regulations 42 and 20
14 May 2003 4/2003	The 2004 Periodic Review of Prices and AMP4 – Further Guidance
16 May 2003 5/2003	The 2004 Periodic Review of Prices and AMP4 – Appraisal Methodology for Water Company Proposals for Drinking Water Quality Improvement Schemes
27 June 2003 6/2003	The Water Undertakers (Information) Direction 2003 - Format for provision of certain information
8 July 2003	Drinking Water Quality - Comparative Measures

Date Information Letter	Subject Information Letter
7/2003	
25 July 2003 8/2003	Monitoring for Dieldrin, Aldrin, Heptachlor and Heptachlor Epoxide under the new Regulations
13 August 2003 9/2003	Authorised and Automatic Supply Point Authorisations
20 August 2003 10/2003	DWI TELEPHONE NUMBERS AFTER 29 SEPTEMBER 2003
3 September 2003 11/2003	Interim Guidance on the Water Supply (Water Quality) Regulations 2000 and 2001
16 September 2003 12/2003	Procedures for the Delivery of Water Treatment Chemicals
30 September 2003 13/2003	Change of allocation of Inspectors to Companies
14 October 2003 14/2003	Technical Audit of Water Companies under Section 86 of the Water Industry Act 1991: Summary of the findings fo the Vertical Audits carried out for Nitrate and Nitrite.
11 November 2003 15/2003	WATER SUPPLY (WATER QUALITY) REGULATIONS 2000 Improvement Programme Documentation - Update for 2004 Zone Delineations
10 December 2003 16/2003	The Water Supply (Water Quality) Regulations 2000 and the Water Supply (Water Quality) Regulations 2001 - Monitoring for Clostridium perfringens (including spores).
19 December 2003 17/2003	Section 19 Undertakings continuing beyond 31 December 2003 and the frequency of monitoring requirements
19 December 2003 18/2003	Monitoring for conservative parameters in water supply zones supplied by bulk supplies of treated water

Appendix 5 DWI tools to standardise notification and ensure prosecution cases

These are two of the standardised forms the DWI has in place. The first is used when water companies notify the DWI of an event that took place. On basis of this and the more extensive 72-hour report the DWI can then decide whether an event should be classified as an incident or not and if so, what consequences the incident should have. If prosecution is a possibility, the DWI may go out to get witness statements that can be filled out on the second form. These can then be used to make a case for prosecution.

Figure 1, Appendix 5: DWI Event Notification Proforma

DWI EVENT NOTIFICATION PROFORMA

Company	
Name of event	
Person making the notification	
Date/time of notification	
Date, time, location of incident	
Nature of incident	
Population affected	
Likely cause(s)	
Action taken to inform/protect consumers	
Action being taken to rectify the situation	
LAs/HAs informed?	
Level of publicity	

PB 7469

Figure 2, Appendix 5: Statement of witness form

STATEMENT OF WITNESS

(CJ Act 1967, Sec. 9; M.C.Act, 1980, ss. 5A and 5B; MC Rules 1981, r.70)

Page 1 of ....

Time Started............

Time Finished..........

Statement of..

Age of Witness (Date of Birth)..

Occupation of Witness..

Address and Telephone Number..

....

....

....

This statement consisting of .... pages each signed by me, is true to the best of my knowledge and belief and I make it knowing that, if it is tendered in evidence, I shall be liable to prosecution if I have wilfully stated in it anything which I know to be false or do not believe to be true.

Dated the .... day of .... 200...

Signed...

Signature witnessed by...

(1) ____

(2) ____

(3) ____

(4) ____

(5) ____

(6) ____

(7) ____

(8) ____

(9) ____

(10) _______________________________________

(11) _______________________________________

(12) _______________________________________

(13) _______________________________________

Signed...

Signature witnessed by (print name)...

Appendix 6 Example of a Protocol from Networks

One of the very many protocols at work in WaterCo. Note the detail of the protocol that is in place for both quality and regulatory assurance. Protocols like this are subject to audits of the DWI.

