Sanitation in Riverine Areas: the Anomaly of Access and Health Outcomes in the Niger Delta

by

Esther Daibi Sample

Submitted in accordance with the requirements for the degree of

Doctor of Philosophy

The University of Leeds

School of Civil Engineering

September, 2017

The candidate confirms that the work submitted is his/her own and that appropriate credit has been given where reference has been made to the work of others.

Chapter 6, 7 and 8 of the thesis contain some materials from a jointly authored publications below;

Sample, E. D., Evans, B. E., Camargo-Valero, M. A., Wright, N. G. & Leton, T. G. 2016. Understanding the drivers of sanitation behaviour in riverine communities of Niger Delta, Nigeria: the case of Odi and Kaiama communities. *Journal of Water, Sanitation and Hygiene for Development*.

The work presented in the publication above was carried out by the candidate who is also the lead author.

Acknowledgements

It has been a journey and I am thankful to God for a successful end.

I would like to specially appreciate my primary supervisor, Prof. Barbara Evans for her unwavering support and encouragement from the start to the end of this work. Your enthusiasm is infectious. Your depth of knowledge and understanding of real problems of sanitation is admirable. Thank you for believing in me. I will also like to appreciate my co-supervisors, Prof. Nigel Wright and Dr. Miller Camargo-Valero for their support especially in the early stages of this research. I would also like to extend my gratitude to Prof. T.G. Leton for his mentoring and continuous support. Not forgetting Elsie and Preye and the department of Civil and Environmental Engineering, University of Port Harcourt for collaboration and support during my fieldwork. I appreciate the Public Health Engineering Laboratory technicians, David Elliott and Sheena Bennett for the training and support through the planning and implementation phase of my fieldwork.

I would also like to appreciate my sponsors for providing funding for this study. I appreciate the people and leaders of Odi and Kaiama community for allowing me into their community to carry out this study.

I would like to appreciate Dr & Mrs John Iheme, Mr & Mrs Emmanuel Udoh, Pastor Sam Obafaiye, Mr & Mrs Amasisi, all members of Eternal Worshipers choir and friends at RCCG Everlasting Father's Assembly . My friends and colleagues; Gloria, Precious, Manal, Martina, Charles, Musa, Ikpe, Christian, Ugochi, George, Vicky, Carolina, Kelechi and all others who supported me in different ways. You all made it easier to carry on.

Finally I appreciate my family, my dad, Dr. E. I. Ita, my brothers, Paul, Daniel and Sammy. Special thanks to my lovely daughters Blessing and Baby Elfreda, my husband Daibi for their love and sacrifices. Not forgetting my precious mum of blessed memory. You were indeed a well to draw strength and courage from. It is done now. I am sure you are proud.

Abstract

Globally, efforts are renewed towards achieving universal access to sanitation by 2030 through the Sustainable Development Goals six. These efforts which focuses on increasing access are mainly directed towards the nearly one billion people without access to any form of sanitation facility and the 2.4 billion using unimproved sanitation majority of whom live in sub-Saharan Africa. However, evidence is mixed on the impact of increased access to sanitation on health outcomes like diarrhoea. Only few studies have explored transmission pathways and how access might impact on it to truncate transmission of faecal contamination in setting where an intervention is planned. This study explored sanitation in riverine communities of Nigeria. Riverine communities in the Niger Delta region of the country have one of the worst sanitation access rates in the country yet the best health outcomes for diarrhoea. There is yet no study exploring how increasing access only in this context could impact of faecal contamination transmission pathways.

To understand this anomaly, a mixed methods study was carried out in two riverine communities of Bayelsa State, Nigeria. The study assessed existing sanitation and water supply access, perceptions, beliefs and behaviours using seven focus group discussions, twenty six semi-structured interviews, four school and 723 households' surveys. Microbiological examination was also carried out to access the resultant impact of existing behaviour on faecal contamination concentration in stored household drinking water, source water and hand rinse samples using E.coli as an indicator. The concentration of faecal contamination was compared between households with access to a toilet at home and those without access.

Findings show boreholes and the river as main sources of drinking water and these were with mean concentrations of E.coli at 4.44 x 10^2 and 1.29 x 10^3 CFU/ml respectively. Treating drinking water was uncommon except for the use of alum to treat river water and camphor balls in stored drinking water. Three main defecation behaviours were identified. Direct defecation into the river, use of poorly constructed toilets and defecation in nearby bushes. Poorly constructed septic tanks resulted in backflow of sewerage into households in the rainy season. Septic tanks were leaking sewage into the environment. However only 238 out of 723 households have access to a toilet at home. Three repeated sampling of stored household drinking water in twenty households showed faecal contamination concentrations were higher in households with access to a toilet than those without access.

Examination of plausible faecal contamination transmission pathways in these communities highlights poorly constructed toilets pose the biggest risk of exposure to faecal contamination. This study concludes that in riverine areas where the behaviour and environment and health outcomes are similar to the study communities, increasing access will only be valuable if it contains faeces adequately at source and does not in itself introduce faecal contamination closer to home and people. Otherwise, people should be allowed to carry on with their current behaviour.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

CHAST	Child Hygiene And Sanitation Training
CHC	Community Health Clubs
CLTS	Community-Led Total Sanitation
DFID	Department for International Development
DHS	Demographic and Health Survey
EHO	Environmental Health officer
FGN	Federal Government of Nigeria
GTZ	German Organisation for Technical Cooperation
HH	household
IDE	International Development Enterprises
IDS	Institute of Development Studies
LGA	Local Government Area
MDGs	Millennium Development Goals
MICS	Multiple Indicator Cluster Survey
NBS	National Bureau of Statistics
NGO	Non-Governmental Organisation
NPC	National Population Commission
NR	Non - Riverine
ODF	Open Defecation Free
PEWASH	Partnership for Expanded Water Supply, Sanitation& Hygiene

PHAST	Participatory Hygiene And Sanitation Transformation
PRA	Participatory Rural Appraisal
R	Riverine
SDGs	Sustainable Development Goals
SM	Sanitation Marketing
SuSana	Sustainable Sanitation Alliance
TSSM	Total Sanitation and Sanitation Marketing
UN	United Nations
UNICEF	United Nations International Children's Emergency Fund
VIP	Ventilated Improved Pit
WASH	Water Sanitation and Hygiene
WHO	World Health Organisation
WSP	Water and Sanitation Programme
WSSCC	Water Supply and Sanitation Collaborative Council

Chapter 1 : Introduction

1.1 Chapter introduction

This chapter introduces this research. It gives the background leading to the research, research aims and objectives, significance of the research and gives a description of the structure of the rest of the thesis.

1.2 Background

The end of the Millennium Development Goals, MDGs, era saw its sanitation target missed. Having set out to reduce by half the proportion of people living without access to sanitation, its end left 1 billion people without access to any form of sanitation hence practicing open defecation (WHO/UNICEF, 2015). Globally, 2.4 billion people use unimproved sanitation facilities (WHO/UNICEF, 2015). Majority of the countries that missed this target are located in sub-Saharan Africa where the number of people practicing open defecation increased between 1990 and 2015 due to the fact that the provision of effective sanitation did not keep pace with population growth (WHO/UNICEF, 2015). Particularly, Nigeria saw its sanitation access decline during the MDGs era. Use of improved sanitation declined from thirty eight percent to twenty nine percent and open defecation increased by one percent between 1990 and 2015 (NPC and ICFI, 2014).

Generally, there were improvements in sanitation access following the MDGs. However, there was inequality in access as location and wealth played a role in

who gets sanitation and who gets left out (Seyoum and Graham, 2016). Hard-to-reach area like mountainous areas, riverine areas and other were among areas deprived of these improvements. To address these failings and achieve universal access to sanitation, Sustainable Development Goals, SDGs, have now been set. SDG 6 seeks to eradicate all open defecation and ensure everyone has access to sanitation by 2030 (UN, 2015b). The focus is to reach vulnerable people and people living in hard –to-reach areas like riverine areas. To achieve this, many different sanitation approaches have been adopted by different countries with varying degrees of success. The main focus is on getting people to have access to sanitation.

However, is access to sanitation alone enough to yield expected impact for diseases such as diarrhoea? Many sanitation intervention programmes over the years have focused on getting households to build toilets and end open defecation stressing the health benefits of doing so but evidence of the impact of interventions on health outcomes like diarrhoea is mixed. With the focus on access, those who already have toilets are assumed to have eliminated the key exposure medium of focus which is open defecation. This could lead to complacency on sanitation in households with toilet seeing that the ultimate goal of having access to a household toilet has been achieved.

Diarrhoea is primarily caused by exposure to faecal contamination where bacteria, viruses and other pathogens are present (Freeman et al., 2017). It causes nineteen percent of all under-five deaths and is responsible for an estimated 1.4 million deaths per year (Lozano et al., 2012, Prüss-Ustün et al., 2014, Boschi-Pinto et al., 2008). In this study, diarrhoea is the health outcome of interest.

For a sanitation intervention to have health impact, it is necessary for it to prevent the transmission of disease causing pathogens contained in faeces to a new host (person). On the contrary, the type of toilet, how it is built and how it is used could introduce a pathway for faecal contamination of households.

As efforts continue towards the ultimate goal of ending all open defecation, there is need to target limited resources on interventions that would not just provide sanitation access but prevent the transmission of faecal contamination to improve health outcomes.

1.3 Study aims, scope and objectives

1.3.1 Aims

The aim of this study is to examine the scope and impact of existing sanitation behaviour on drinking water quality in riverine communities of developing countries where ending open defecation is still a challenge. The outcomes of this study could inform the focus of water supply planning and sanitation intervention programs on key aspects that could intercept faecal contamination transmission through reduced exposure, resulting in better health impact of programs.

1.3.2 Scope

The research focus is on the context of low income riverine communities in developing countries using the case of Odi and Kaiama communities in Bayelsa State, Niger Delta, Nigeria. Using fieldwork as the main data source, this study applied mixed-methods design using qualitative and quantitative methods through interviews, focus group discussions and surveys to explore existing

mechanisms for drinking water supply and sanitation behaviours within both communities. It also included actual on-site microbial assessment of drinking water sources, stored household drinking water and hand rinse samples to examine concentration of faecal contamination. Results of the qualitative, quantitative and microbial assessment were combined to address the research objectives below.

1.3.3 Research objectives

- To explore access to water and sanitation infrastructure in the study communities.
- Assess perceptions, behaviours and attitude to water and sanitation in study communities.
- Examine resultant faecal contamination levels in stored household drinking water and how this differs between households with access to a toilet and those without.
- Assess plausible faecal contamination transmission pathways resulting from current sanitation conditions and behaviour.

1.4 Significance/justification of study

Adequate sanitation in terms of managing human faeces is essential for public and environmental health and good quality of life. Many developing countries fall short of meeting this important need. Efforts have been made to improve sanitation in developing countries especially after the establishment of the Millennium Development Goals, MDGs by United Nations but challenges still exist especially for hard-to-reach areas like riverine communities. Most existing affordable sanitation options like pit latrines which are often promoted in 'dry land' rural areas of developing countries are challenging to use in riverine communities partly due to their physical environment (high water table, loose soils). Of particular interest to this research is the sanitation situation in riverine communities of Bayelsa State, Niger Delta, Nigeria. These communities have long history of open defecation especially into water bodies which also serve as a source of water supply for most members of the community. Despite this, they have the lowest reported diarrhoea rates in Nigeria. Hence, this study seeks to understand the reasons for this anomaly.

Findings from this study will be useful in focusing the design and implementation of sanitation interventions in riverine areas as the country strives to achieve SDG 6. Applying these findings could ensure that in focusing on increasing sanitation access, households are not indirectly exposed to more faecal contamination than was the case when they had no sanitation access.

1.5 Structure of thesis

This thesis is organised in nine chapters.

Chapter 1 gives background of the research, aims, objectives and justification for the study.

Chapter 2 is a review of sanitation approaches, interventions and impact. Chapter 3 gives a brief description of sanitation and health in Nigeria.

Chapter 4 is a synopsis of the study area.

Chapter 5 gives details of research design and methodology.

Chapter 6 reports on infrastructure service levels, behaviours, attitudes and perceptions for water supply and sanitation.

Chapter 7 assesses resultant contamination of drinking water from existing sanitation and drinking water management behaviour.

Chapter 8 is a discussion of key findings of the thesis

Chapter 9 gives research conclusions, limitations and recommendation for further research.

Chapter 2 : Review of Sanitation approaches, interventions and impact

2.1 Chapter introduction

The previous chapter gave background to this research. This chapter focuses on exploring the body of knowledge for water and sanitation in developing countries. It will also identify the gap in literature where this research aims to fill.

2.2 Literature search strategy

2.2.1 Methodology

The topic investigated in this study is an overlap of several areas. This includes, water, sanitation, open defecation, behaviours and perceptions. The following databases were searched using keywords; Web of Science, Scopus, ProQuest and Pubmed. The keywords and phrases used were various combinations of the following words:

toilet, latrin*, pit latrin*, flush latrin*, flush toilet*, excreta disposal, defecat*, poo, open defecat* human faeces, end open defecat*, sanita*, sanita* drinking water treatment*, point of use treatment*, intervent*, diarrh*, stunt*, water, drinking water, piped water, non piped water, borehole*, water sourc*, water collect*, water stor*, developing countr*, sub-saharan Africa, low income countr*, emerging economy*, low-middle income countr* and global south.*

The researcher ensured update of the literature to the final stages of the research. Key searches were saved on the databases and alerts setup for

notification of any new publication. This was used to continually update the list of literature.

The result was 3468 records excluding duplicates. Titles and abstract were screened to include only papers that were relevant and studies that took place in developing countries. 392 records were selected. Reference list of selected literature were further searched to include relevant studies. Also, the website and publications of organisations working in the water, sanitation and health sector were searched for grey literature. These organisations include: WHO, World Bank, GTZ, SuSana, IDS, UNICEF, WSSCC, WaterAid, DFID and UN.

2.3 Effect of poor access to water supply and sanitation

Sanitation involves sustainable safe disposal of human faeces and maintenance of proper personal and environmental hygiene. Poor sanitation has detrimental effects for public and environmental health (Nelson and Murray, 2008). According to Bartram et al. (2005) “Far more people endure the largely preventable effects of poor sanitation and water supply than are affected by war, terrorism, and weapons of mass destruction combined. Yet those other issues capture the public and political imagination—and public resources—in a way that water and sanitation issues do not”.

Poor sanitation affects the economy of a nation through lost productivity resulting from time lost to poor health and even death which reduces available human capacity. Absence of sanitation also affects education and productivity in terms of time lost walking to or searching for an open defecation site (Evans et al.,

2004). Research has also shown that poor sanitation contributes to poor cognitive development which in turn leads to poverty since affected people cannot contribute fully to economic development (Guerrant et al., 2013). The absence of sanitation facilities in schools have affected school attendance especially for girls during their menstrual period (Sommer and Sahin, 2013). This leads to absenteeism making girls miss out of essential education needed to help shape their future.

In 2015, it was estimated that 1 child in 12 in sub-Saharan Africa and 1 child in 19 in Southern Asia died preventable deaths (UN, 2015a) majority of which could be related to poor water and sanitation. Globally, of the 663 million people without access to improved drinking water, majority come from two regions, 319million from sub-Saharan Africa and 134million from southern Asia and countries with the lowest sanitation coverage are also located in these two regions (WHO/UNICEF, 2015). This suggest that there could be a link between access to water and sanitation and child mortality rates in these regions. Research has shown that access to water supply has impact on under five mortality rates (Abdel-Razik et al., 2015).

Exposure to faecal contamination has been identified as a major pathway to diseases. These include diarrheal disease, gastrointestinal, soil-transmitted helminth infection, trachoma, schistosomiasis and other infections that can reduce nutrient absorption resulting in long term growth problems in developing countries (Humphrey, 2009, Briceño et al., 2015, Prüss-Üstün et al., 2008). Inadequate access to water supply and sanitation increases the risk of pathogenic intestinal protozoa and parasitic infections and diarrhoea especially in children (Abossie and Seid, 2014, Abouteir et al., 2011, Speich et al., 2016).

Poor access to water supply and poor sanitation behaviour increases the risk of exposure to faecal contamination. Unsafe water, poor sanitation and hygiene is estimated to cause over one million deaths every year (Lozano et al., 2012). Diarrhoea is among the primary causes of death in children especially those less than five years old (WHO, 2016), causing 1.9million deaths every year (Clasen et al., 2012). Lack of access to safe and sufficient water supply and sanitation has also been identified as a contributing factor to stunting in children (Karra et al., 2017, Torlesse et al., 2016, Spears et al., 2013).

Water pollution resulting from poor sanitation practices like open defecation into water bodies contribute to poor water quality with grave implications for humans (especially in areas where such water is also used for personal hygiene and domestic purposes) and the aquatic ecosystem (WHO/UNICEF/WSSCC). The leading cause of diseases is poor sanitation and poor access to clean water supply (Uddin et al., 2012).

Research has shown that improvement in sanitation can significantly reduce the prevalence of diseases such as diarrhoea, ascariasis, hookworm infections and trachoma (Esrey et al., 1991b, Prüss et al., 2002, Fewtrell et al., 2005) and improve other health aspects too. Other than health benefits, sanitation also provides benefits such as privacy, dignity, reduced risk of sexual harassment (especially for women), promotes social status and provides convenience (Cairncross, 2004, Jenkins and Sugden, 2006). Therefore, improving water and sanitation can lead to improvement in health, social and economic development of a people (Mara et al., 2010).

2.4 Interventions to improve water and sanitation access

2.4.1 Water supply interventions

Immense progress has been achieved with improving access to water supply. In the past era of the MDGs, many countries met the target for improving access to water supply before the deadline of 2015. Globally, access to improved water supply increased from 76% to 97% and the target for drinking water access was met 5 years ahead of the deadline. However this still left many people without access; countries with the lowest coverage levels are predominantly in sub-Saharan Africa (WHO/UNICEF, 2015).