JOB PRIORITY (From date of initial report being received).	
PRIORITY 1 - WITHIN 24 HOURS	
PRIORITY 2 - WITHIN 72 HOURS	
PRIORITY 3 - WITHIN 1 WEEK	
PRIORITY 4 - WITHIN 2 WEEKS	
PRIORITY 5 - WITHIN 1 MONTH	
PRIORITY 6 - WITHIN 21 DAYS -SERVS	
PRIORITY 7 - WITHIN 2 MONTHS	

JOB CODES AND DESCRIPTIONS	TIME SCALE	VALID REASON FOR CHANGE IN TIME SCALE AND REVISED PRIORITY (IN BRACKETS)
ACI - INSTALL A R VALVE CHAMBER	[illegible]	
ACN RENEW/REBUILD A R VALVE CHAMBER	[illegible]	Injury risk (1) unless made safe
ACT - RESET AIR VALVE COVER	[illegible]	Injury risk (1) unless made safe
APNE REPACK/REWASHER AIR VALVE NO EXCAVATION	[illegible]	Network Leak (2)
APNEL- REPACK/WASHER A/V NO EX 151-750MM	[illegible]	Network Leak (2)
AR - REPAIR AIR VALVE	[illegible]	Network Leak (2)
ARNE REPAIR A R VALVE NO EXCAVATION	[illegible]	Network Leak (2)
BBI INSTALL BOUNDARY BOX	[illegible]	No supply (1) Network leak (2) Private leak (2)
BBN RENEW BOUNDARY BOX	[illegible]	No supply (1) Network leak (2) Private leak (2)
BBNL REPLACE BOUNDARY BOX . D	[illegible]	Injury risk (1)
BBR REPAIR BOUNDARY BOX	[illegible]	No supply (1) Network leak (2) Private leak (2)
BBRNE REPAIR BOUNDARY BOX NO EXCAVATION	[illegible]	No supply (1) Network leak (2) Private leak (2)
BBRRA REMOVE REDUNDANT B/B COVER & FRAME	[illegible]	Injury risk (1) unless made safe
BBS RESITE BOUNDARY BOX	[illegible]	
BBT RESET B/B COVER AND FRAME	[illegible]	Injury risk (1) unless made safe
CCA - ANIMAL INFESTATION COMPLAINT	[illegible]	Single property complaint investigation by NST (Also inform Network Control Duty Manager when confirmed) Multiple complaints (not on shared supply) investigation by Network Control (1)
CCAIR AERATED WATER COMPLAINT	Telephone Response No Visit	
CCAIRP AIR PRIVATE PROBLEM	Telephone Response No Visit	
CCAP ANIMALS, PRIVATE PROBLEM	Telephone Response No Visit	
CCAV ABORTIVE COMPLAINT VISIT	Telephone Response No Visit	
CCB CUST COMP BITS	[illegible]	
CCBC BOGUS CALLER	[illegible]	
CCBN CUST COMPLAINT BITS N NETWORK	[illegible]	Investigation by NST. If associated smell, unusual colour or back siphonage risk (1)

CCBP CUST COMPLAINT BOPP PROCEDURE	Telephone Response No visit	
CCBPP BITS IN WATER, PRIVATE PROBLEM	Telephone Response No visit	
CCCT - CHLORINE TASTE COMPLAINT	24 hours	Investigation by NST. If associated smell or backsiphonage risk. (1)
CCCW CELLAR WATER COMPLAINT	Within 5 working days	
CCCWP CUST COMPLAINT WORKING PRACTICE	Within 5 working days	Injury risk (1) Obstructing access (2)
CCD CUSTOMER COMPLAINT DISCOLORATION	2 hours	Complaint investigation by NST.
CCDA CUSTOMER COMPLAINT DEFECTIVE APPARATUS	24 hours	Injury risk (1) unless made safe No supply (1)
CCDAR CUSTOMER COM DEFECTIVE REINSTATEMENT	24 hours	Injury risk (1) unless made safe
CCDARX CUSTOMER COM DEFECTIVE REIN NOT STW	Telephone Response No visit	Injury risk (1) unless made safe
CCDGR CUSTOMER COM DANGEROUS APPARATUS	2 hours	
CCDIS DISCONNECT SUPPLY	Within 5 working days	
CCDP DISCOLOURATION PRIVATE	Telephone Response No visit	
CCDW DISCOLOURED WASHING	Within 5 working days	
CCDWP DISCOLOURED WASHING, PRIVATE PROBLEM	Telephone Response No visit	
CCDX DISCOLOURATION MULTIPLE	2 hours	
CCEIS EMERGENCY ISOLATION SHUTOFF	2 hours	
CCH - CUSTOMER COMPLAINT HEALTH	2 hours	Single property complaint investigation by NST. (Also inform Network Control Duty Manager) Multiple complaints (not on shared supply) investigation by Network Control. (1)
CCHP CUSTOMER COMPLAINT HIGH PRESSURE	Within 5 working days	
CCILL/X CUSTOMER COMPLAINT ILLNESS	2 hours	Single property complaint investigation by NST. (Also inform Network Control Duty Manager) Multiple complaints (not on shared supply) investigation by Network Control. (1)
CCIU CUSTOMER COMPLAINT ILLEGAL USE	2 hours	
CCMAJ MAJOR ACCOUNT	2 hours	
CCML CUSTOMER COMPLAINT METER LEAK	24 hours	
CCN NOISE ON SUPPLY PIPE COMPLAINT	Within 5 working days	
CCNA CUST COMPLAINT APPARATUS NOISE	Within 5 working days	
CCNP NOISE ON SUPPLY PIPE COMPLAINT	Telephone Response No visit	
CCNS CUSTOMER COMPLAINT NO SUPPLY	2 hours	Complaint investigation by NST.
CCNSP NO SUPPLY, PRIVATE PROBLEM	Telephone Response No visit	
CCPR POLLUTION REPORT	2 hours	
CCPS CUSTOMER COMPLAINT POOR SUPPLY	24 hours	Complaint investigation by CSA
CCPSP POOR SUPPLY COMPLAINT PRIVATE	Telephone Response No visit	
CCS - SPILLAGES	24 hours	If liable to lead to pollution **2 hour response time**
CCSB- BLOCKED SEWER	24 hours	- **within 2 hours** if flooding or potential flooding affecting properties internally - within 6 hours if flooding of garden or open spaces - next working day if no flooding/pollution
CCSC - COLLAPSED SEWER	24 hours	If injury risk **2 hours response time.**
CCSCGR -GRAVITY SEWER REPAIR	24 hours	Same working day.
CCSCRM - PRESSURISED (RISING MAIN)	24 hours	Same day. **2 hour response time.**

CCSF - FLOODING FROM SEWER	24 hours	2 hours response time. This may be delayed during periods of bad weather due to the high volume of jobs
CCSFP - SEWERAGE FLOODING PRIORITY	24 hours	**Response required on site within 2 hours.** These customers have been subject to previous flooding and must be dealt with urgently
CCSINR - REMOVAL OF EXISTING SEWERAGE INTERCEPTOR	[illegible]	Unless causing blockage. (1)
CCSMH - SEWER MANHOLE PROBLEM	**72 hours**	**If injury risk 2 hours response time**
CCSMHC -SEWERAGE MANHOLE CONSTRUCTION & REPAIR	**72 hours**	4 hours response time if unable to make safe
CCSMHN- RENEW EXISTING MANHOLE COVER & FRAME	**72 hours**	4 hours response time if unable to make safe
CCSMHR- RESET MANHOLE COVER & FRAME	**72 hours**	4 hours response time if unable to make safe
CCSNRV - INSTALL SEWERAGE NON RETURN VALVE	**72 hours**	
CCSO - OTHER SEWER PROBLEM	**72 hours**	Dependent on nature of the report
CCSP- POLLUTION FROM SEWER	24 hours	**2hrs response time**
CCSPS - SEWAGE PUMPING STATION	24 hours	Dependent on nature of the report
CCSS - SMELL FROM SEWER	**72 hours**	Same day phone call by Duty Desk.
CCSV SUBSEQUENT COMPLAINT VISIT	Within 5 working days	
CCSX CUST CONT SMELL NOT STW RESPONSIBILITY	Telephone Response No visit	
CCPR- POLLUTION REPORT	24 hours	**2hrs response time**
CCTB CUST COMPLAINT DELIVER/COLL WTR/BWSR	2 hours	
CCTEM TASTE EARTHY MUSTY	2 hours	
CCTLF - CUST COMP TRAFFIC LIGHT FAILURE	Telephone Response No Visit	
CCTS - TASTE/SMELL COMPLAINT	2 hours	Single property complaint investigation by NST. (Also inform Network Control Duty Manager) Multiple complaints (not on shared supply) investigation by Network Control. (1)
CCTTCP TASTE TCP	2 hours	
CCUC - CUSTOMER COMP UNUSUAL COLOUR	2 hours	Single property complaint investigation by NST. (Also inform Network Control Duty Manager) Multiple complaints (not on shared supply) investigation by Network Control. (1)
CCUTS - CUSTOMER COMP UNUSUAL TASTE & SMELL	2 hours	Single property complaint investigation by NST. (Also inform Network Control Duty Manager) Multiple complaints (not on shared supply) investigation by Network Control. (1)
CCWN CUSTOMER COMP WATER WASTING NETWORK	2 hours	
CCWP CUSTOMER COMP WATER WASTING PRIVATE	24 hours	Investigation by NST
CECI - CUSTOMER ENQUIRY CHASE INFORMATION	24 hours	
CECRD CUSTOMER ENQUIRY CHASE REPAIR DATE	24 hours	
CEETO VALVE OPERATION CUSTOMER REQUEST	24 hours	No supply (1) Network leak (2) Private leak (2)
CERD CUST ENQ CHASE REPAIR DATE	24 hours	
CETA CUST ENQ TRACE APPARATUS	Within 5 working days	
CETNA CUST ENQUIRY TRACE NETWORK APPARATUS	Within 5 working days	No supply (1) Network leak (2) Private leak (2)
CETPA CUST ENQ TRACE PRIVATE APPARATUS	Within 5 working days	
CEZCD CHECK CONTRACTOR DAMAGE	24 hours	No supply (1) Network leak (2) Private leak (2)
CEZTA TRACE APPARATUS RECHARGEABLE	1 week	No supply (1) Network leak (2) Private leak (2)
CLF LOCATE APPARATUS ON COMM PIPE	[illegible]	No supply (1) Network leak (2) Private leak (2)
COU CUT OFF COMM PIPE AT MAIN	[illegible]	No supply (1) Network leak (2) Private leak (2)
CPCO CLEAN OUT COMM PIPE	1 week	No supply (1) Poor pressure (3)