Although access to water sources of an improved type has greatly improved globally, there is still concern for the microbiological quality of water (Alexander et al., 2015). In an intervention in India, households had 100% access to improved water sources but still had faecal contamination in their household drinking water (Arnold et al., 2010). Where piped water supply is available, intermittent supply and the state of the distribution network enhances microbial contamination of water (Arnold et al., 2013).

Overall, interventions for water supply are simpler to implement when compared to sanitation interventions. Where sanitation is poor, this can undermine the impact of a water supply intervention.

2.4.2 Sanitation interventions

Introduction

Often, interventions in sanitation are combined with that of water supply. This may result in inadequate attention being paid to the implementation of the sanitation component (Waterkeyn and Cairncross, 2005, Jewitt, 2011). This widely-reported effect may be due to the fact that the characteristics of water projects such as; already existing demand, short duration for implementation, required skills and decision making process, are all different when compared with sanitation (Jenkins and Sugden, 2006). many commentators suggest that interventions be phased for each component (say water or sanitation) to enhance focus and efficiency (Fewtrell et al., 2005). It is also often said that there is a need for careful selection and strategic implementation of sanitation intervention programmes to suit different contexts. For instance, sanitation in rural areas seems to require simple engineering technology but more complex social considerations when compared with peri-urban and slum areas where the reverse is the case (Mara, 2003). Therefore, a sanitation intervention that was successful in a peri-urban area may not necessarily be successful in a rural context and vice versa. The poor coverage of sanitation in developing countries is not the absence of technological options (Mara, 2012) neither is it waiting for a superb scientific breakthrough (Bartram et al., 2005) but requires strategic planning and implementation taking into consideration the context and all stakeholders playing their part and being committed.

Approaches to Sanitation Intervention

Fewtrell et al (2005) describes sanitation as an intervention that provides a means for the disposal of human excreta at household level and in public places. There are several approaches adopted for the implementation of sanitation intervention programmes. Research has shown that the conventional supply driven approach which often relies on the provision of direct subsidies has not been successful in providing large scale sustainable use of sanitation (Cairncross, 2004, Jewitt, 2011, Ahmed, 2008, Rosenboom et al., 2011, Mukherjee, 2009, Frias and Mukherjee, 2005). Evidence from a survey of sanitation projects in Maharashtra, India suggest that of the 1.5million toilets built by the project, more than half the number were abandoned and many others misused (Cairncross, 2004). Some of the major commentators on sanitation report convincingly that these failures result from the implementation of sanitation interventions with little or no understanding of the state of demand for such sanitation and motivations that could create demand (Jenkins and Sugden, 2006, Jenkins and Scott, 2007).

In shifting away from the subsidy and supply driven approach to sanitation interventions, demand-led participatory approaches have been developed and implemented. Kalbermatten while at the World Bank in the 1970s was one of the early proponents of the shift in approach to sanitation planning in developing countries (Kennedy-Walker et al., 2014). These approaches are used for planning interventions that induce behaviour change and create demand for sanitation (Peal et al., 2010). They propose that benefiting communities should be involved with a project from the design phase through the implementation life of the project and be a part of the decision making process to avoid the selection

of expensive, inappropriate and unsustainable sanitation options (Cole et al., 2014). However, it is pertinent that communities are presented with feasible sanitation options along with their pros and cons to help them make informed decisions on options that suit them most and their sustainability (Santos et al., 2011).

The culmination of the move away from supply-driven sanitation approaches has been the development of a set of specific participatory methods for sanitation interventions. These are briefly reviewed below but the focus will be on Community-Led Total Sanitation, CLTS, Sanitation Marketing, SM and Total Sanitation and Sanitation Marketing, TSSM. This is because research suggests these approaches as the most promising for low-income communities especially in developing countries (Mara et al., 2010, Devine, 2010) and more likely, these are the most commonly used approaches at the moment.

2.4.2.1 Participatory approaches to sanitation interventions

Participatory Hygiene And Sanitation Transformation, PHAST

This approach is used to promote hygiene and sanitation behaviour change (Peal et al., 2010). It was developed from Self-esteem, Associative strengths ,Resourcefulness , Action-planning, and Responsibility (SARAR) methodology for participatory learning and peoples creative ability to solve their own problems (WHO, 1997). It was developed based on the principle that people will be motivated to make changes to their behaviour if they understand the health benefits associated with the proposed habit (WHO, 1997). It was applied widely in projects in health clubs in Zimbabwe in East Africa (Waterkeyn and Cairncross,

2005). However, evidence from these studies have shown that using health benefits as the main message in sanitation or hygiene promotion has not been very successful because people have stronger motivations from other factors like comfort, privacy, social status and so on (Jenkins and Curtis, 2005, Cotton et al., 1995).

Child Hygiene And Sanitation Training, CHAST

This approach is based on the principles of PHAST but the focus is on improving hygiene practices of children especially in rural areas (Peal et al., 2010). It started in Somali and involved encouraging children to discuss their sanitation and hygiene habits openly with peers and also uses exercises and educational games to show children the link between hygiene, sanitation and health (de Vreede, 2004). It captures children's natural attributes of curiosity and learning ability (de Vreede, 2004, Peal et al., 2010) which make it easy for them to influence other children and even adults with what they learn.

Participatory Rural Appraisal, PRA

Participatory Rural Appraisal involves moving away from approaches which involved the extraction of information from communities (e.g. using questionnaires) to that in which the communities themselves play a more define role (Chambers, 1994). In the 1990s, PRA evolved out of an earlier approach, the Rapid Rural Appraisal which was developed in the 1980s (Chambers, 1994). Its underlying principle is that no matter the level of education or poverty, people know and understand their situation better than an 'outsider' would do (Peal et al., 2010). It is often used as the first step in an intervention rather than as an intervention on its own (Peal et al., 2010) to understand the prevailing situation

of the target behaviour of an intervention. It employs qualitative research tools to explore situations (Freudenberg, unknown). Like all the other approaches discussed earlier, the quality of the facilitators of these approaches (in terms of knowledge, commitment and skill) is paramount to the success of its use.

Community Health Clubs, CHC

According to Peal et al (2010), "Community Health Clubs (CHC) are free voluntary, community-based organisations formed to provide a forum for information and good practice relating to improving family health". Evidence suggest it has been used extensively in Zimbabwe. This approach seeks to use community cohesion through the clubs to change social norms and beliefs within the community with respect to sanitation and hygiene and its membership is open to men, women and children (Waterkeyn and Cairncross, 2005). Like all other approaches, CHC need a skilful facilitator that will design programmes to actively engage children, youths, men and women.

Community-Led Total Sanitation, CLTS

This is an integrated demand-led sanitation approach which focuses on getting an entire community (rather than some individual households which is why it is called 'total' sanitation) to stop open defecation and use any form of fixed place defecation (Kar and Chambers, 2008, Ahmed, 2008). The approach has been acknowledged by various development organisations and national governments as an effective approach to get communities on to the first step on the 'sanitation ladder' by becoming Open Defecation Free, ODF (Ahmed, 2008). It has been applied and adopted in many countries especially in Asia and Africa like India,

Pakistan, Indonesia, Cambodia, Kenya, Ethiopia (Chambers, 2009), Tanzania, Malawi and Nigeria.

It was initiated in 1999 by Dr. Kamal Kar who was engaged by WaterAid Bangladesh, working in collaboration with a local NGO, Village Education Resource Centre, VERC to evaluate sanitation projects in Bangladesh (Kar and Chambers, 2008). It involves the use of PRA methods to 'trigger' communities by helping them analyse their own sanitation practices and the consequences and therefore make a collective decision to act by getting everyone to change behaviour and stop open defecation without any outside financial assistance (Kar and Chambers, 2008). Like other participatory approaches, its success depends on skilful and trained facilitators (Chambers, 2009). CLTS is said to work best in communities where there has been no previous sanitation interventions especially subsidy based interventions (Kar and Bongartz, 2006).

However, the principles of this approach has been criticised to neglect vulnerable people and its use of 'shame and disgust' to stimulate behaviour change deemed inappropriate (Fawzi, 2010). Notwithstanding, CLTS has produced the results required which is to get as many people as possible to stop open defecation.

It has also been suggested that the message of CLTS which urges people to build latrines and not open defecate so they don't eat each other's faeces overlooks the need for people to actually understand the pathways which faecal contamination can follow even when they own a latrine at home (Chatterjee, 2011). The approach may give the impression that once people build latrines at home and no longer open defecate, then there is a less health risk. Therefore, combining hygiene education with CLTS process could improve the intended

health benefits (not just access to and use of latrines) of an Open Defecation Free, ODF environment. Setting up a good follow-up team for communities that become ODF is necessary to enhance sustainability of the adopted behaviour.

The application of CLTS principles has been particularly challenging for littoral areas. It is necessary to note that despite the huge success of CLTS in Bangladesh, they still had the 'hard – to – reach' or challenging areas such as hill tracts, river islands and coastal areas (Ahmed, 2008). Also, the implementation of CLTS in Moma district of Nampula Province, Mozambique, did not yield expected results as many households said the challenges in the environment like the soil conditions were a constraint to building latrines (Godfrey, 2010) (though there were other factors that may have contributed to the failure like the skill of the facilitators). In East Java, Indonesia, communities located near water bodies had the poorest outcomes of becoming Open Defecation Free (Mukherjee, 2011). Open defecation in the river means that the transect walk component of CLTS (which aims to trigger shame as people walk through defecation places with faeces lying around) may not be effective in littoral areas as most faeces are deposited in the water bodies. Therefore, there is need for some innovation in CLTS for its application in littoral areas or its combination with other approaches that could overcome the identified challenges.

The guidelines for CLTS which does not prescribe any sanitation option for communities (Kar and Chambers, 2008) has not been very effective in getting people up the 'sanitation ladder' especially where there is no existing market for sanitation. Bangladesh had a fairly established market for sanitation before the inception of CLTS. This may have been a contributing factor to the success of

the uptake of latrines by households as they had fair access to sanitation services and market.

Sanitation marketing

This is one of the most recent approaches for participatory sanitation interventions. It involves the application of social and commercial marketing principles to generate demand for sanitation and also provide appropriate supply mechanisms to meet resulting demand (Cairncross, 2004, Jenkins and Scott, 2010, Cole et al., 2012). Social marketing involves the use of marketing techniques to achieve voluntary behaviour change resulting in social good of the society (Jenkins and Scott, 2007). It has been applied by various organisations in the promotion of many public health interventions; the prevention of malaria through the use of insecticide treated bed nets and prevention of HIV through the use of condoms (Donovan and Henley, 2003), prenatal care, immunisations (Grier and Bryant, 2005) just to mention a few. This shows the potential of the application of social marketing to sanitation which also has direct effect on health. However, in public health applications of social marketing to achieve behaviour change, the target audience do not get an explicit benefit for their investment or change of behaviour when compared to commercial marketing where a price is paid for an obvious (even on the spot) benefit (Rothschild, 1999). The benefit of the target behaviour change is not always just to the individual but also to the wider society. This brings on the need for innovation in implementation of sanitation marketing so as to convince the target audience of the need and benefits of the intended behaviour change.

Research (Cairncross, 2004) has shown that sanitation marketing is important because it is sustainable, cost effective, guarantees that people have the kind of sanitation they want and are willing to pay for and those who purchase toilet have an understanding of the need to change their sanitation behaviour therefore they are more likely to use it. Sanitation interventions using subsidy has provided some households with sanitation but may other households still build toilets on their own without any financial support or subsidy (Jenkins and Scott, 2007). This indicates that given the right environment and support (which is what sanitation marketing tries to provide), many households could invest in their own sanitation.

Key stakeholders in sanitation marketing are the households (the consumers of the product), the private sector (sanitation service providers, producers of sanitation products and marketers of the produced sanitation products) and the public (government, development agencies and NGOs who promote sanitation, educate people on the need for sanitation, regulate the practice of sanitation providers and provide enabling environment for the market to thrive) (Jenkins and Scott, 2010).

Sanitation marketing focuses on generating demand for sanitation and strengthening the capacity of the supply side (sanitation products and services) to cope sustainably with growing demand for sanitation (Godfrey et al., 2010). Its design depends on findings from an initial formative research. There is evidence that through sanitation marketing, even poor households have been able to build their own toilets without any financial aid from government or NGOs (Mukherjee, 2009, Frias and Mukherjee, 2005) whereas subsidy based interventions have not utterly benefitted most poor people (Rosenboom et al., 2011).

The sanitation behaviour of target for change in this research is an end to open defecation in water bodies as well as sustained progress from open defecation and use of jetty or overhang latrines, to the use of improved sanitation options. It is perceived that the development of few sanitation technologies based on the outcomes of a formative research will produce products that are easier to promote within the context of the environment studied (Devine, 2010).

Total Sanitation and Sanitation Marketing

The combination of CLTS and sanitation marketing in programmes such as Total Sanitation and Sanitation Marketing, TSSM helps to provide the market for sanitation alongside the awareness from CLTS (Godfrey et al., 2010, Devine and Kullmann, 2012). This approach seems promising for countries where there is poor existing market for sanitation and for areas with challenging environments where knowledge of feasible sanitation technologies could be limited. CLTS focuses on creating demand for sanitation by getting the target population to stop open defecation while sanitation marketing aims to generate demand for sanitation using products that fit into the environmental and sociocultural preferences of the target population. Therefore, a combination of both approaches in TSSM provides a cushioning effect on their individual weaknesses and complements their strength. TSSM has been implemented by the World Bank in Tanzania, Indonesia and India through it Water and Sanitation Programme, WSP with funding from the Bill and Melinda Gates Foundation (Godfrey et al., 2010, WSP, 2009). CLTS could trigger desire for behaviour change and Sanitation Marketing could step in to improve information on feasible technical options and also develop the supply side to meet demand for sanitation services.

2.5 Sanitation interventions and outcomes

Sanitation interventions could focus on the provision of hardware (like the construction of toilets or provision of subsides for toilet construction), software (like sanitation education, marketing, promotion of self-help) or a combination of both (Peal et al., 2010, Garn et al., 2016). Sanitation interventions have been implemented in various countries with varying success rate. It is important to note that sanitation coverage in terms of access to a toilet/latrine does not necessarily mean sanitation usage. Studies have reported continuing open defecation even in areas where sanitation coverage was high following an intervention (Barnard et al., 2013, Arnold et al., 2010). Also, research suggest that interventions to reduce diseases should include improvements in sanitation (Abu-Elyazeed et al., 1999). However, these should not be access to sanitation facilities only. Therefore, it is important to infer with care where an intervention reports only of improvement in access.

2.5.1 Health outcomes

Several studies have evaluated the impact of sanitation interventions on health. A study in rural Tamil Nadu, India, showed no difference in diarrhoea rates between the intervention villages and the control villages with a slightly higher mean prevalence rate in the intervention group (Arnold et al., 2010). This study also showed no difference in stunting rate between both groups. Another study, a cluster randomised control trial in rural Madhya Pradesh, India showed modest increase in individual household toilets and a little reduction in open defecation following the implementation of the Total Sanitation Campaign programme (Patil

et al., 2014). This improvements were insufficient to produce health effects despite the large scale of the intervention.

Furthermore, an evaluation of a CLTS intervention programme in Mali, 18months after completion showed no difference in diarrhoea rates in the intervention villages when compared with the control villages but stunting reduced by 6% in the intervention group (Pickering et al., 2015). However there was increase in access to mainly unimproved toilets but this may not have been sufficient to intercept critical faecal transmission pathways for diarrhoea disease.

Similarly, a study in Tanzania to evaluate the impact of a large scale randomised trial handwashing and sanitation intervention programmes found no clear health impact (Briceño et al., 2015). Though the design of these intervention programmes on their own have the potential to ensure reduced exposure to faecal contamination, sustaining the intended behaviour change is challenging for the beneficiaries for multiple and probably complicated reasons.

On the other hand, though there is weak evidence of the health benefits of improved sanitation in low income setting (Clasen et al., 2010, Engell and Lim, 2013), some reviews have shown reductions in diarrhoea diseases following interventions to improve access to improved sanitation. A review by Esrey *et al*. (1991) showed a 265 reduction in diarrhoea morbidity rates and 65% median reduction in overall child mortality rates following water and sanitation interventions (Esrey et al., 1991a).

Also, in another review, improvements in water supply and sanitation showed potential for reductions in diarrhoea disease (Wolf et al., 2014a). However, this study and others acknowledged that household members may still be exposed

to faecal contamination if their neighbours have no improved sanitation (Wolf et al., 2014a, Root, 2001, Harris et al., 2017). This is possibly because of the contamination pathways that exist in such context.

Similarly, a review of 13 studies from six different countries showed some evidence of prevention of diarrhoea from interventions to improve human faeces disposal, however, the authors acknowledged that the evidence was poor (Clasen et al., 2010). Also, an evaluation of intervention projects in Ethiopia 5 years after baseline showed a significant decrease in stunting following a water and sanitation intervention (Fenn et al., 2012).

It is worthy to note here that it is challenging to quantify the impact of intervention programmes given the heterogeneity of context which play a key role in pathogen transmission and methods used in different studies. However, the key transmission pathway for the health outcome of interest can be identified and interventions tailored to reduce its effectiveness.

There is mixed evidence on measurable impact of water and sanitation interventions on health outcomes. This study speculates that the mixed evidence could be because of factors such as poorly implemented programmes, factors other than sanitation affecting health, measuring impact too soon after an intervention, seasonality, external factors like famine among other factors. Despite these mixed evidence, the consequences of the lack of access to safe water and improves sanitation cannot be overemphasized.

Most research on the impact of sanitation have focused on health impacts like diarrhoea and very few have assessed the impact of sanitation access on faecal contamination exposure pathways (Sclar et al., 2016). It is important to know

whether sanitation interventions are getting faecal contamination out of the immediate environment. Identifying critical transmission pathways would mean interventions are appropriately targeted.

This research seeks to make a useful contribution to knowledge by exploring possible faecal contamination transmission pathways arising from current sanitation behaviour.

A cross-sectional study of 60 villages (30 intervention and 30 control villages) of a cluster-randomized controlled sanitation trial in Puri District of Odisha, India, showed 27point increase in functional latrine coverage following the intervention but found no evidence of reduced human faecal contamination in water sources, stored household drinking water and hand rinse samples (Odagiri et al., 2016). This implies that the intervention may not have intercepted faecal contamination pathways despite increased latrine access but it is unclear how households which gained access to a toilet differ from those that did not gain access in terms of the concentration of faecal contaminants.

This research seeks to explore how households with access to a toilet at home vary in the concentration of faecal contamination in stored drinking water and hand rinses to help establish the gains if any, for households with toilet.

2.5.2 Outcomes relating to source water quality

The previous section has shown the difficulty in matching improvement in sanitation to commensurate improvement in health. Here let us look at water quality specifically.

A cross-sectional study carried out in India to compare source water quality between open defecation free and non-open defecation free villages found 31% point more contamination in water sources of non-open defecation villages (Rajgire, 2013). However, this study did not state if these villages were comparable in terms of other factors like population density, physical characteristics and so on other than open defecation status.

Two cluster-randomised control trials carried out to evaluate the impact of India's Total Sanitation Campaign found no positive impact on the quality of drinking water sources following latrine provision from the programme (Clasen et al., 2014, Patil et al., 2014). Another cluster randomised trial in Mali to assess the effectiveness of a CLTS intervention found no effect of source water quality but latrine access and use was high (Pickering et al., 2015). This suggest that sanitation access alone may not always be sufficient to eliminate contamination in water sources.

2.5.3 Outcomes relating to stored household drinking water quality

A trial in India showed no effect on the overall faecal contamination levels in stored household drinking water following a sanitation intervention (Clasen et al., 2014). Also, a cross sectional study in Orissa to compare households with shared latrines and those with individual latrines found no difference in faecal

contamination levels in their stored household drinking water (Heijnen et al., 2015). Similarly, in Hyderabad, households with contaminated stored drinking water had no significant difference in demographics, water handling nor sanitation (Eshcol et al., 2009). We speculate that access to a toilet alone may not be sufficient to prevent contamination of stored drinking water in households.

2.5.4 Outcomes relating to contamination on hands

Hand rinse samples are commonly used as a proxy for contamination levels on hands. A cluster randomised trial was carried out in Kenya to evaluate the impact of a school based hygiene and sanitation intervention on pupil hand contamination levels. This study showed an increase in hand contamination levels for pupils in schools that received intervention when compared to the control group between the baseline and follow-up (Greene et al., 2012). This could be because anal cleansing materials were not provided as part of the intervention and pupils may have adopted unsafe practices for anal cleansing leading to more contamination on hands. This is consistent with the point that access to sanitation without proper use may have unintended consequences.

Furthermore, a study in Tanzania found no significant associations between detecting virus in stored drinking water and hand rinse samples between households with a child suffering from diarrhoea and one where there was no diarrhoea case (Mattioli et al., 2014). The study also found better stored household drinking water quality in households with diarrhoea cases. This could possibly mean that households with a sick child ensure better safety of drinking water or that other factors other than drinking water quality could be responsible for diarrhoea cases in the study setting as suggested elsewhere (Levy, 2015).

2.6 Open defecation behaviour and faecal contamination exposure pathways

The main transmission pathway for faecal contamination which results in diarrhoea disease is the faecal-oral route (Byers et al., 2001). This could be through ingestion of contaminated water, food, person-to-person contact or direct contact with faeces (Clasen et al., 2010).

The focus of most sanitation interventions in context where open defecation is prominent is often to ensure all households have access to a toilet at home. This study however argues that this alone may not be the most appropriate intervention in all context. Pathways of exposure to faecal contamination may vary from place to place and between seasons in a particular context. Behavioural and social factors causing even people in households with a toilet to continue the practice of open defecation are essential components of reducing faecal contamination exposure.

A study in India showed that following a sanitation intervention, 88% of households were practicing open defecation irrespective of their toilet access status, yet diarrhoea rates were low (Arnold et al., 2010). Open defecation was primarily in open fields in the study population so this defecation place may not constitute a pathway for diarrhoea causing pathogens for children under 5 years hence costly sanitation improvements may not likely yield significant health benefits (Arnold et al., 2010). This points out the importance of establishing a significant contamination pathway before the implementation of a sanitation intervention if the benefit of lower exposure to faecal contamination is to be achieved.

Increased use of poorly functioning and unsafe toilets could have unintended consequences for groundwater contamination and exposure to faecal contamination defeating their benefits (Greene et al., 2012) especially for riverine areas where water table is high.

Therefore, to achieve the benefit of ending open defection, everyone in the target population need to stop the behaviour of open defecation and use sanitation systems that safely manages human faeces and appropriately intercepts the transmission route of faecal contamination in the setting. The ability of an intervention to intercept the pathways shown in Figure 2.1 increase its chances of having health impacts.

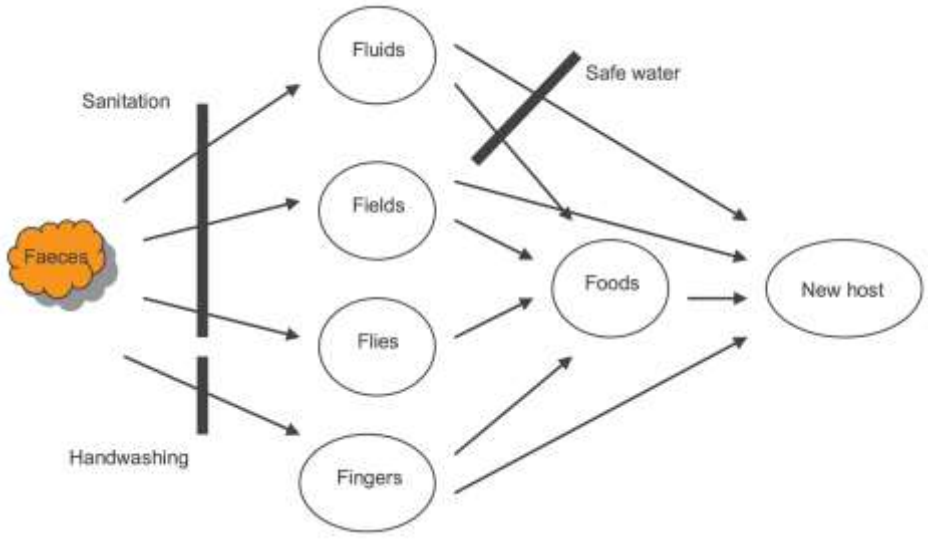


Figure 2.1: Faecal contamination transmission pathways and interventions to break them. Adapted from (Mara et al., 2010)

The place of defection, mode of defecation, hygiene and other behaviours determine how faecal contamination move from source (faeces) to a new host in

different context and seasons. Different activities and behaviour can influence how faecal contamination moves in the environment both indoors and outdoors. Household activities (Pickering et al., 2011), drinking water storage and management in households (Clasen and Bastable, 2003), hand washing behaviour (Saboori et al., 2013) among other factors influence the transmission of faecal contamination. In Figure 2.1 also called the F-diagram, some exposure pathways may be more relevant than some in different context. For example, where fields do not exist near communities or keeping of farm animals not common, fields may not be a significant pathway.

2.6.1 Why is faecal contamination transmission pathways important?

The effectiveness of an intervention programme is dependent on its ability to intercept a transmission pathway of exposure to contamination thus reducing the possibility of an infection. For example, an evaluation of a sanitation programme showed no evidence of reduced exposure to faecal contamination hence no impact on preventing diarrhoea disease (Clasen et al., 2014). Access to well managed and safely constructed toilets and consistent use together with good hygiene could contribute to reducing exposure to faecal contamination by truncating the transmission pathway.

2.7 The challenge of ending open defecation and its effects

The past three decades have seen increased effort to end open defecation in the world. Open defecation here refers to any defecation practice where human faeces is not deposited in a designated place where it can be safely contained, treated and disposed or reused. It is the practice of directly depositing human faeces into the environment whether on land or into water bodies. It is a threat to public health and leads to faecal and bacteriological contamination of water sources and the environment and transmission of faecal-oral and gastro-enteric diseases (Jenkins and Curtis, 2005, Sanan and Moulik, 2007). This practice leads to exposure to pathogens expelled in human faeces because it increases the chances of people having contact with contaminated faeces thereby exposing them to contamination that could lead to disease. Common open defecation places include but are not limited to bushes, open fields, beaches and water bodies.

Open defecation has social, economic and public health impact through incidences of poor sanitation related illnesses, spending on health care to treat illnesses, time lost at work, school and play as well as poverty (Galbraith, 2009). Aside from health risk, open defecation exposes women and girls to the risk of harassment, results in loss of dignity and it is uncomfortable and inconvenient (Chambers, 2009).

In an effort to end open defecation, urine diverting toilets were provided to households in eThekwini, South Africa, however, these were not regularly used initiating a need for a further intervention to encourage sustainable use (Tilley and Gunther, 2016). Where sanitation facilities are provided but do not safely

contain faeces and are not also used regularly, the benefits in terms of reduced exposure or even disease reduction could be defeated (Weaver et al., 2016). Onsite sanitation systems when located at least 10m from a water source, has limited opportunities to contaminate groundwater (Sorensen et al., 2016). Ensuring this distance can however be challenging for densely populated locations. It is also difficult to say where toilet facilities are located in neighbouring properties where concrete walls are used as fence around properties as is the case in some developing countries. Therefore, depending on the water table, the depth of latrines and their distance from a water source, it may be possible to have faecal contamination of ground water.

Furthermore, a CLTS intervention in Nambale and Nyando, two sub-counties in Kenya was successful and both communities were declared Open Defecation Free, ODF (Njuguna, 2016). An evaluation of the programme in both locations showed a significant decrease in diarrhoea rates when compared with other sub-counties that were not open defecation free (Njuguna, 2016). The study used diarrhoea prevalence data for a 3-year period from January, 2012 to December, 2014, as recorded by Kenya Health Information System. However, Nambale sub-county was certified ODF in June, 2012 (six months into the 3-year period) while Nyando was certified ODF in October 2013 (one year and ten months into the 3-year period). It is therefore unclear what the diarrhoea rates were in these sub-counties prior to them becoming ODF certified when compared with rates after ODF certification. Also, not all diarrhoea cases may be reported in healthcare facilities because some could be treated at home.

India's large scale Total Sanitation Campaign to improved access to individual household toilets with modest health impacts but did not eliminate open

defecation (Barnard et al., 2013). Increase in coverage was less than expected following a sanitation intervention in Orissa, India (Boisson et al., 2014).

Most toilets built following CLTS interventions are unimproved toilets. Although this is a step onto the sanitation ladder moving away from open defecation, it is unclear the extent to which contamination pathways are intercepted to ensure health gains from the behaviour change. It is also possible for new contamination pathways to be created in the process.

2.7.1 Challenges with open defecation in riverine Communities

Riverine communities are the worst hit by poor sanitation resulting from a combination of factors including their proximity to water bodies and the challenge of finding a feasible and sustainable sanitation system that fits their physical environment.

In Vietnam, there are challenges with sanitation especially for rural areas (Herbst et al., 2009). The Mekong Delta in Vietnam is a densely populated riverine area where inhabitants predominantly settle along river banks with agriculture and aquaculture as important sources of income. This region is perceived to have an enormous burden of typhoid fever (Luxemburger et al., 2001, Herbst et al., 2009) and other water related illnesses where poor sanitation is a key contributing factor. Surface and groundwater pollution resulting from the discharge of untreated sewage is leading to an increase in chemical and microbial load in water bodies (Herbst et al., 2009). Fish pond toilets (shanty structures built over ponds where fishes are kept) and direct defecation into rivers are the common ways of disposing human faeces in the area (Herbst et al., 2009). Research has

shown that the sanitation behaviour of residents of Mekong Delta reflects that there is still limited appreciation of the relationship between poor sanitation and public and environmental health. Therefore, there is need to incorporate prevailing sanitation behaviour into the strategies for design of any sanitation intervention programme in such areas.

However, to explore the possibility of improving sanitation in Vietnam, International Development Enterprises, IDE carried out a pilot study from 2003 to 2006 to examine the potentials of sanitation marketing in improving sanitation in the country (Devine, 2010, Devine and Sijbesma, 2011). This pilot scheme helped some households to acquire sanitation systems without any subsidy from government or NGO. Subsequently, a study was carried out by the Water and Sanitation Programme, WSP, to examine the sustainability of IDE's sanitation marketing programme (Devine and Sijbesma, 2011). This study highlighted that the marketing approach alone was not sufficient to eradicate open defecation (similarly reported is another study (Mukherjee, 2001)) because it lacked the fundamental stimulation for behaviour change and therefore recommends the combination of CLTS with Sanitation Marketing to cushion that effect. Without a change of behaviour, people could build toilets but still use open defecation as their sanitation option.

Similarly, Cambodia which has a predominantly rural population (NIS, 2009), in 2011 69% of rural dwellers still practice open defecation (the national figure is 58%) (WHO/UNICEF, 2013). World Bank's Water and Sanitation Programme, WSP, carried out a research into the state of sanitation in Cambodia (Salter, 2008) and this revealed good prospects of demand for sanitation and private sector participation in the supply side of the sanitation market.

In these riverine areas, sanitation is poor and water bodies are polluted with human faeces through direct defecation into the water which they also use for other purposes and in some cases drinking (Van Huu et al., Brown et al., 2010). Beyond the challenge of behaviour change and creating demand and supply for sanitation, there is the challenge of finding a technical sanitation system that can work for riverine communities like floating communities and communities living in flood prone areas and also deal with multiple generations of people who have no previous exposure to good sanitation practices (Brown et al., 2010). The Live and Learn Environmental Education Cambodia in partnership with Engineers Without Borders Australia have worked with floating communities, using participatory intervention methods to develop sanitation technology that can work in these communities (Brown et al., 2010). This developed from creating awareness of the need to change sanitation behaviour through to getting inputs from the community on what they would want in a sanitation technology with technical support in an iterative design process. This reinforces the importance of user participation in the design and development of sanitation technologies, especially for people living in challenging environments (with little or no experience of using improved sanitation) because developing a 'successful' sanitation technology on one end, does not necessarily mean having a 'happy and willing' user of the developed technology at the other end.

Similarly, Indonesia has a large number of littoral communities living along river banks, coastlines and areas with high water table (Djonoputro et al., 2010). WSP also carried out research to study the state of sanitation in Indonesia as part of its work in East Asia (Djonoputro et al., 2010). In the communities studied, river water is used for domestic purposes and also as a receptor of faeces from fixed

point defecation through overhung latrines and floating toilets. This project was part of WSP's 'Global scaling up rural sanitation Programme' which was implemented in three countries (Indonesia, India and Tanzania). The programme started with using CLTS to help communities analyse their existing sanitation practice and its consequences and then it followed on with sanitation marketing to help communities access different types of sanitation systems that met their desire in terms of design and cost (Cameron and Shah, 2010). From an impact evaluation study of the project in Indonesia, 40% of households in the study still practice open defecation and 87% (90% of the whole sample live along rivers) reported that cost was the greatest impediment to constructing a toilet (Cameron and Shah, 2010). This shows that despite having the 'trigger' from CLTS and Sanitation Marketing to strengthen the supply of sanitation services, there is a need to evaluate existing financing mechanisms in the community of interest and include a strategy in the programme design to help households access available sanitation systems (provided by the sanitation market created).

Also, a study carried out in three countries, Cambodia, Vietnam and Indonesia, showed that access to open beaches, rivers and fields could reduce demand for sanitation (Mukherjee, 2001). This makes the case of littoral communities more challenging. The study also noted that demand was low for sanitation systems that interfered with the local practices relating to human faeces. Also, the experience of early toilet adopters such as collapse of pit or flooding of pits creating a smelly mess, inhibits adoption of sanitation by neighbours or friends of such adopters (Mukherjee, 2001). These pit collapses and flooding would be common in littoral areas given that their soils are often sandy and they are more likely to experience flooding when compared with upland areas. Here, formative

research prior to an intervention could capture the level of existing technical skills requirements for developing sanitation technologies suitable in the particular context and the needed support can be captured in a strategy for designing sanitation interventions for such areas. A good sanitation intervention should create demand, enhance supply capacity to meet created demand and also provide for sustainable improvements in sanitation behaviour.

It is important to note that in countries like Bangladesh, exposure to previous sanitation interventions and the existence of a strong sanitation market played a role in the success of CLTS there. Other countries may not have similar conditions hence expected success rate may differ. Designing sanitation interventions for communities where there has never been any sanitation intervention of any sort or hygiene promotion or education or prior exposure to the use of improved sanitation systems needs some careful innovation. Getting people to use just any simple latrine may not result in sustainable use compared with developing designs that people like and building financing mechanisms to help them purchase the sanitation system they desire. It is challenging to change behaviour but it is not impossible.

2.8 Sanitation and its effect of household drinking water

Where in-house piped connections for water supply is unavailable and drinking water storage is practiced, sanitation behaviour could influence stored water quality. A study in Durban, South Africa, showed households that practiced open defecation had the highest levels of E.coli in their stored drinking water when compared with households that had toilets (Singh et al., 2013). However, it is unclear the nature of the open defecation practice in the study area, that is, is

open defecation around houses, in fields, into water bodies and so on. This would give an idea of possible faecal contamination transmission pathways in the study setting.

2.9 Identified gap in literature

Research has shown that access alone has not successfully eliminated the effect of poor sanitation. Only few studies examined possible contamination pathways resulting from existing sanitation behaviour. No studies reported assessing exposure pathways prior to implementation of a sanitation intervention programme. None has examined this exposure pathways in the context of riverine communities where open defecation is predominantly in the river. It is also unclear if households with a toilet in a context with widespread open defecation have lower faecal contamination levels.