CPCLL3 CUSTOMER DRIVEN REPLACEMENT	21 days	No supply (1) Network leak (2) Private leak (2)
CPCLN3 CUST DRIVEN REPLACEMENT	21 days	
CPCO CLEAN OUT COMM PIPE	1 week	No supply (1) Poor pressure (3)
CPSLN3 CUST DRIVEN REPLACEMENT	21 days	No supply (1) Network leak (2) Private leak (2
CPCSN3 CUST DRIVEN REPLACEMENT	21 days	No supply (1) Network leak (2) Private leak (2
CPMLL3 INFRASTRUCTURE MAINTENANCE	21 days	No supply (1) Network leak (2) Private leak (2
CPMLN3 INFRASTRUCTURE MAINTENANCE	21 days	No supply (1) Network leak (2) Private leak (2
CPMSL3 INFRASTRUCTURE MAINTENANCE	21 days	No supply (1) Network leak (2) Private leak (2
CPMSN3 INFRASTRUCTURE MAINTENANCE	21 days	No supply (1) Network leak (2) Private leak (2
CPNL RENEW COMM PIPE LONG	21 days	No supply (1) Network leak (2) Private leak (2)
CPNLI RENEW COMM PIPE LONG WAS GI	21 days	No supply (1) Network leak (2) Private leak (2)
CPNLIX RENEW C/PIPE LONG WAS GI LONG	21 days	No supply (1) Network leak (2) Private leak (2)
CPNLL RENEW C/PIPE LONG WAS LEAD	21 days	No supply (1) Network leak (2) Private leak (2)
CPNL RENEW COMM PIPE LONG	21 days	No supply (1) Network leak (2) Private leak (2)
CPNLLX RENEW C/PIPE LONG WAS LEAD COLLAR	21 days	No supply (1) Network leak (2) Private leak (2)
CPNLX RENEW C/PIPE LONG COLLAR	21 days	No supply (1) Network leak (2) Private leak (2)
CPNS RENEW C/PIPE SHORT	21 days	No supply (1) Network leak (2) Private leak (2)
CPNSI RENEW C/PIPE SHORT WAS GI	21 days	No supply (1) Network leak (2) Private leak (2)
CPNSIX RENEW C/PIPE SHORT WAS GI COL	21 days	No supply (1) Network leak (2) Private leak (2)
CPNSL RENEW C/PIPE SHORT WAS LEAD	21 days	No supply (1) Network leak (2) Private leak (2)
CPNSLX RENEW C/PIPE SHORT LEAD COLL	21 days	No supply (1) Network leak (2) Private leak (2)
CPOS CUT OFF COMM PIPE SERVICE	2 months	Private Leak (2) Network Leak (2)
CPOSL CUT OFF COMM PIPE SERVICE - LEAD	2 months	Private Leak (2) Network Leak (2)
CPOSP CUT OFF COMM PIPE SERVICE-PERIDUP	2 months	Private Leak (2) Network Leak (2)
CPOSX CUT OFF COMM PIPE SERVICE-COLLAR	2 months	Private Leak (2) Network Leak (2)
CPR - REPAIR COMM PIPE	72 hours	No supply (1) Network leak (2) Private leak (?)
CPRX - REPAIR COMM PIPE/COLLAR	72 hours	No supply (1) Network leak (2) Private leak (2)
CPSAS - AIR SCOUR SUPPLY AND COMM PIPE	[illegible]	No supply (1) Poor Supply (2)
CPSCI- CLEAN OUT SUPPLY/COMM PIPE INIT JOB	72 hours	No supply (1) Poor Supply (2)
CPSF - CHANGE SERVICE PIPE FILTER	[illegible]	No supply (1) Poor supply (2)
CPTL - TRANSFER LONG COMM PIPE > 4M	2 months	No supply (1) Poor supply (2)
CPTS -TRANSFER SHORT COMM PIPE < 4M	3 months	No supply (1) Poor supply (2)
CPZR - REPAIR COMM PIPE - RECH, FULL EXC	72 hours	No supply (1)
CPZRN - REPAIR COMM PIPE - RECH, NO EXC	72 hours	No supply (1)
CUSR - REPAIR CUSTOMER SERVICE PIPE	1 week	No supply (1)
FMBB - FREE METER BOUNDARY BOX	[illegible]	
FMCPNS - RENEWAL OF COMM PIPE (NON LEAD) - FROPT	[illegible]	