Also, several studies have identified continuous behaviour of open defecation but the dynamics of how these changes depending on where people are within the community at the time they need to defecate is unclear.

To fill this gap, this study therefore aims to examine sanitation behaviours in a riverine context, identify possible transmission pathways exposing households to faecal contamination and explore how these contamination levels vary between households with access to a toilet at home and those without. The outcomes will contribute to enhanced design of sanitation interventions to help riverine communities achieve Sustainable Development Goal 6.2 and 6.3 which aims to end all open defecation paying particular attention to people in vulnerable situations and also improve water quality.

For riverine communities, this research explores the case of riverine communities in Bayelsa state to explore existing faecal exposure pathways and critical points where an intervention could make impact.

2.10 Chapter summary

This chapter explored existing knowledge on water and sanitation. It highlighted approaches to sanitation interventions and their strengths and weakness. It assessed intervention programmes and their outcomes. Effects of poor sanitation on stored household drinking water were highlighted. It summarised the gap in literature where this research seeks to fill. The next chapter will give a brief on sanitation in Nigeria.

Chapter 3 : Sanitation and Health in Nigeria

3.1 Chapter introduction

This chapter assesses the sanitation situation in Nigeria. It explores access to sanitation and health impact in terms of reported diarrhoea rates. It uses data from the most recent Multiple Indicator Cluster Survey, MICS, and Demographic and Health Survey, DHS for Nigeria. It examines the data for the strongest predictor of reported diarrhoea rates in the country and justifies the selection of the study location.

3.2 Sanitation and diarrhoea

Poor sanitation leads to several health consequences and is a leading cause of diarrhoea. Exposure to diarrhoea causing pathogens is mainly through using water contaminated by faeces and unhygienic practices in the management and disposal of faeces (NPC and ICFI, 2014). 2300 children die daily in Nigeria making the country the second largest contributor to global under-five mortality (UNICEF, 2012). In 2015, there were more than 143,000 deaths caused by diarrhoea in Nigeria (IHME, 2017). In Nigeria, reported cases of diarrhoea increased from 7.8 percent in 2010 to 9.4 percent in 2013 and diarrhoea with blood also rose from 2.6 percent to 11.5 percent in the same period (NBS, 2014b).

3.3 Sanitation Policies in Nigeria

Over the years, government at the federal, state and local government level have paid less attention to sanitation when compared with water supply (FGN, 2000). The era of the Millennium Development Goals saw improvement in sanitation policies in Nigeria. The provision of sanitation facilities at household level is currently the sole responsibility of the household.

Nigeria launched a national water supply and sanitation policy in year 2000. Policies on sanitation were not clear and roles and responsibilities for individual stakeholders, like the different tiers of government, NGOs, communities and individuals were not clearly defined (FGN, 2004). This has significantly affected the development and implementation of sanitation programmes. The water sanitation policy published in 2004 fills this gaps with clear roles and responsibilities, institutional framework and policy implementation strategies. However, current trends in sanitation improvement in Nigeria puts a question on the implementation of the policy

Renewed efforts to improve sanitation has led to the development of Partnership for Expanded Water Supply, Sanitation & Hygiene (PEWASH) Programmed Strategy (2016 – 2030). This is a multi-sectoral collaboration of stakeholders in sanitation to enhance efforts towards achieving SDG for sanitation by year 2030 (FGN, 2016). This renewed effort is building on existing successful approaches like CLTS, Sanitation Marketing and others to ensure one hundred percent access to water and sanitation and eliminate open defecation by 2030 in line with SDG 6. Sanitation approaches like CLTS which is policy in Nigeria has

successfully helped households end open defecation and take the first step on to the sanitation ladder.

3.4 Sanitation access in Nigeria

Access to and use of improved sanitation is important for public health (Ogbonna and Idam, 2007). The Nigeria Population Commission in its Demographic and Health Survey report, groups sanitation facilities in Nigeria into; improved not shared, improved shared and unimproved facilities. three out of every ten households in Nigeria use an unshared improved sanitation facility, 25 percent use shared and 45 percent use unimproved sanitation facilities while 29 percent have no sanitation facility (NPC and ICFI, 2014). The most common type of improved facility if the flush/pour flush toilets connected to septic tanks while the most common unimproved facility is open pit latrine. Nigeria is making effort to improve sanitation access in the country. One of the steps taken to achieve this is the adoption of CLTS as policy in Nigeria. However, despites these efforts, overall sanitation access in Nigeria has followed a downward trend.

3.5 Relationship between proximity to rivers and diarrhoea rates

Data from the 2013 Demographic and Health survey shows diarrhoea rate for all the states in Nigeria including the Federal Capital Territory, FCT, Abuja. This data shows variations in reported diarrhoea rates across the country. States in the riverine Niger Delta region tend to have lower rates of diarrhoea compared to states in the dry area (see Figure 3.1).

State	% of all diarrhoea	Riverinr or Non - Riverine	Poverty Rate	Land area in m^2	population	Population Density	% of HH with OD	%HH using Hanging Latrine	% HH with improved facility	% of HH using surface water as main drinking water	% disposal of child faeces in rivers	% of HH where place of handwashing was observed
Abia	2.5	R	50	4900	3256642	665	1.2	2.9	80	9.2	0	5.3
Anambra	5.7	NR	54	4865	4805646	988	14.9	0	78.3	16.7	1.2	6
Akwa Ibom	5.5	R	51	6900	4625119	670	3.6	0.6	84.2	16.8	0	13.8
Bauchi	25.7	NR	84	49119	5515303	112	35.2	0.1	10.7	3.6	0.2	79.7
Bayelsa	1.8	R	44	9059	1970487	218	32.1	39.3	17.2	59.9	61	27.9
Benue	9.5	NR	73	30800	4942141	160	52.9	0	26.4	39.6	0	38.6
Borno	10.8	NR	60	72609	4944033	68	22.7	0.4	48.9	0.1	0.4	11.3
Cross Rive	8	R	60	21787	3344410	154	53.6	3.3	28.8	46.3	0.3	12.5
Delta	2.8	R	54	17108	4825999	282	23.1	6.3	51.2	5.2	22.2	23.3
Ebonyi	13.2	NR	82	6400	2504085	391	45.5	1.2	64.1	31.9	0	3.1
Edo	2	R	63	19187	3700706	193	22	1.1	64.1	16.8	1.1	36.7
Ekiti	6.6	NR	57	5435	2801161	515	60.8	0	51.7	8.7	0	9.4
Enugu	14.7	NR	60	7534	3796685	504	48.6	0	47.2	18.3	0	9.3
Gombe	16.7	NR	82	17100	2775400	162	27.3	0	12.4	14.6	0	6.3
Imo	12.2	R	39	5288	4609038	872	15.8	0	78.2	8.1	0	8.8
Jigawa	14.8	NR	89	23287	5041491	216	48.1	0	41.2	0	0	37
Kaduna	13.5	NR	63	42481	7102877	167	7.8	0	66.1	2.6	0.1	63.4
Kano	6.5	NR	70	20280	11087814	547	4.3	0	71.5	5.4	0	36.7
Katsina	7.7	NR	78	23561	6740479	286	11.5	0	38.9	2.3	0	28.8
Kebbi	13.6	NR	72	36985	3802526	103	37.5	0	19.5	8.7	2	31.1
Kogi	3.3	NR	68	27747	3850369	139	65.8	0	27.2	43.9	2	36.4
Kwara	5.3	NR	72	35705	2748148	77	50.5	0	43.8	12.7	0	23.9
Lagos	7.5	NR	40	3671	10694915	2913	2	0	97	0	1.3	35.8
Nasarawa	8.3	NR	79	28735	2171906	76	50.8	0	28.7	28.3	0	11.6
Niger	8.2	NR	51	68925	4687610	68	47.5	0	37.6	21	0	36.5
Ogun	1.9	NR	59	16400	4424069	270	11.7	0	80.9	2.1	0	25.6
Ondo	5.5	R	58	15820	4020965	254	47.6	0	43.9	34.9	13.4	2.3
Osun	4.1	NR	37	9026	4009839	444	39.2	0	59	8.2	0.9	10.8
Oyo	9.2	NR	51	26500	6615061	250	54	0	44.4	10.5	0	18.6
Plateau	5.6	NR	72	27147	3669993	135	56.2	0	33.7	25.4	2.4	23.6
Rivers	5	R	47	10575	6162063	583	16.6	15.6	59.8	0.5	12.1	54.9
Sokoto	4.6	NR	86	27825	4301896	155	30.7	0	47.7	4.4	0.1	46.9
Taraba	19.7	NR	69	56282	2652880	47	52.5	0.2	15	44.4	0	19.4
Yobe	34.6	NR	80	46609	2765286	59	39.5	0.3	24.1	1.2	0	49.7
Zamfara	6	NR	69	37931	3847793	101	9.8	0.2	37.7	17.1	0.1	43.3
FCT Abuja	5.6	NR	45	7607	2238752	294	20	0	75.6	7.8	0	24.6

Figure 3.1: Reported diarrhoea rate and potential factors affecting rate

Figure 3.1 shows all the states in Nigeria and their corresponding reported diarrhoea rate along with other factors that could potentially affect diarrhoea. To establish if being riverine plays a role in diarrhoea rates for states in Nigeria, an independent-samples T-test was carried out. The test addressed the question:

> Is mean reported diarrhoea rates higher in non-riverine States and is the difference significant?"

The status of the state (riverine or non-riverine) was the independent categorical variable while reported diarrhoea rates was the dependent continuous variable. The one – tailed test showed a statistically significant difference in mean scores on reported diarrhoea rates between riverine and non-riverine states (Table 3.1) with a P- value of 0.015 (less than 0.05). Lagos state was given a density of 1000 people per square metre. This was to prevent its density of nearly 3000 people per square metre from skewing the analysis.

Table 3.1: T-test comparing Diarrhoea rates between riverine and non-riverine states

Status of State	N	Mean	Standard Deviation	P – value	t	Effective size (eta squared)
Riverine	9	5.033	3.385	0.015	2.253	0.13
Non-Riverine	28	10.696	7.237			

To establish that this difference is not just by chance, the effective size was calculated. Effective size, gives the magnitude of the difference in means

between the groups compared to ensure that the difference is not by chance (Pallant, 2013). The effective size is estimated using the statistic Eta squared.

According to Pallent (2013);

$$Eta\ squared = t^2 \div (t^2 + [N_1 + N_2\ - 2])$$

Using the values from Table 3.1, the effective size is 0.13. In interpreting effective size (Cohen, 1988);

a value equal to 0.01 = small effect

a value equal to 0.06 = medium effect

a value equal to 0.14 = large effect

An effective size of 0.13 therefore shows a large effect and that the difference in mean diarrhoea rates between riverine and non-riverine states is not by chance.

3.6 Predictive strength of factors affecting diarrhoea rates

In literature, there are many factors that affect diarrhoea rates. To assess how some key factors along with being riverine affect diarrhoea rates, a standard multiple regression analysis was conducted. The factors used in the analysis include: poverty rate, population density, open defecation, use of hanging latrines, use of improved sanitation facilities, use of surface water as a primary source of drinking water, disposal of child faeces in rivers and possession of a designated place of hand washing within a household. The regression model was used to evaluate how each of these factors predict reported diarrhoea rates in Nigeria.

The model had R square of 0.511. This means that this model can explain 51% of the variance in diarrhoea rates. The model reached statistical significance at P = 0.010 (less than 0.05).

In evaluating the unique contribution of each variable to predict diarrhoea rates, standardized coefficient Beta values were used. Use of improved sanitation had the largest Beta value. This shows that from the model, the use of improved sanitation makes the strongest unique contribution to reported diarrhoea rates. This contribution is also statistically significant with a P-value of 0.003.

This agrees with the direction of investments in sanitation as reported in literature. The focus of SDG 6.2 is to eliminate all open defecation and get more households to use improved sanitation with the aim of reducing the incidence of diseases such as diarrhoea.

Table 3.2: Results from standard multiple regression analysis

Variables	Sig (P-Values)	Standardized Coefficients (Beta)
Riverine status of State	0.941	-0.013
Poverty rate	0.922	-0.022
Population density	0.093	0.384
Open defecation	0.500	-0.150
Use of hanging latrines	0.742	-0.136
Use of improved sanitation	0.003	-1.021
Use of surface water as main source of drinking water	0.220	-0.250
Disposal of child faeces in river	0.572	-0.227
Designated place of hand washing in household	0.319	0.171

3.7 Justification for selection of study area

In contrast to the results of the analysis described earlier in the chapter that access to improved sanitation is the strongest predictor of reduced reported diarrhoea rates, Bayelsa states has one of the lowest diarrhoea rates in the country and the Niger Delta region despite having very poor access to improved sanitation (see Figure 3.2). This suggest that access to improved sanitation might not be the strongest predictor of reported diarrhea rates in this setting or context.

State	% of all diarrhoea	Pov Rate	Population Density	% of HH doing OD	%HH doing Hanging Latrine	% HH with improved facility	% of HH using surface water as main drinking water	% disposal of child faeces in rivers	% HH where place of handwashing was observed
Abia	2.5	50	665	1.2	2.9	80	9.2	0	5.3
Akwa Ibon	5.5	51	670	3.6	0.6	84.2	16.8	0	13.8
Bayelsa	1.8	44	218	32.1	39.3	17.2	59.9	61	27.9
Cross Rive	8	60	154	53.6	3.3	28.8	46.3	0.3	12.5
Delta	2.8	54	282	23.1	6.3	51.2	5.2	22.2	23.3
Edo	2	63	193	22	1.1	64.1	16.8	1.1	36.7
Imo	12.2	39	872	15.8	0	78.2	8.1	0	8.8
Ondo	5.5	58	254	47.6	0	43.9	34.9	13.4	2.3
Rivers	5	47	583	16.6	15.6	59.8	0.5	12.1	54.9

Figure 3.2: Values of reported diarrhoea rate and predictive factors for Niger Delta States

Also, the analysis showed that being riverine significantly reduces reported diarrhoea rates. Bayelsa state is a riverine state in the Niger Delta region of the country. Interestingly, Bayelsa state also has the largest use of surface water as the main source of drinking water. Also, nearly 40% of households use hanging latrines where faeces are deposited directly into surface water and over 60% of child faeces in the Bayelsa is deposited into rivers. This shows that a large proportion of all faeces in the State ends up in surface water bodies.

Also, a good proportion of the population are exposed to surface water and the risk of faecal contamination from drinking such water. Despite these odds, Bayelsa still has the lowest reported diarrhea rates in the country. To find possible explanations for this anomaly, this study explores the case of Bayelsa State using two riverine communities.

Also, given that the current sanitation access level seem not to lead to increase in reported diarrhea rates and SDG 6 seeks to end all open defecation and increase the use of improved sanitation facilities, this study will explore current faecal contamination levels in households with sanitation access and those without access. This is to see if households with a sanitation facility have gains in terms of reduced faecal contamination in stored household drinking water when compared with households without access.

3.8 Chapter Summary

This chapter explored sanitation in Nigeria and reported diarrhoea rates. It established that access to improved sanitation is a key predictor of reported diarrhoea rates in Nigeria. It also showed that riverine states in Nigeria had significantly lower diarrhoea rates that non-riverine states. It also justified the selection of communities in Bayelsa State as the study area and the need to compare households with toilets access at home and those without access. The next chapter will give details about the study area.

Chapter 4 : Synopsis of research study area

4.1 Chapter introduction

This chapter give a brief background of the research study area. It also describes geographical, cultural and physical characteristics, water, sanitation and other factors.

4.2 The Niger Delta Region

The Niger Delta region in located in the south of Nigeria (see Figure 4.1). Nine states make up the region with a population of over 35million people (NBS, 2013a). These includes: Abia, Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo and Rivers state (see Figure 4.1). The region which has about 40 ethnic groups speaking up to 250 languages and settled in predominantly small scattered hamlets with fishing and farming as their main occupation (NDDC).

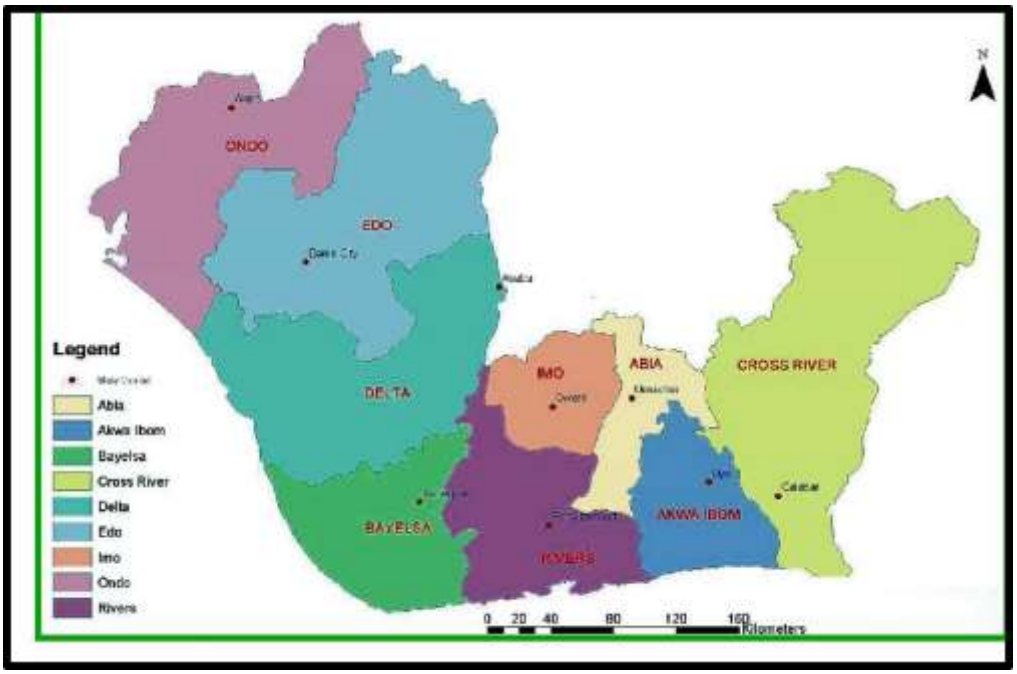


Figure 4.1: Map of Niger Delta showing its nine states (Adapted from NDDC's Niger Delta Master Plan)

Looking at distribution of households by sanitation facility, Table 4-1 shows that only 33% of the population of the region have access to improved unshared sanitation (NBS, 2013b). 22% still practice open defecation with the worse cases being Bayelsa state (with 39% of its population using hanging latrines and 32% open defecation), Cross River (54% open defecation) and Ondo state (48% open defecation)(NBS, 2013b). Factors such as high water table, loose soils, water logged soils, erosion and flooding among others are common in the region. These contribute to difficulty with construction and sustainable use of simple and cheap sanitation technologies like the pit latrines.