FMCPSL -RENEWAL OF COMM PIPE (LEAD) - FROPT	[illegible]	
HADGR - HIGHWAY AUTHORITY DANGEROUS REINS	2 Hours	
HZCN-RENEW/REBUILD HYD CHAMBER	21 days	Injury risk (1) unless made safe.
HZCNM-RENEW/REBUILD HYD CHAM MET	21 days	Injury risk (1) unless made safe.
HZCNU-RENEW/BUILD HYD CHAM UNMET	21 days	Injury risk (1) unless made safe
HZCT-RESET HYD COVER	21 days	Injury risk (1) unless made safe.
HZCTM-RESET HYD COVER METALLED	21 days	Injury risk (1) unless made safe
HZCTU-RESET HYD COVER UNMETALLED	21 days	Injury risk (1) unless made safe
HZI-INSTALL HYDRANT	21 days	
HZIL-INSTALL HYDRANT151-250MM	21 days	
HZIM-INSTALL HYDRANT METALLED	21 days	
HZIP-INSTALL HYDRANT MARKER POST	21 days	
HZIU-INSTALL HYDRANT UNMETALLED	21 days	
HZM - REMOVE HYDRANT	21 days	Network Leak (2)
HZMM - REMOVE HYDRANT METALLED	21 days	Network Leak (2)
HZM - REMOVE HYDRANT UNMETALLED	21 days	Network Leak (2)
HZN - RENEW HYDRANT	21 days	Network Leak (2)
HZNL - RENEW HYDRANT 151-250MM	21 days	Network Leak (2)
HZNM - RENEW HYDRANT METALLED	21 days	Network Leak (2)
HZNU - RENEW HYDRANT UNMETALLED	21 days	Network Leak (2)
HZP - REPACK HYDRANT	21 days	Network Leak (2)
HZPL - REPACK HYDRANT 151-250MM	21 days	Network Leak (2)
HZPM - REPACK HYDRANT METALLED - EXC	21 days	Network Leak (2)
HZPNE - REWASHER/PACK HYD NO EXC	21 days	Network Leak (2)
HZPU - REWASHER/PACK HYD UNMET	21 days	Network Leak (2)
MRLC - REPAIR LARGE MAIN WITH COLLAR	72 hours	No supply (1)
MRLL - REPAIR LARGE MAIN WITH LENGTH	72 hours	No supply (1)
MRLP - REPAIR LARGE MAIN WITH PIECE	72 hours	No supply (1)
MRLUP -REPAIR LARGE MAIN UNDER PRESSURE	72 hours	No supply (1)
MRSC - REPAIR SMALL MAIN WITH COLLAR	72 hours	No supply (1)
MRSL - REPAIR SMALL MAIN WITH LENGTH	72 hours	No supply (1)
MRSP - REPAIR SMALL MAIN WITH PIECE	72 hours	No supply (1)
MRSUP -REPAIR SMALL MAIN UNDER PRESSURE	72 hours	No supply (1)
MRT - REPAIR TRUNK MAIN	72 hours	No supply (1)
MRTUP -REPAIR TRUNK MAIN UNDER PRESSURE	72 hours	No supply (1)
MTH -TRIAL HOLE FOR BURST MAIN	72 hours	No supply (1)
MZRL - REPAIR MAIN > 200MM RECHARGE	72 hours	No supply (1)
MZRM REPAIR MAIN 150-200MM RECH FULL EXC	72 hours	No supply (1)
MZRMN REPAIR MAIN 150-200MM RECH NO EXC	72 hours	No supply (1)
MZRP REPAIR MAIN<150MM RECH FULL EXC	72 hours	No supply (1)
MZRPN REPAIR MAIN<150MM RECH NO EXC	72 hours	No supply (1)
PRZAC PRIVATE REPAIR AT COST	1 week	No supply (1)
PRZAG PRIVATE REPAIR ABOVE GROUND	1 week	No supply (1)
PRCHG PRIVATE REPAIR AT COST	1 week	No supply (1)
PRZDA PRIV REP ABOVE GROUND DISCOUNTED COST	1 week	No supply (1)