Table 4-1: Household Sanitation Distribution in Niger Delta

Type of sanitation facility	Percentage distribution of household
Improved sanitation facility (not shared)	33
Improved sanitation facility (shared by 5 households or less)	14
Improved sanitation facility (shared by more than 5 households)	9
Public improved sanitation facility	4
Unimproved sanitation facility (not shared)	6
Unimproved sanitation facility (shared by 5 households or less)	3
Unimproved sanitation facility (shared by more than 5 households)	3
Public unimproved sanitation facility	6
Open defecation	22

Data from MICS 2011

4.3 Research setting

This research was carried out in Odi and Kaiama, two riverine communities of Bayelsa State, Niger Delta, Nigeria. Bayelsa is one of the last states that were created in 1996 in Nigeria. Its capital city is Yenagoa and it has eight local government areas. It has an area of 9059 square kilometres and a projected population of about 2 million people in 2011 and experiences two seasons, rainy season and dry season (NBS, 2014a). In contrast to most rural areas riverine communities in Bayelsa are more densely populated because of the challenge of space and physical conditions of their environment given that two-thirds of its land mass is covered by water. Key ethnic groups in the state include Ijaw, Atissa, Biseni, Igbriran, Ekpetiama and Kolokunu with Izon, Epie-Atissa, Nembe, and Ogbia as the most dominant local languages. Figure 4.2 shows the location of Bayelsa State in Nigeria and the location of Kolokuma-Opukuma LGA where the study communities are located.

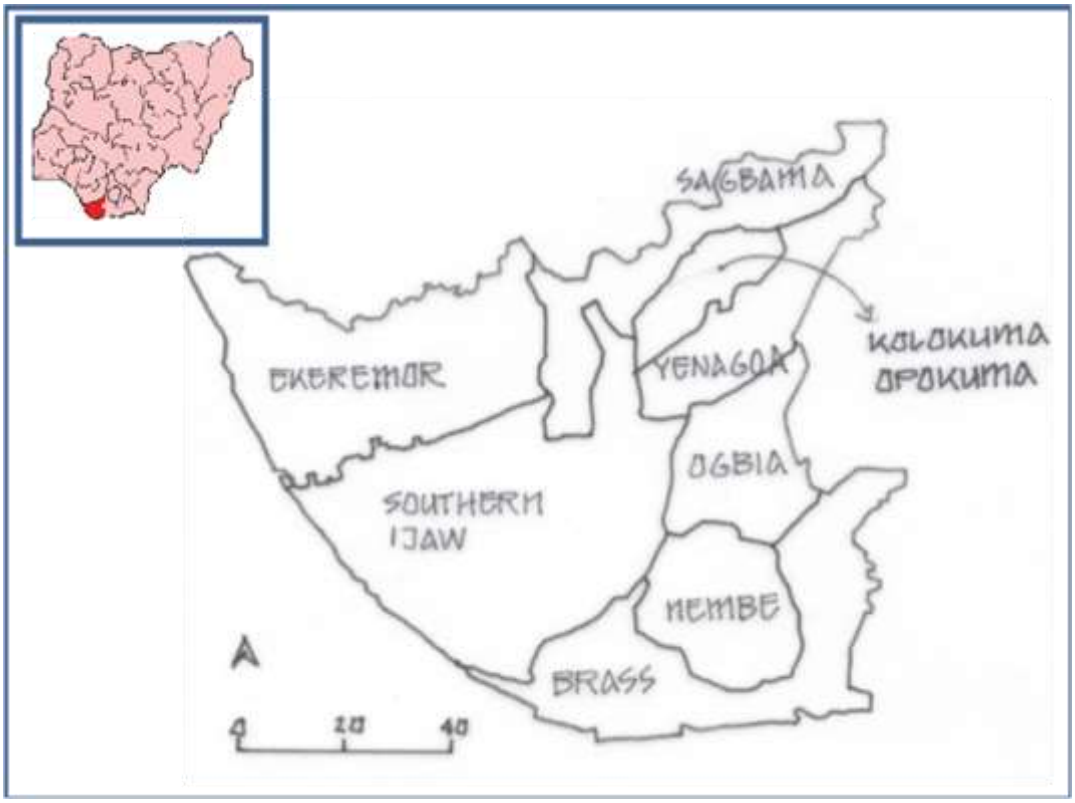


Figure 4.2: Map of Bayelsa State showing study area

Source: (Kakulu and Brisibe, 2014)

Bayelsa state plays a very important role in the economy of Nigeria. It is the second largest producer of crude oil in Nigeria. The first oil well discovered by Royal Dutch Shell company is in Oloibiri, a village in Bayelsa State (Egberongbe et al., 2006). Despite its economic contributions, Bayelsa is like the goose that lays the golden egg. Environmental degradation resulting from oil production operations (oil spills, gas flaring and others) has led to poverty as the main source of livelihood of the people, fishing and farming, is destroyed (Egberongbe et al., 2006, Odularu, 2008). Underdevelopment and absence of commensurate infrastructural development among other factors led to unrest and militancy in

Bayelsa State. Water and sanitation in Bayelsa is not spared in the underdevelopment sequence.

4.4 Sanitation in Bayelsa State

The percentage of households with access to improved sanitation and improved drinking water supply in Bayelsa State is one of the worst in Nigeria. Data from the most recent MICS shows that thirty nine percent use hanging latrines build over surface water where faeces is deposited directly in to surface water bodies (NBS, 2013b). The MICS also shows that sixty percent of households in Bayelsa use surface water as their main source of drinking water (NBS, 2013b). sixty one percent of child faeces is disposed into surface water in Bayelsa State (NPC and ICFI, 2014).

With nearly two-thirds of households in Bayelsa drinking surface water where majority of all faeces in the state are disposed, it will be expected that an epidemic of diarrhoea would plaque Bayelsa State. However, it appears this is not the case as the state has one of the lowest reported diarrhoea rates in Nigeria.

The most common sanitation facility in Bayelsa State is the hanging latrine as shown in Figure 4.3. Contrary to what is tenable in most other states especially where many communities are rural, the use of pit latrines is uncommon in Bayelsa state with just one percent of households using it as a sanitation facility (see Figure 4.3).

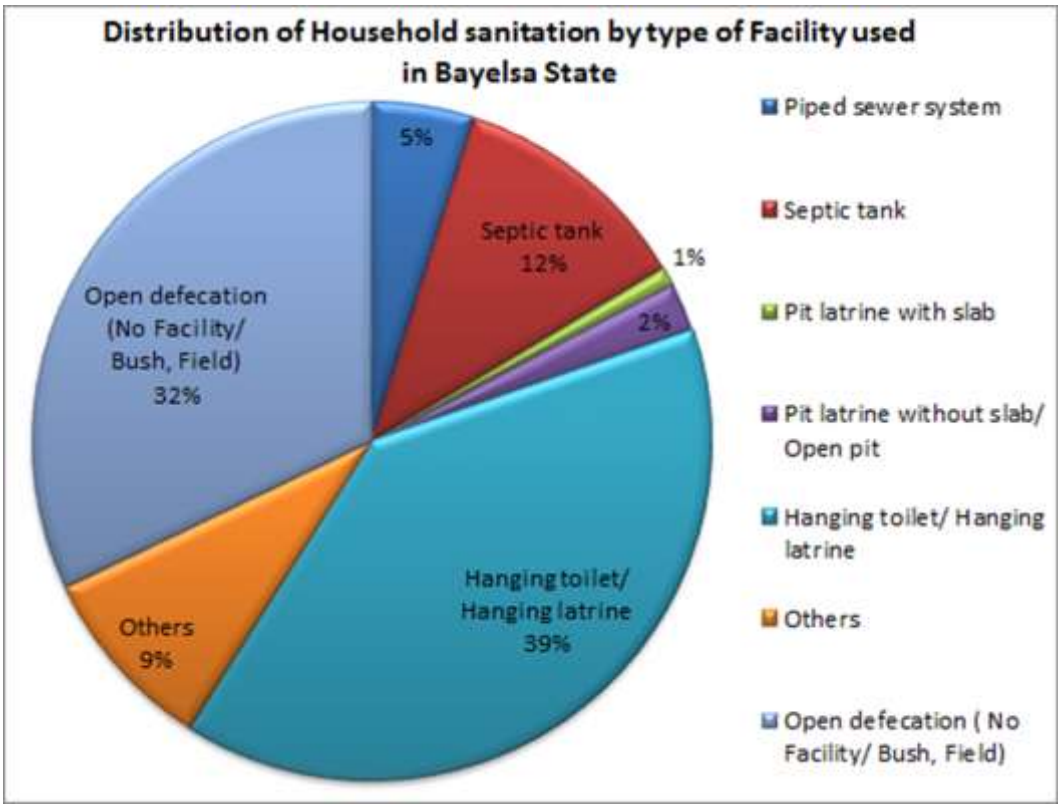


Figure 4.3: Distribution of Household sanitation by type of facility in Bayelsa State

Water supply from improved sources is poor in Bayelsa state. The most common improved water source as is the case with other states in Nigeria are boreholes. These can be publicly provided by the government or privately owned by individuals. It is also a source of revenue as privately owned boreholes sell water to members of the public.

4.5 Study communities in Bayelsa State

The study took place in Odi and Kaiama, two riparian rural towns in Bayelsa State. Odi (GPS coordinates: 5° 10' 30.1008" N, 6° 17' 47.4648" E) and Kaiama (GPS coordinates: 5° 8' 4.9848" N, 6° 18' 5.6592" E) communities are located on the fringes of River Nun in Kolokuma-Opukuma Local Government Area. The projected population for Kolokuma-Opukuma for 2010 was 91,636. Sanitation facilities used are similar to other parts of Bayelsa State as shown previously in Figure 4.3 above. The people of both communities speak English language but their local language is Izon. Figure 4.4 shows the location of the study communities along River Nun.

Figure 4.4: Location of study communities along River Nun

Both communities have road access. This has made them attractive especially for people living in communities that can only be accessed by sea. Kaiama is the administrative headquarters of the Local Government Area. Government offices at the Local Government level are located in Kaiama.

Odi and Kaiama have experienced serious unrest in the past. Following a misunderstanding between government officials and militant groups, Odi suffered a massacre in 1999 where almost all houses were completely destroyed and nearly 2500 civilians lost their lives (Omeje, 2004). The community is still recovering, buildings are new and community leadership is stronger to help prevent reoccurrence. As a result, there appear to be distrust between community members and the government. Carrying out research in this context where community members initially assume all research is for the government is very challenging especially when it concerns behaviour as it relates to sanitation.

4.6 Chapter summary

This chapter give a brief summary of the region, state and communities where the study was carried out. It outlines key aspects in relation to water sanitation and health. The next chapter would give details of study design and methods.

Chapter 5 : Research Design and Methodology

5.1 Chapter Introduction

This chapter gives details of the research design and methodology that was employed to address set research objectives. It presents different methods used to address each research question, design of selected methods and data collection methods. It also gives details on how data analysis was carried out and ethical approval for the study.

5.2 Research objectives and selected methods

The table below gives shows research methods employed to address research questions set for this study. Justifications and description of methods are in subsequent sections of the chapter.

Table 5.1: Research objectives and selected methods

Research objective	***Research questions***	***Method employed to address objective***
To explore access to water and sanitation infrastructure in the study community.	• What kinds of water supply infrastructure do people have access to and use? • What sanitation options do people have access to and use? • Why do people use these water sources and sanitation options?	Qualitative Methods– Focus group discussions, semi-structured interviews, Multiple Indicator Cluster Survey reports, Demographic and Health Survey reports, Abstracts of Statistics,
Assess behaviors and attitude to water and sanitation.	What are the practices, attitudes and perceptions of current water supply in the community? What are the attitudes and perceptions on sanitation practices?	Quantitative methods – households surveys, school surveys
Examine resultant faecal contamination levels in households.	• What is the quality of water at drinking water sources? • What is the quality of stored household drinking water? • How do households with a toilet differ from those without a toilet in terms of their stored household drinking water quality?	Microbiological sampling and examination – stored household drinking water samples, source water samples, adult hand rinse samples and child (age under 5) hand rinse samples

5.3 Research approach, design and strategy

A research design describes the plan for a research and how data will be collected and analysed to address the questions of interest. It includes the research strategy, the conceptual framework within which the strategy is embedded, what or who will be studied and tools that would be employed to collect and analyse data (Punch, 2014). Research design is the logical sequence connecting data to the underlying research questions (Yin, 2014). For this research, the research approach used is mixed methods, the research design is exploratory sequential design and different methods were used to collect data.

5.3.1 Mixed methods

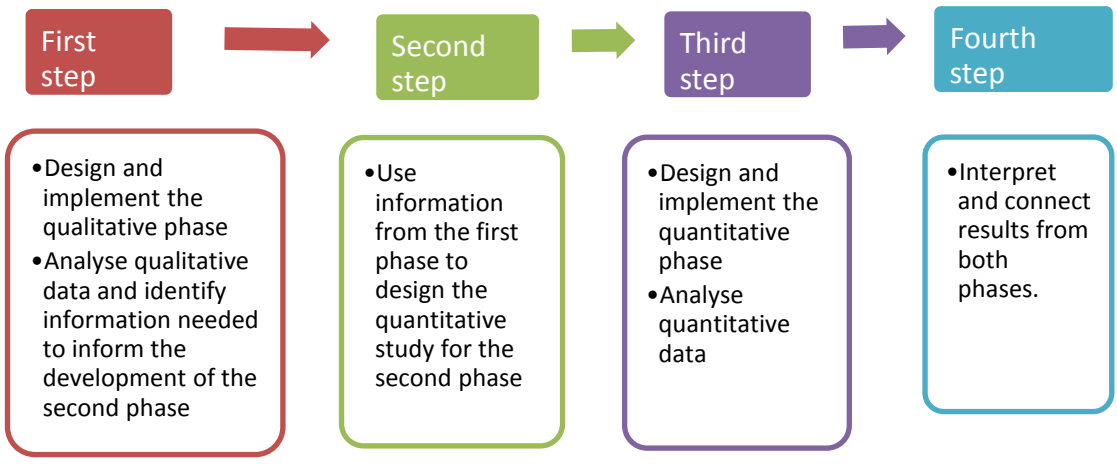
This research used a mixed methods research design. This method combines both qualitative and quantitative research methods within the same study (Johnson and Onwuegbuzie, 2004). Greene et al., 1989

"*defined mixed-method designs as those that include at least one quantitative method (designed to collect numbers) and one qualitative method (designed to collect words), where neither type of method is inherently linked to any particular inquiry paradigm*"(Greene et al., 1989).

This method combines the strength of qualitative and quantitative research methods as well as compensate for their weaknesses thereby giving a more complete understanding of the problem studied than either method would do standing alone (Punch, 2014, Creswell, 2014). Within mixed methods, this research applied exploratory sequential design.

5.3.2 Exploratory sequential design

This is a two-phase mixed methods design where qualitative data is collected and analysed in the first phase, and quantitative data is collected and analysed in the second phase building on findings from the first phase (Punch, 2014, Creswell and Plano Clark, 2011). Results from the first phase is used to inform and develop the second phase. The procedure for implementing exploratory design is shown in Figure 5.1 below.



Adapted and modified from Creswell and Planto Clark, 2011

Figure 5.1: Procedures for implementing exploratory design

This research collected data in two phases. The first phase collected qualitative data to give a foundation of understanding to the situation of water and sanitation in the study area. Building on the findings of the first phase, the second phase collected quantitative data to examine the distribution and measure the resultant effect of existing water and sanitation behaviours in the study area.

5.3.3 Philosophical worldviews (framework)

This research applied multiple worldviews. The overarching worldview applied is the pragmatic worldview. This combines worldviews that applies to qualitative research with those that applies to quantitative research using diverse types of data which best provides a complete understanding of the problem being studied (Creswell, 2014). The qualitative phase of this research used the constructivist worldview while the quantitative phase used the postpositivist worldview. Constructivist worldview involves a focus on the participants' view of the situation being studied, the specific context where participants' live and an understanding of the cultural setting and norms (Creswell, 2014). The postpositivist worldview also called the scientific method involved making and testing research hypothesis and accepting or rejecting them based on results of the test (Creswell, 2014).

This research combines the constructivist and postpositivist worldviews under the pragmatic worldview. These worldviews make up the underlying framework on which this research is developed.

5.3.4 Triangulation

The research strategy used triangulation at every stage to crosscheck between different data collection methods. Triangulation is a process used to establish validity within a dataset by employing multiple data collection methods to answer the same research question. It increases the richness of a research in terms of depth, rigour and validity (Liamputtong, 2013). The idea here is not just to establish if similar findings were obtained from different data sources or methods

but to test for consistency in the data obtained (Patton, 2002). This study combined data triangulation and methodological triangulation. Data triangulation involves the use of data obtained from different sources such as from different stakeholders while methodological triangulation is the use of different methods to collect the data (Guion et al., 2011, Patton, 2002). This research analysed qualitative data collected through focus group discussions and semi-structured interviews, and quantitative data collected through household surveys, school surveys and microbiological sampling, and merged the findings to get an overall interpretation to address the aims of the study.

5.3.5 Case study research approach

The research approach was based on a case study to understand details in a specific study area. This approach is a strategy for carrying out detailed investigation using appropriate methods and data for a purposively selected case to gain in-depth understanding in its natural setting or context (Punch, 2014). Case study approach is appropriate to answer “how” and “why” questions (Yin, 2014). Table 5.1 shows the research questions for this study most seeking to know “how” and “why”. The case study strategy was used in this study because the focus was to understand existing water and sanitation behaviour in the context of riverine communities of Niger Delta and it implications for exposure to faecal contamination.

5.3.6 Survey research approach

A survey research involves studying a sample of a population to obtain numeric description of trends, opinions or attitudes (Creswell, 2014). Survey is an economical method for collecting data from a large number of participants in a reasonable amount of time.

The survey approach was applied in the quantitative phase of this research. Using questionnaire as the main tool, this research used cross-sectional household and school surveys to explore the scale of water and sanitation behaviours, attitudes and perceptions identified in the qualitative phase of the research.

5.3.7 Validity and reliability

Validity is used to establish the accuracy of findings. In this study, triangulation (as described earlier in the chapter) was used to provide a coherent justification for findings. Reliability is the consistency of a study and the repeatability of all the steps or procedures to obtain the same results (Yin, 2014). This study combined multiple methods and data sources to achieve triangulation. In the qualitative phase, multiple stakeholders participated in sessions applying different methods such as focus groups and semi-structured interview. Interview guides were used to ensure consistency of questions for all participants. The questionnaire used for survey was pilot tested in a different but similar setting and modified prior to application in the study location. Details of these techniques employed to ensure validity and reliability are described in subsequent sections of this chapter.

5.3.8 Study area

The study took place in two typical riverine communities in Bayelsa State, Niger Delta Nigeria. Both communities, Odi and Kaiama, are located along the banks of River Nun. The major occupation of residents is fishing, farming and trading. The traditional language of the people is Ijaw but English is spoken by nearly everyone. The first phase of the study took place from June to August, 2014 and the second phase took place from April to September, 2015. More details about the study area are in the preceding chapter.

5.4 Qualitative phase

5.4.1 Qualitative research

The qualitative phase was carried out to understand what the situation is with water and sanitation in the study communities and use the outcomes to inform the quantitative phase then combine results from both phases as described in Figure 5.1.

Qualitative method gives in-depth reflection of the diversity within the particular group under study (Barbour, 2001). It is said that results from qualitative research are valid rather than reliable when compared with quantitative research which is said to be more reliable than valid (Mays and Pope, 1995). Findings from quantitative research can be generalizable but may not be an effective method for understanding multifaceted issues relating to human behaviour (Marshall, 1996). Therefore, qualitative method is most suitable for understanding the current water and sanitation behaviour of dwellers of riverine communities of developing countries. Nevertheless, the results of qualitative research can be

applied or transferred to communities with a similar context. The efficiency of this method also lies in the ability of the researcher to ask the right questions that will draw out the information the research seeks to find (Tongco, 2007).

This research used qualitative methods to gain an understanding of the current water and sanitation challenges faced in riverine communities and also assess perceptions of current behaviour. The study also used this method to explore existing access to water and sanitation services and providers. Its findings were used to facilitate the design of the quantitative study.

The tools adopted for this study have been widely used in sanitation research. In Vietnam, semi-structured interviews and focus group discussions were used to evaluate the sustainability of a sanitation marketing project, three years after its completion (Sijbesma et al., 2010).

5.4.2 Participants selection and sample design

Since the essence of the qualitative phase was to gain in-depth knowledge of the situation under study, the choice of participants was not random but purposive. Participants were selected based on their potential to give detailed information relating to the study objectives in study context. A description of some key participants is presented below.

Community leaders: Nigeria has a structure of traditional government in communities. The chiefs and other traditional leaders govern and oversee the affairs of the community. They have in-depth knowledge of the situation in their communities and so were a reliable source of information. This group primarily consisted of males.

Women groups: commonly, women are responsible for direct daily care of children and domestic management of the home. They are in a good position to give information about sanitation practices in their homes. They can also give information relating to the health of their children and family members since they may be more involved in their care. This makes women groups a reliable source of information for this research. The field study explored focus groups of women who are familiar with each other (women group in the local church) and another for women who are strangers to each other but who share key experiences (pregnant and nursing mothers at the health centre).

School Children: it is perceived that children are good at telling stories and giving good description of situations. This makes them a good source of information on a subject that centres on water and sanitation behaviour. This study explored a group of primary school pupils and a group of secondary school students.

People who had improved sanitation options: this study explored information from people who had a toilet at home. Their experience and how they moved away from the popular sanitation habits in the community was a good insight.

Masons: these participants were selected to provide information and insight on the availability of skills required for the construction of sanitation facilities and provide services like pit or septic tank emptying.

Leader of community youths: this is the leader of a group of young people who are between 15 and 24 years old but are yet to start a family. This participant gave information on the sanitation behaviour of young people and their perceptions.

Staff of Health Centre: these participants were selected to give insight into the health of the community and to examine any prevalent health issue that might be linked to poor sanitation.

Sanitation Unit of the Local Government Area: this category of participant were important because they were responsible for sanitation matters at the local government level. They gave information on the challenges with the provision of improved sanitation services, policies and current strategies employed by the local government to manage sanitation.

Others: this included; landlords, tenants, owner occupiers and groups that became necessary in the field

Selecting the above categories of participants provided Information from a broad range of informants within a small study area. Participant selection ensured homogeneity to allow for shared experiences of participants to be explored. Participants were selected to reflect different categories of people in the community.

How participants were approached.

For focus group discussion sessions at the health centre, following permission from management of the health Centre, participants were approached at the health centre as they came for their regular immunisation and antenatal classes. The management of the Health Centre specified a date when they would be able to provide a venue and accommodate the session prior to the normal immunisation and antenatal classes. Participants were approached by the researcher to introduce the research, check their availability on the scheduled day and get their consent to participate.

For the focus group session in the local church, the researcher approached the church priest to introduce the research and give all the necessary information about the research. The priest gave consent and arranged a meeting between the researcher and the leader of the women group. The researcher was invited to the meeting of the group to introduce the research to the group and get consent and number of people willing to participate. A date was agreed with the participants from the group and the priest gave permission for the session to be held in the church premises.

For interviews, some participants were approached within the community by the researcher. Some for example, the masons and the youth leader were approached following description from the traditional ruler of the community or other community members. Health Centre staff, Environmental Health Officers and WASH personnel were approached in their places of work by the researcher. After all permissions and informed consent, appointments were made for interviews.

5.4.3 Data collection for qualitative phase

Why use focus groups and semi-structured interviews?

In the qualitative phase of this research, data collection was through focus group discussions and semi-structured interviews. Focused group discussions were used because they are very useful when the purpose of a research is to explore the experience and knowledge of a group of people which is the objective of this research (Liamputtong, 2013).

Semi-structured interviews are useful to capture the perspective, thoughts and experiences of the participant in their own words (Liamputtong, 2013). In this

phase, semi-structured interviews are suitable as it gives participants the opportunity to share their experiences of water and sanitation in the study community using their own words rather than just respond to questions with set answers as is the case with surveys.

5.4.4 Focus groups

Focus group discussions were used in this study to gain information on water and sanitation practices, perceptions and beliefs at community level in the study area.

A focus group is a small group of typically 6-10 people meeting together to discuss topics relating to a specific subject and usually last 1-2 hours (Patton, 2002). It is useful in exploring peoples' experiences and knowledge, feelings, beliefs, as well as their attitudes, what they think, how they think and the reason why they think the way they do (Kitzinger, 1995, Liamputtong, 2013, Gibbs, 1997). A focus group involves people with similar experiences or concerns from a similar context or social and cultural background meeting to discuss issues with the guide of a moderator (Liamputtong, 2011). It should take place in an environment where participants are comfortable enough to engage with each other in a dynamic discussion (Liamputtong, 2011).

The discussion is often facilitated or moderated by the researcher though it is advised that there be an assistant to help with observation, note taking and managing equipment such as tape recorders (Patton, 2002, Liamputtong, 2013). Focus groups discussions rely on the dynamics of the interactions taking place between the participants and its success depends on the ability of participants to establish rich interactions (Liamputtong, 2013, Parker and Tritter, 2006).

Through focus group discussions, common and shared knowledge within the group can be identified making the technique sensitive to cultural variables or social norms (Kitzinger, 1995). Based on the aforesaid, focus group discussions was an appropriate technique here because this study seeks to explore peoples' perceptions, attitude and behaviours as it relates to water and sanitation.

However, as with many research techniques, focus groups have their own challenges. A large volume of data may be generated from focus group discussions and these need careful analysis to draw out the required information. The researcher needs good skills to control the direction of discussions as this could go off the focus (Morgan and Spanish, 1984). It is also more difficult to assemble a focus group when compared with say, interviews as all participants need to be free at the scheduled time and the venue must be selected carefully such that it is comfortable for all participants (Gibbs, 1997). These challenges can be managed by the researcher in skilfully helping participants to focus on the subject of discussion, and encouraging quieter participants to speak and controlling dominance by any single participant.

Development of study protocols

A topic guide was developed for focus group discussion sessions. This is good practice for conducting focus group discussion sessions (Liamputtong, 2011) This contained questions on the main issues that were to be discussed in the sessions. The guide also contained probing and follow-up questions to stimulate further discussions on topics that may not have been discussed adequately and interesting issues that came up during discussions. The topics and questions on

the guide were not followed chronologically, but participants were stimulated to discuss all topics on the guide.

Conducting focus group

Seven focus group discussions were conducted. Three in Odi community and four in Kaiama community. Each group discussion had an average of 8 participants. Venues that were used were those that the participants were already familiar with. The session with the local church women group took place within their church premises prior to their usual weekly fellowship meeting. The session with nursing mothers took place in the health centre where they attend for their routine immunisation of children and pregnant women. The session was conducted before their usual pep-talk from a health personnel in the health centre.

The selection of these venues not only meant participants did not have to go to a ‘strange’ environment but it provided a free venue for the research and participants were very comfortable since it was a very familiar environment for them. With the permission of participants, sessions were recorded on audio recording device. The researcher was the moderator during sessions stimulating participants to actively engage in discussions. The researcher had a trained note-taker who helped to record notes, issues emerging from discussions and factors that were important for data analysis and interpretation. The researcher also took notes especially of unplanned probing questions that were asked because of unexpected issues that came up during discussion sessions. The note-taker regularly checked that the recording device was working as expected.

5.4.5 Semi structured interviews with key informants

The crux of interview is to get information such as thoughts, feelings, intentions, perspective that cannot be obtained by direct observation (Patton, 2002). This study employed semi-structured interview approach. This approach involves the use of an interview guide with a list of key topics for discussion so it gives an opportunity for each respondent to have a say about each topic raised (Harding, 2013). The use of the interview guide helps to focus the discussions in the research to the things the researcher is interested in investigating.

Though interviews are helpful in obtaining detailed information on people's attitudes, perceptions, motivations and decision making process, it can be time consuming since it involves one respondent at a time and produces a large amount of data (Harding, 2013). This study used purposive sampling to select participants. This provides a medium to interview mainly key stakeholders that have good knowledge of the subject (in this case water and sanitation in the community) of interest.

Interview guide design

The interview guide was designed to have a list of open ended questions grouped under topics relating to the research objective. It also contained probing questions which the researcher asked if not already covered by the respondent in answering a focused question asked. The guide was flexible to accommodate unplanned probing questions and questions were not asked in a strict order. Questions were asked in the exact wording as they were on the guide to ensure consistency and reduce bias. However, any question from participants asking for more clarification on any question was answered.

The use of interview guide help to ensure that the participants' time is effectively used (Kvale, 1996). It also enhances analysis by making it easier to find and compare responses (Oppenheim, 2003, Harding, 2013). This study used three different interview guides for WASH office personnel and Environmental Health Officers, EHO, Health workers and others. This was to reflect the kind of information required form different stakeholders participating in the study.

Interview administration

The interviews were face-to-face interviews administered by the researcher. Some interviews took place at a scheduled place that was convenient to the participant, others took place right after consent on the same day the participant was invited to participate.

Prior to the start of each interview, participants' were given more details about the research and their informed voluntary consent to participate was confirmed. They were also informed that they were free to stop the interview or withdraw their participation at any time. Interview sessions lasted 20-50 minutes. At the end of each interview session, comments on the interview were recorded in a field note.

5.4.6 Data analysis for qualitative phase

Recorded data were played and transcribed. Reflexive field notes and transcripts were organised using QSR NVivo version 10 and systematically analysed using qualitative content analysis technique. Key themes relating to the study objectives were extracted into a coding frame on which all other parts of the data were classified. Data was double coded to enhance the validity of the coding frame. The two rounds of coding coincided.

Qualitative content analysis

This involves systematically describing the meaning of information contained in the qualitative data by assessing consecutive sections of the data and assigning them to categories on the coding frame. (Flick, 2013, Schreier, 2012). This method helps the researcher to focus on aspects of the data that are relevant to the objective of the study. It also helps to reduce data as the focus in the analysis is on relevant content only.

5.5 Quantitative phase

5.5.1 Quantitative research

This involves different methods used for systematic investigation of social phenomena using numerical data and testing hypotheses using statistical test (Watson, 2015, Hoe and Hoare, 2013). This research used quantitative methods to measure numerically the extent of the findings of the qualitative study.

5.5.2 Household and school surveys

Household questionnaire surveys and group school surveys were the tools used in this study. The school survey is a quick method to collect information about a large number of households in a target community.

Participant selection and sample design

Participants in a survey need to be selected such that they give a representative sample of the population studied. To make this selection, a sampling frame is required. A sampling frame is a list of all possible individuals in the population to

be studied (Fowler, 2008). For this study, our focus is on households rather than individual persons.

For household survey, sampling frame for the study would therefore be a list of all the households in Odi and Kaiama communities. However, due to the lack of reliable data, a common phenomenon in remote communities in Nigeria, an existing list of all households which could serve as a sampling frame was not available.

The use of satellite images from Google earth to generate a reliable sampling frame was explored. All houses were identified and numbered. However, this was also not suitable. The most recent satellite images for the study communities were four years old. It was also impossible to separate buildings occupied by households from those used for business for example offices and shops. Also, Odi community is still rebuilding following the massacre of 1999, therefore images that are four years behind may not reflect actual structures in the community.

To overcome this, the survey sample included all households within the community. All households were surveyed. Households were given identification numbers and GPS coordinates of their location were recorded. 14 households making up less than 2% of the total number of households did not take part in the survey. This was because at the time of the survey, there was no one aged 15 and above in the household. Two repeated visits were made but no suitable person was found. These households were excluded from the analysis.

Females, mainly mothers were the primary target respondent within the household. English was the language of communication. In very few cases, a

form of English called ‘pidgin’ was used where the respondent was not very familiar with formal English. An interpreter was not needed as the researcher could speak the ‘pidgin’ English.

For the school survey, secondary school students in the first year were the target population. This is because they are mainly aged between 9 and 12 years. It is assumed that at this age, they are old enough to understand questions and not old enough to be inhibited by questions relating to water and sanitation behaviour (CGSW, 2014).

There were 2 public secondary school in each of the study communities. Student in the first year of secondary education from all four schools were targeted for the survey.

5.5.3 Data collection for quantitative phase

Survey instrument development

Questionnaires were the main survey instruments used. Each questionnaire contained sections on demographic characteristics of participant and household, water supply services and stored household drinking water management, sanitation behaviour, hand hygiene and knowledge of diarrhoea. The sections were developed in line with the research objectives and findings of the qualitative study. The focus was also to explore the extent to which key themes from the qualitative study were common in the wider study community.

Survey administration

Household survey questionnaires were administered face-to-face by the researcher. After giving information about the research and obtaining informed

consent, the researcher asked the questions as recorded on the questionnaire and records respondents' answers.

In school surveys, the questionnaire was administered as recommended by the school survey method described in the SANIPATH rapid assessment tool manual (CGSW, 2014). The method has been successfully used in sanitation research in Accra Ghana, Vellore India and Maputo Mozambique among others by the Centre for Global Safe Water at Emory University, Atlanta USA.

Prior to the survey, the researcher, visited each school and met with the school principal. Details of the research were discussed and informed consent obtained. The principals then scheduled another meeting between the researcher and the class teacher for year one students. At this meeting, the researcher introduced the research to the class teacher, obtained informed consent. The class teacher then met with the school principal to agree on a convenient date for the survey. When a date was confirmed, the researcher visited the school and carried out the survey. The researcher introduced the research to the students and emphasized that their participation was voluntary.

In carrying out the survey, the researcher gave out plastic buttons as tokens to all the children. The researcher read each question and all possible answers to the children and asked if they all understood the question. The children were then asked to vote for the answer that is most appropriate to them.

To eliminate bias and pressure to vote for an answer that their friends voted for, the researcher asked the children to put their heads down on their desk when voting for an answer. To vote, children raised their hands with the token. The researcher collected in the tokens for each answer, counted and recorded the

number of votes. This is repeated until all answer options for each question are exhausted. The process was then repeated for all the questions on the questionnaire.

The use of the token helped ensure that no child voted more than once for the same question and putting down their heads to vote ‘blindly’ reduced the chance of peer pressure influence on answers.

5.5.4 Data analysis for quantitative phase

Data from both surveys were analysed using Microsoft Excel and IBM SPSS statistics 22. The questions and answers from the questionnaire were coded and entered as variables in SPSS. Coding involves assigning unique numbers to answers on the questionnaire. This is done because SPSS does only accepts data in numeric form (Greasley, 2008). Data was analysed for descriptive statistics. This gives summary information about the data being analysed (Greasley, 2008). Descriptive statistics were obtained using frequencies and cross tabulation analysis.