PRZDB PRIV REP BELOW GROUND DISCOUNTED COST	1 week	No supply (1)
PRZFOC PRIV REP WAIVED CHARGES	1 week	No supply (1)
PRZHW PRIV REP HIDDEN WASTE	1 week	No supply (1)
PRZREV PRIV REP REVISIT	1 week	No supply (1)
PRZET PRIV REP REWASHER FITTINGS	1 week	No supply (1)
PRZSUB PRIV REP SUBSIDISED	1 week	No supply (1)
PRZVW PRIV REP VISIBLE WASTE	1 week	No supply (1)
REIN REINSTATE JOB	[illegible]	Injury risk (1) unless made safe
REINA REINSTATE JOB METHOD A	72 hours	Injury risk (1) unless made safe
REINB REINSTATE JOB METHOD B	72 hours	Injury risk (1) unless made safe
REINCD REINSTATE CONSEQUENTIAL DAMAGE	1 week	Injury risk (1) unless made safe
REINR REINSTATEMENT REPAIR	72 hours	Injury risk (1) unless made safe
REINRA REINSTATEMENT REPAIR ALT TEAM	72 hours	Injury risk (1) unless made safe
SCCO CLEAN OUT STOP TAP CHAMBER	[illegible]	No supply (1) Network leak (2) Private leak (2)
SCN RENEW/REBUILD STOP TAP CHAMBER	[illegible]	No supply (1) Network leak (2) Private leak (2)
SCT RESET STOP TAP COVER/FRAME	[illegible]	Injury risk (1) unless made safe
SI - INSTALL STOP TAP AND CHAMBER	[illegible]	No supply (1) Network leak (2) Private leak (2)
SN - RENEW STOP TAP AND CHAMBER	[illegible]	No supply (1) Network leak (2) Private leak (2)
SNL - REPLACE STOP TAP LID ONLY	[illegible]	Injury risk (1) unless made safe
SR - REPAIR STOP TAP AND CHAMBER	[illegible]	No supply (1) Network leak (2) Private leak (2)
SRNE-REPAIR STOP TAP AND CHAMBER NO EXC	[illegible]	No supply (1) Network leak (2) Private leak (2)
STFLY FLY NUISANCE COMPLAINT	2 hours	
STSMEL SMELL NUISANCE COMPLAINT	2 hours	
TB - DELIVER/COLLECT BOWSER	24 hours	
TFB - REFILL BOWSER	24 hours	
TFST - FIX STANDPIPE	24 hours	
VCN - RENEW/REBUILD VALVE CHAMBER	2 months	Injury risk (1) unless made safe
VCT - RESET VALVE COVER AND FRAME	2 months	Injury risk (1) unless made safe
VFES - FIT EXTENSION SPINDLE TO VALVE	2 months	
VI - INSTALL VALVE	2 months	
VIP - INSTALL/MAINT PLATES AND MARKERS	2 months	Injury risk (1) unless made safe
VLF - LOCATE APP FOR VALVE/HYDWO	2 months	Network leak (2)
VLN - RENEW VALVE 151-250MM	2 months	Network leak (2)
VLP - REPACK VALVE 151-250MM	2 months	Network leak (2)
VN - RENEW VALVE	2 months	
VNL - REPLACE VALVE LID	[illegible]	Injury risk (1) unless made safe
VP - REPACK VALVE	2 months	Network leak (2)
VLPNE - REPACK/WASHER LRGE VALVE NO EXC	2 months	Network leak (2)
VLNE - REPACK/WASHER VALVE NO EXC	2 months	Network leak (2)
VRRA - REMOVE VALVE COVER & FRAME	2 months	Injury risk (1) unless made safe
VRFC - REPAIR FLOW CONTROL VALVE	2 months	Network leak (2)
WCN - RENEW/REBUILD WASH OUT CHAMBER	1 week	Injury risk (1) unless made safe
WCT - REST W/O COVER AND FRAME	1 week	Injury risk (1) unless made safe
WI - INSTALL WASHOUT	2 months	Discoloration complaints received. (4)
WIL - INSTALL WASHOUT 151-250MM	2 months	Discoloration complaints received. (4)
WIP - INSTALL/MAINTAIN W/O MARKER POST	1 week	Injury risk (1) unless made safe
WM/WML - REMOVE WASHOUT /151-250MM	2 months	
WN - RENEW WASHOUT	2 months	Network leak (2)
WNL - RENEW WASHOUT 151-250MM	2 months	Network leak (2)
WP - REPACK WASHOUT	2 months	Network leak (2)