The household survey questionnaire had open ended questions on hand washing behaviour and knowledge of diarrhoea. These open ended questions were first qualitatively analysed by thematic coding to identify key themes. These themes were then entered as variables into SPSS and responses entered accordingly.

5.6 Microbiological examination

5.6.1 Overview

Microbiological examination of water and hand rinse samples were carried out to examine the levels of faecal contamination. This was done to assess the impact of current sanitation behaviour on contamination levels in water. The study used questionnaire survey and microbiological sampling to explore the characteristics of stored household drinking water and its microbiological quality for households with toilets at home and those without.

This microbiological study was after the household surveys were completed so as to eliminate researcher bias that could be introduces by prior knowledge of stored household water quality when collecting responses for the survey (Eshcol et al., 2009).

5.6.2 Sampling design and participating household selection

A total of 20 households took part in three rounds of sampling. Households were selected using the criteria shown in figure …. Households from the household survey were grouped into those with a child under 5 and those without. Of those with a child under 5, the households were further grouped into those with access to a toilet at home and those without. A random sample of 10 houses were selected from each group to make a total of 20 households. With three rounds of sampling, each household was visited three times with an average of three weeks between visits.

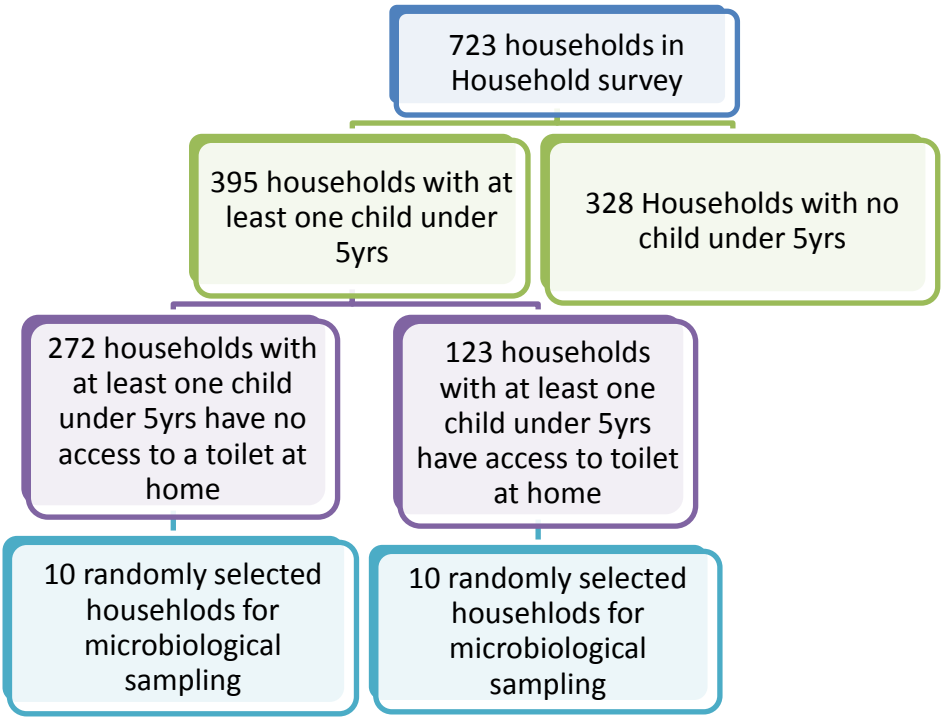


Figure 5.2: Sample size for microbiological sampling

5.6.3 Questionnaire survey

All participating households answered questions in a short researcher - administered questionnaire. This was different from the questionnaire used for the household survey. The data collected on the questionnaire included reported source from which stored water was collected, the duration from when the water was collected from the source to the time of sampling, material of the storage container, any household water treatment method employed and other household stored drinking water management practices.

5.6.4 Selection of indicator bacteria

It is impractical, challenging and expensive to test for specific pathogens in water as a sample of water can possibly contain hundreds of pathogens (José Borrego et al., 2007). Thus, some microorganisms which are easier to detect and can be used to predict the presence of pathogens are commonly used to assess the quality of water. These organisms are called indicators. Commonly used indicators of water quality include: Total Coliforms, E.coli, Fecal Streptococci, Enterococci, Staphylococci, and Bacteriophages among others.

In this study, the indicator bacteria used was E.coli. Research has shown that E.coli is a more specific indicator of faecal contamination in water (Dufour, 1977). It has been used extensively in research as an indicator of faecal contamination of water (Levy et al., 2012, Moe et al., 1991, Brown et al., 2008). It also has the ability to provide conclusive evidence of recent faecal contamination (WHO, 2011).

Also, given the location of the study area and the absence of access to a standard laboratory, E.coli was selected as affordable field laboratory equipment exist to quantify its concentration in samples. Three episodes of sampling was carried out in all participating households and water sources.

5.6.5 Microbiological sample collection

Sampling took place in the rainy season from July to September, 2015. The rainy season is recommended as studies suggest faecal-oral transmission of pathogens peaks in this season therefore may likely represent the worst case scenario (CGSW, 2014). Three types of samples were collected; source water samples, stored household drinking water samples and hand rinse samples

Water samples

Two types of water samples were collected; source water samples and stored household drinking water samples.

Water sources commonly used by residents of the community as reported in household survey were purposively selected for sampling. The selection considered spatial coverage as sources were selected from the north and south of each community. Grab samples were collected from boreholes, wells, the River Nun and rainwater. As commonly seen in developing countries, each of the sampled boreholes had a tap connected to an overhead PVC storage which contains groundwater pumped into it using a mechanised pump (Macharia et al., 2015). The borehole taps were not sterilized or flamed before sample collection. This was to represent water quality at the source as accessed by any typical user (Moe et al., 1991, Levy et al., 2008, Eshcol et al., 2009).

River and well water samples were collected with a sterile sampling cup attached to a cord that allowed it to be lowered into the water then poured into sample bags. Rainwater samples were collected by placing the sterilised sampling cup on a raised surface to collect rainwater falling directly from the sky.

To collect stored household drinking water, the researcher requested to see the storage container. Then the participating adult drew water from the storage as they usually do when the need a drink (Brown et al., 2008). This was then poured into the sampling bag.

All samples were collected in sterile 100ml stand-up whirl-Pak bags (by Enasco) and immediately sealed and stored in an ice chest.

Hand rinse sample collection

Hand rinse samples were collected from one child under 5 and a mother/primary carer in each participating household per sampling episode. To collect hand rinse sample, researchers guided each participant to place one hand in a sterilized 1 litre stand-up Whirl-Pak bag containing 350ml of Ringer's solution, shake hand and wiggle fingers for 10 to 15seconds then repeat procedure with the second hand in the same bag (Pickering et al., 2010, Saboori et al., 2013, Ram et al., 2011). Sample bags were sealed and stored in an ice chest.

5.6.6 Laboratory analysis of samples

All samples were processed within 2-6hours of collection and analysed for E.coli using membrane filtration method using Wagtech Potatest® 2 Advanced Portable Water Quality Laboratory (Microbiological). Ringer's solution was used to dilute samples before membrane filtration process. Serial dilution was used to dilute samples up to the order of 10^{-5}. All samples were processed with a minimum of three dilutions and a raw sample. Membrane Lauryl Sulphate Broth (MLSB) was the growth culture media used and was sterilised by Tyndallisation process. Samples were filtered through 47mm membrane filters (0.45µm pore size) which were then placed on 47mm absorbent pads soaked in growth media and held in Petri dish. Samples were resuscitated in the incubator for 4 hours at 30^0C then incubated at 44^0C for 18hrs. After incubation, yellow colonies greater than 1mm diameter were counted as E.coli colonies.

The formulas below were used to estimate E.coli concentrations from dilutions;

No. of Colony Forming Units per ml (CFU/ml) of dilution

$$= \frac{No.\ of\ colonies\ counted}{volume\ of\ dilution\ filtered}$$

No. of CFU/100ml of original sample

$$= \frac{No.\ of\ \ CFU/ml\ of\ dilution}{Dilution\ factor}\ x\ 100$$

Dilution factors ranged from 10^{-1} to 10^{-5}

5.6.7 Quality control in sample processing

A blank control sample containing 100ml of sterile deionised water was analysed for E.coli between each batch of samples using membrane filtration methods. Each batch of sample consist of a raw sample collected and all its serial dilutions. Formaldehyde gas produced from the combustion of methanol was used for sterilization between each filtration process as described in the equipment user manual (Palintest®). The media was sterilised by tyndallisation and the Petri dishes and other materials in a hot water bath at 100^0C for 15minutes.

5.6.8 Statistical analysis

Data was analysed using Microsoft Excel and IBM SPSS version 22 software. Descriptive statistics were calculated. A Mann Whitney test was carried out to compare stored household drinking water quality and hand rinse samples between households with toilets and those without toilets. Chi square test of independence was carried out to see if there was any association between access to household toilet and duration of storage of drinking water. P values less than 0.05 were considered statistically significant.

5.7 Ethical approval

This study design and protocol were approved by the University of Leeds Faculty of Mathematics and Physical Science, MaPS and Faculty of Engineering joint faculty research ethics committee. All participants gave voluntary informed consent prior to taking part in the study. Consent was obtained from the mother/primary carer for children to take part in the study. Hard copy of data were stored in a safe storage at the University of Port Harcourt, Nigeria. These were later converted to soft copies and stored on the University of Leeds M-drive.

5.8 Chapter summary

This chapter gave a description of the methods used in this study. It showed how we went from the research questions to the results. An exploratory sequential mixed method design was used in the study. Microbiological sampling of water and hand rinse samples were also carried out.

The next chapter reports on the results of the exploratory study.

Chapter 6 : Infrastructure service levels, behaviours, attitudes and perceptions for water supply and sanitation

6.1 Chapter introduction

The previous chapter gave detailed description of the methods used in this research to collect data and analysis methods. It also described the research design and strategy. Using results from the exploratory study, this chapter focuses on findings for existing water and sanitation provision in the study area. It also gives a description of behaviours, attitudes and perceptions of current sanitation practices in the study context.

6.2 Results

The results are reported in the sequence followed by the exploratory design. Results from the qualitative phase is reported first followed by results from the quantitative phase.

6.2.1 Results from the qualitative phase

Demographics of participants

Participants were purposively selected for this study. Table 6.1 shows demographics and characteristics of participants. Participants were selected to include various stakeholders involved in different aspects of the water and sanitation including masons, government environmental health officers, and

health care providers. Women were the main target for behaviour relating to water and sanitation because they are often responsible for water collection and care of children. Though our sample was purposively skewed towards women, it included a broad range of categories of people representative of the community.

Water supply infrastructure and service

At the time of this study, participants in both communities reported that there was no water utility company or an official water supply provider. The sources of water supply reportedly used by participants are boreholes, water from the River, wells and rain water. Most respondents also reported the use of multiple water sources. Water from boreholes was the most reportedly used drinking water source followed by water from the River.

Well sources

Shoreline of River Nun

Non-functional water project

Figure 6.1: Water sources used in study communities

Figure 6.1 shows drinking water sources commonly used in these communities. Boreholes were predominantly privately owned. The private borehole owners sold water to members of the community. Participants reported that they purchased 20 litres of water for 20 Naira (0.06USD). To collect water from a borehole, participants reported walking to the borehole, filling up their containers, paying for the water and carrying it home on their heads.

The community was connected to the national power supply grid but had intermittent power supply. Participants reported they can sometimes go for weeks without any power supply and this affected the cost of water from the boreholes. At such times, participants reported using alternative water sources for drinking especially the river.

Water from wells was mainly used for household chores and cleaning. To collect water from a well, participants reported using 4 litre size buckets with the handle tied to a rope. The bucket is dropped into the well to fill it up and the rope is pulled to bring the bucket now full of water to the top. The researcher observed some wells were protected (have raised sides made of cement blocks and a lid), some had raised sides but with no lids and others were not protected. Most participants reported that during rainfall events especially in the rainy season, unprotected wells fill up with storm runoff which increases the risk of falling into a well when walking through flood waters.

When discussing water quality in both communities, participants had varying opinions. Those who had access to water from the solar-powered water point in Kaiama expressed more satisfaction with their water quality when compared with users of privately-owned boreholes. In Odi, some participants expressed greater

satisfaction with the quality of water from the river when compared to the borehole. They primarily stated that the water from the river had a better taste than water from any other source. They also reported rusty water from some boreholes.

Table 6.2 shows some extracts from the coding frame on themes and categories relating to water supply infrastructure and service level in the study communities

Table 6.1: Demographic Characteristics of participants.

Type of participant	No. of interviews/FGDs	Total number of participants
Interviews		
Traditional rulers	2	2 (2 males)
Landlords	2	2 (1male, 1 female)
Tenants	3	2 (1male, 2 female)
Environmental Health Officers	2	2 (1male, 1 female)
WASH unit staff	1	1 (1 male)
Plumbers	2	2 (2 males)
Masons	2	2 (2 males)
School teachers	2	2 (1 male, 1 female)
Farmer	2	2 (female)
Fisherman	1	1 (male)
Market woman	1	1 (female)
Handyman	1	1 (male)
Single teenage mother	1	1 (female)
Youth leader	1	1 (male)
Elderly woman	1	1(female)
Elderly man	1	1 (male)
Local church priest	1	1 (male)
Focus groups		
Nursing and pregnant mothers	2	15 (females)
Health workers (matron, nurses, ward assistants)	2	13 (1 male, 12 females)
Secondary school students	2	17 (4 males, 13 females)
Local church community women group	1	9 (females)
Total	26 interviews, 7 FGDs	80 (59 females, 21 males)

.

Table 6.2: Reported water supply infrastructure and service provision

Key themes	Odi Community	Kaiama Community
Water sources	"*I buy my drinking water from the borehole. I have a well behind my house for washing and other things*" (Female, Odi) "*this facility that you can see is a water treatment plant that was installed by previous administration in the state. The pump is broken and we have no power supply so the facility has been abandoned*" (Male, Odi) "*The river has been serving this community for many generations. That's the main source of water for almost everything here*" (Female. Odi)	"*Borehole is the main one that we use here especially for drinking water. We can cook and wash with water from the river or well*". (Female. Kaiama) "*We have boreholes where we buy water from. Some people have wells and neighbours can share and ofcos, we have the River which is our favourite*!" (Male, Kaiama)
Infrastructure construction	"If *you look around our community, you will see some water projects that were built by government or other organisations. However, almost all of them are not functional*." (Male, Odi)	"*All the boreholes selling water here are privately built. The owner of the borehole source for the workers and negotiate the cost of construction*" (Female, Kaiama)
Water availability	"*The river water is always there even in the dry season. The borehole depends on the owner. Light is the main challenge. Sometimes too, the owner may travel*" (Female, Odi)	"*we have enough water though …but at least we have rain and the River so there is always an alternative*" (Female, Kaiama)
Water quality	"*It depends on where you collect water from. Some boreholes have rusty water so you have to know which particular one to buy from*." (Female, Odi) "*The water from the River just look dirty but it is not. If you just add alum and allow to settle then pour out the clear part, it is even better than borehole water*" (Female, Odi)	"*We are lucky here in Kaiama. Our water is clean compared to people in places like Sobama where borehole and well water is almost the same*." (Female, Kaiama)

Attitudes, behaviours and perceptions of existing water supply provision

Water quantity

Majority of participants reported satisfaction with the amount of water available to them. Particularly, they reported the reassurance that the river was available which meant there would never be a time when they would completely lack access to water. They expressed their desire for improved water sources closer to their homes but were happy that they have the River to fall back on when they need it and that it is always available and they never have to go without any water.

In Kaiama, participants reported the use of water from a solar water supply infrastructure that was built as part of a partnership investment between the government and a donor agency. They expressed relief on the cost of water and their ability to access it at all times since its power source was not dependent on electricity from the national grid. The solar water point had no connections to households so community members still have to walk to the source to collect water and transport it to their households. However, participants living far from the solar water expressed concern that they could not gain any benefit from the infrastructure as it would take so much time to walk over there to collect water. Participants also expressed concern about long queues at the solar water point especially in the morning.

Some participants expressed concern over the availability of non-functional water infrastructures within the community. Participants in Odi community were of the opinion that if the existing water infrastructure were all functional, they

would not have to spend much on purchasing water from privately owned boreholes. Some participants noted the challenges faced as a result of intermittent supply at the private boreholes. This challenge was expressed in focus group discussions and power supply was noted as the main cause. Participants reported a hike in the price of water when there is no public power supply. At such times, the private borehole owners use power generating sets to pump water and so pass on the cost of fuel to the consumers. Also, most participants reported that the frequent scarcity of fuel in the country adds to the ordeal as private borehole operators have to purchase fuel at a higher price from 'black marketers' to power their generators. Participants reported that not all privately owned boreholes sold water to members of the community. Some had the borehole for their own use only. This was reported more in Odi.