Abbreviations

AC	Activated Carbon
A.D.	Anno Domini
ANT	Actor Network Theory
AQC	Analytical Quality Control
BATNEEC	Best Available Technology Not Entailing Excessive Cost
B.B.C.	British Broadcasting Corporation
B.C.	Before Christ
BOD	Biochemical Oxygen Demand
CAS	Clinical Assessment Software
CATNAP	Cheap Alternative Technologies Narrowly Avoiding Prosecution
CATNIP	Cheapest Available Technology Not Involving Prosecution
CEC	Commission of the European Communities
CSC	Customer Service Committees
DEFRA	Department for Environment, Food & Rural Affairs
DoE	Department of Environment (changed into DEFRA)
DBP	Disinfection By-Product
DDT	Dichlorodiphenyltrichloroethane
DWI	Drinking Water Inspectorate
EA	Environment Agency
EC	European Commission
EEA	European Economic Area
EEC	European Economic Community
ENDS	Environmental Data Services Limited
EP	European Parliament
EPA	Environmental Protection Agency, US
ESC	Economic and Social Committee
EU	European Union
EUREAU	European Union of National Associations of Water Suppliers and Waste Water Services
GAC	Granular Activated Carbon
GC-MS	Gas Chromatography Mass Spectrometry

ICP-MS	Inductively Coupled Plasma Mass Spectrometry
ICT	Information and Communication Technology
IMS	Immunomagnetic Separation
ISO	International Organization for Standardization
KCL	Solution
MAC	Maximum Admissible Concentration
MLGA	Membrane Lactose Glucuronide Agar
MLSB	Membrane Lauryl Sulphate Agar
MTBE	Methyl Tertiary Butyl Ether
NRA	National Rivers Authority
NWWA	North Wales Water Authority
Ofwat	Office of Water Services
OJ	Official Journal of the European Communities
OSH	Occupational Safety and Health
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
PSR	Public Sector Research
PUS	Public Understanding of Science
PVC	Prescribed Concentration or Value
QI	Quality Inspector
RA	Risk Assessment
R&D	Research and Development
RWA	Regional Water Authrity
SARS	Severe Acute Respiratory Syndrome
SCOT	Social Construction of Technology
SSK	Sociology of Scientific Knowledge
STS	Science and Technology Studies
TOC	Total Organic Carbon
TSC	Trypose Sulfite Cycloserine Agar
UK	United Kingdom
UKAS	United Kingdom Accreditation Service
UKWIR	United Kingdom Water Industry Research
USA (or US)	United States of America
UV	Ultra Violet

WHO	World Health Organisation
YEA	Yeast Extract Agar

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[2] It is interesting to note that I bought the book in 2003, while it is only published in 2004.

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