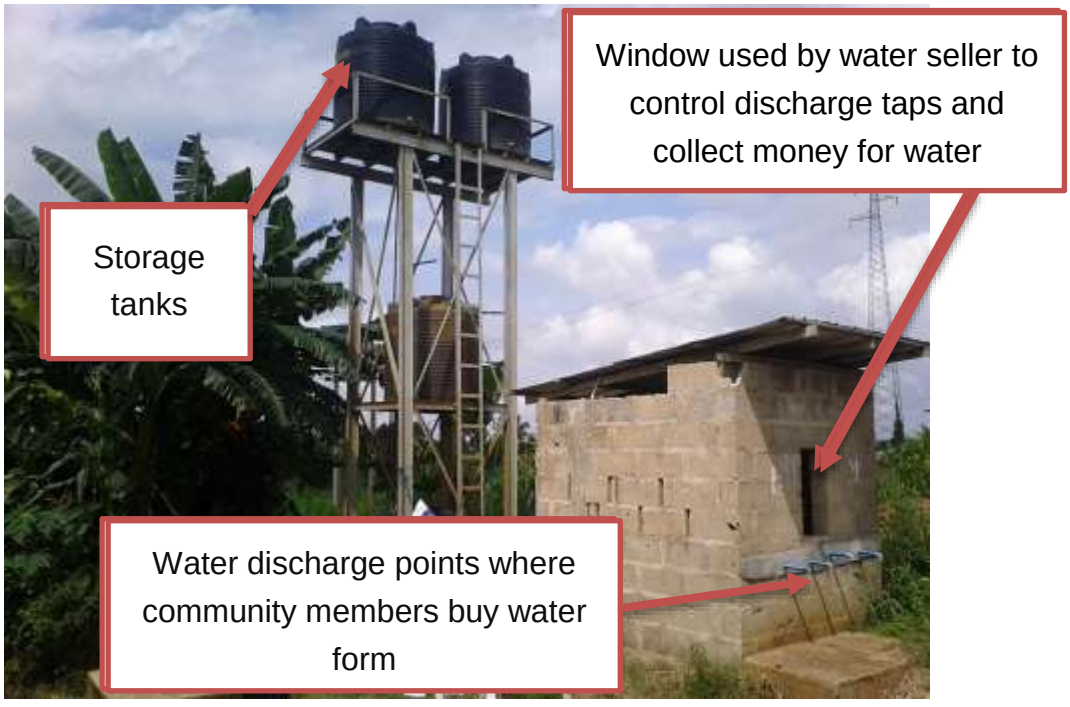


Figure 6.2: Description of a typical private borehole in study area

According to an Environmental Health Officer, privately owned boreholes that sell water to members of the public are classified as a ‘public’ water supply source by the local government because members of the public had access to it.

Water collection

Nearly all participants reported having no in-house connection. Some compounds where private boreholes were located had connections within the buildings and the supply was from the borehole. Community members go to the water points, collect water from taps connected to overhead plastic tanks where water from the boreholes has been pumped into see Figure 6.2 . Participants reported carrying the water on their heads and transporting them to their various homes. They reported the use of closed containers to stop water from spilling and getting them wet and also to keep the volume collected. Women and girls were reportedly more responsible for water collection than boys and men.

Participants who collected water from the river stated that they step into boats by the shoreline, paddle out a short distance on the river and collect their water. They also reported that in doing so they avoid the “dirty” water at the shoreline where activities like defecation, washing and bathing commonly takes place. To collect water, participants reported dipping their container into the river and lifting the filled container into their boat. They reported that the trip to the river was often a multitasking one as they can do many other things including defecation and having a bath making it more rewarding.

Drinking water treatment

Most participants reported no treatment of drinking water. They stated that treatment such as boiling is expensive and would not make any difference. However, some reported the use of alum to treat river water and camphor (Naphthalene balls) in household drinking water storage containers. They said this was to help the 'dirt' settle so they can pour out the clear part. They stated that the river water where the 'dirt' is visible and can be removed was safer than the borehole water that could have dangerous invisible dirt.

Drinking water storage

All participants reported storing drinking water in their household. The most commonly reported container for storage were plastic buckets and plastic drums with cover. Participants stated that because they have no in-house connection, it was the only way of providing drinking water within the household. The use of buckets and drums was reported to be more convenient for all household members than using narrow mouth jerry cans. According to a participant:

> "When *I am away from home, the children can easily get a drink without spilling water and damaging other things in the house. My aged grandmother also lives with me and will be unable to get a drink of water if I used a jerry can*" (Female, Kaiama)

Also, some participants reported that storing water helps them plan their work.

> "*If I decide to spend the morning of a Saturday to collect water, I would not want to do the same on a Sunday morning too. So storing enough water to last for some days means I can focus on other things*" (Female, Odi)

River water

Almost all participants reported they have drank water from the river. The reported that water from the river was cooler, had better taste and had healing powers. According to a participant;

> "*This our River water can cure sickness. It taste very nice and I prefer it to borehole water*." (Female, Odi)

It was also reported that there was no danger to health from drinking water from the river because the river was flowing and takes away any dirt dropped in it. Participants also reported that the river brings in fresh water always.

> "…*the river water is very good. See that my great grandmother sitting by the fire over there, that is what she has been drinking all her life and she is nearly ninety years old*" (Female, Odi)

Many participants at focus groups reported they used drinking water from boreholes only because it is more convenient to collect and looks clearer so they will not need alum.

Table 6.3 shows some extracts from the coding frame showing participants perceptions on water supply.

Table 6.3: Reported perceptions and attitudes on water supply

Key themes	Odi Community	Kaiama Community
Water quantity	*"…the main issue is with drinking water but we are managing well. It is difficult when there is no light (power supply) and the borehole people don't have fuel or when their generator spoil (breakdown). That time we will just have to drink from the river because the price of the water will be more than double for the same 20 litres bucket*" (Female, Odi)	*"… It's the amount of money that you have that will decide how much water you have. Like the rich people in this our community, they have their private boreholes. Some their children from the city come and build them boreholes. But for those of us that don't have, it the quantity that you can buy from the borehole sellers that you will manage to do your things*" (Female, Kaiama)
	"*We are almost like fishes! (laughing). We have enough water in the river. If I want to wash clothes now, its just for me to put the clothes and soap in a bucket and take it to the river. It is very easy especially as I don't have to fetch water and carry home first before washing*" (Male, Odi)	"*Walking to the river is difficult especially when you have small children. That would have been the best o for washing. It not easy to buy water and use it to wash clothes. You will only use as little as possible so you won't have to spend too much money on just water*" (Female Kaiama)
Water collection	"*All of us here collect our drinking water from borehole. It is not free but looks cleaner than well and river water*." (Female, Odi)	"*I collect my water from the solar water borehole over there. I am just lucky that it is near my house and it is free*." (Male, Kaiama"
	"*In the morning when I wake up, I first go to the borehole, collect water and carry it back home on my head*." (Female, Odi)	"*My younger sister collects water for me. It is far from my house so she has to start early. Its free so I can save money for my coming baby*" (Female, Kaiama)
Drinking water treatment	" *I don't treat it o. There is no need, the water is clean*" (Male, Odi)	" *I don't treat it o. Boiling is expensive because of kerosene price*" (Female, Kaiama)
	"*I use alum to remove dirt from river water*" (Female, Odi)	
Drinking water storage	"*I store my drinking water in a plastic bucket with cover. It is easier for my children to collect from the bucket than from the jerry can*" (Female, Odi)	"*I use plastic drum. It is big so I can just fill it up and relax for some days*" (Female, Kaiama)

Existing sanitation infrastructure and defecation practices

The sanitation infrastructure reportedly used in the community by those who have access to a household toilet is flush/pour-flush toilets. Participants reported that there was no public toilets in the community however people shared toilet in places of worship which were mainly churches. Many participants reported having no access to a toilet at home and direct defecation into the river was their sanitation option. Pit latrines were discussed extensively and was reported as uncommon in both study communities. Abandoned VIP latrines were seen near a primary school in Odi and children were seen defecating and urinating around it but not going inside to use it (see Figure 6.3).

Also, participants stated that at times when it is inconvenient, such as during torrential rainfall especially at night, they defecate in a plastic bag and leave it outside and dispose with household waste into the river the next morning.

Figure 6.3: School kids open defecating around a public toilet.

Participants reported that the responsibility of building a toilet depends on each person's circumstance. They said it is easier to make a decision on building a toilet if you own your own house than if you are a tenant. It was also reported that people living within family compounds do make contributions to build a toilet for their use. Participants also reported that households with grown up children living in the city are more likely to have a toilet when compared to others. It was unanimously stated in focus group sessions that no government organisation or Non-governmental Organisation had ever built a toilet for individual households in either of the communities. However, in Odi, some participants mentioned that the youth organisation in the community was planning to build a superstructure over the river on the shoreline to provide shelter from weather elements like rain so community members can be more comfortable while defecating. Participants reported that this project was not yet approved by the traditional rulers council as they are not satisfied that everyone defecating into the river at one fixed point would be better for their community. Participants also reported that there were specific defecation places for males and females respectively along the shoreline. So males have a separate place where they go when they defecate into the river as well as women. Participants reported that this provided a sense of security and privacy for women as there was a penalty for any man seen going to the women defecation area and vice versa.

Also, in Kaiama, it was reported that an attempt was made by a project which was funded jointly by the federal government and an international NGO to provide public toilets in the community. However, it was reported that the project failed in its very early days due to poor planning for its management and had long been abandoned.

Furthermore, participants reported the challenge of finding people with the right skills to build a toilet properly. They stated that such jobs are seen by many as ‘degrading’ and done by people of very low social status. They reported that this has left the job of building toilets to poor people who do not have the right skills but can do anything to make a living. This results in poor toilets that are often abandoned. Alternatively, they reported masons can come from outside the community but their services were always more expensive.

Attitudes, behaviours and perceptions of existing sanitation

Preferred sanitation infrastructure

Participants reported the challenge with sanitation access. Many participants stated that they only sanitation option available to them was defecation into the river. Yet, almost all participants report that the ‘modern toilet’ (flush toilet) was their preferred sanitation option. Irrespective of their financial status, many participants reported that they would rather continue with their attitude of defecating in the river than use any other sanitation option except the ‘modern toilet’.

Participants expressed great dislike for pit latrines. They said it was ‘old fashioned’ and using it would mean that they are not making any better progress in life when compared with their ancestors. Participants also stated that it was dangerous for women to use pit latrines as the ‘heat’ from the latrine pit causes infections that could lead to infertility and even cause a pregnant woman to have a miscarriage.

Participants stated that if provided with ‘modern toilets’, they would prefer to use it than open defecation in the river. However, many other participants disagreed.

They indicated that the use of toilets is not good for their community. The main reason they gave was that toilets bring faeces too close to the household therefore it is easier for children to get sick. They further compared their health to that of people in the city where the use of toilets is a common phenomenon stating that they are healthier without toilets. According to a participant;

> "*Faeces are supposed to be carried away by the river. If you bring it (faeces) home in the name of toilet, you are bringing disease. When you compare us to the big cities, you will understand what I am telling you*" (Male, Kaiama)

Furthermore, participants expressed concern over the use of toilets in compounds where they also have wells. They reported that they fear the risk of faeces flowing into the well through ground water given that their ground water is very high and could be above ground in the peak of the rainy season. They stated that this would be a risk for households with young children and elderly who depend on the well for water for chores.

There was concern too for having continuous access to toilets. Participants reported that some households that have already invested in building their own toilets cannot use it all year round. According to an environmental health officer;

> "*When the water table becomes so high in the rainy season, most houses with toilets will stop using them because the experience backflow of sewage into their homes. The septic tanks are poorly constructed and people want to use the smallest space possible hence thy end up with pits rather than septic tanks*." (EHO, Kaiama)

Some participants also said that open defecation was free, no toilet building nor maintenance cost. They said the ‘waterside’ was airy compared to a stuffy smelly toilet hence they prefer to continue with open defecation.

Participants who had toilets reported that they have never had to empty their septic tanks. They reported that all septic tanks contained water which made it impossible for them to connect their bathrooms to it. So the septic tanks only receives sewage from the toilet. They said they did this to reduce the effect of the backflow of sewage during the rainy months when the ground water table becomes very high and they may not even be able to use their toilets anymore.

Knowledge of the effect of sanitation on health

Questions and topics were discussed to assess participants’ perceptions of their current sanitation behaviour and its effect on health. Participants had mixed and varying opinions on the effect of sanitation on health. However, the most dominant was that their current sanitation behaviour had no negative effect on their health. They stated that open defecation in the river is a long standing behaviour in their community and has not impacted on their health. According to a participant;

“*We were born into this habit of using the river to toilet just like our parents. There is no problem with it. Anybody that will live long will live long not because of the place they toilet.”* (Female, Odi)

A staff of the health centre reported that they do have health education as part of their antenatal clinic where they talk to young mothers and pregnant women about the importance of good sanitation and its impact on health. This participant

also stated that during sessions, young mothers want to know why most rich people still lose their babies even when they have toilets at home.

Many participants reported that many other factors such as wealth, access to healthcare and medicines have greater impact on health than where they defecate. They noted that as the most commonly practiced form of defecation is defecating directly into the river, the risk is minimal. They also stated that as long as the river is flowing and takes away all that is deposited it, there is no health effect from defecating in the river, rather, that using a toilet could cause diseases.

Cultural belief

Participants expressed that defecation in the river and anal cleansing with water is a cultural practice. They stated that it was a taboo to go around with possible particles of faeces attached to ones' body. Also, that the use of toilets inhibits proper cleaning with water when compared to open defecation in the river where one can have a bath after defecation and be completely clean. They stated that this practice has been with them for many generations and has had no negative effect on them.

According to participants;

> "*Washing with water after defecation is the only way to clean out all faeces from the body. This is what we saw our parents do. It is especially important for us as women to prevent infection and infertility*" (Female, Odi)
>
> "*It is important to wash all faeces from your body after defecation and this is very easy to do in the river*" (Male, Odi)

Participants said that open defecation in the river helps strengthen their social relationships because friends can go together while discussing a subject of interest.

Children faeces were reported by participants as being ‘harmless’ and so can be disposed anywhere like in bushes near the home. Young children aged 3 years were allowed to go with friends to defecate in the river. Participants reported that this makes them learn independence early and cultivate their defecation culture.

6.2.2 Results from quantitative phase

Demographic characteristics

The qualitative phase included household and school surveys. 723 households participated in household surveys and 4 secondary schools participated in school surveys. Table 6.4 shows demographic characteristics of participants. 84% of participants in the household survey were women. This was intentional as the survey targeted primary carers in the household which is predominantly women. The household survey targeted all households in the study area. A total of 14 households did not participate in the survey. This was because at the time of the survey, there was no one at least 15 years old in the household to give informed consent and participate. Visits were repeated twice to these households and no one was found who met the criteria. All other households approached participated in the survey. More than 80% of participants had at least primary school education and 12% had attained tertiary education. Mean household size was 4.03. Farming was the predominant occupation of participants.

There were two secondary schools in Odi and two secondary schools in Kalama. All four secondary schools took part in the study.

Water supply and household drinking water management

Following the qualitative study, this phase of the study explored how dominant factors identified in the qualitative study were in the households that make up the community. Table 6.5 shows the proportion of responses for different variables relating to water supply and household drinking water management behaviour.

Primary source of drinking water

Results show two main sources of drinking water; boreholes and river water. By primary source here we mean the source which the household uses the most for drinking water collection. About seventy percent of households use boreholes as their main source of drinking water (see Table 6.5). Results also indicate the use of multiple sources of drinking water. Other drinking water sources include wells and rainwater.

Table 6.4: Demographic characteristics of study participants

Variables	Household survey	School survey
Sample size (No. of households and schools)	723	4
Total no. of respondents	723	182
Female gender, respondents (%)	604 (84)	86 (47)
Male gender, respondent (%)	119 (16)	96 (53)
Highest level of education of respondent		
No education, respondent, (%)	81 (11)	
Primary school, respondent (%)	275 (38)	-
Secondary school, respondent (%)	284 (39)	
Tertiary education, respondent, (%)	83 (12)	
Tenancy		
Owner occupied	155 (21)	-
Rented	368 (51)	
Rent free but not owned	200 (28)	
Occupation		
Farming	221(31)	
Fishing	91 (13)	-
Trading	131 (18)	
Civil servants	81 (11)	
Others	199 (27)	
Age range of participants		
15 – 25	195 (27)	
26 – 35	180 (25)	
36 – 45	188 (26)	
46 – 55	100 (14)	
56 and over	60 (8)	
No. of households with at least one child under 5	395 (55)	-
Mean household size	4.03	-

No. of Respondents (%)

Table 6.5: Proportions for variables relating to household drinking water management

Variables	Household survey	School survey
Primary source of drinking water		
Borehole	513(71)	127(70)
River	190(26)	33(18)
Wells	15(2)	9(5)
Rainwater	5(1)	4(2)
Others	0	9(5)
Type of household storage container		
Bucket with cover	373(52)	72(40)
Drum with cover	303(42)	63(34)
Jerry can with cover	48(7)	18(10)
Others	54(8)	29(16)
Household drinking water storage duration in days		
2-4	195(27)	107(59)
5-10	347(48)	44(24)
Over 10 days	181(25)	31(17)
Modes for drawing up stored drinking water		
Using any container with a handle	181(25)	55(30)
Using any container with or without a handle	484(67)	116(64)
Others	58(8)	11(6)
Household drinking water treatment method		
No treatment	525(73)	148(81)
Leave to stand and pour out clear portion	66(9)	34(19)
Add Alum	71(10)	-
Add camphor	233(32)	-

No. of Respondents (%)

Household drinking water storage

All households reported storing their drinking water in containers within the household. This was the main method used by households to ensure availability of drinking water within the household. Plastic buckets and drums were the most common household drinking water storage containers (see Table 6.5). All households used covered containers to store water. Results show preference for wide-mouth containers as over ninety percent of households used wide-mouth containers.

The duration of storage of an episode of collected water was explored. By this we mean the duration for which a particular portion of water was collected and brought into the household and used until it runs out. No household nor participants in school survey replaced their drinking water daily. While the results from school surveys showed almost sixty percent replace their drinking water every two to four days, the results of the household survey shows twenty seven percent for this storage duration. From both surveys, more than seventy percent of households store an episode of collected drinking water for up to ten days.

Mode for drawing up drinking water from storage container

This is the method used to collect a portion of water from household drinking water storage container when someone needs a drink. With the use of wide mouth containers, drawing up water was by dipping while for very few households using narrow mouth containers was by pouring out of the container. There was no report of having a dedicated dipper for collecting water in any household. From both surveys, more than sixty percent used any kind of utensil (cup, plates) whether it had a handle or not to dip into the storage container to

collect water. Results also showed that non-household members like relatives and neighbours were allowed to collect water from storage containers. Children were also allowed to collect water on their own (see Table 6.6).

Household drinking water treatment

This variable was used to assess household drinking water treatment methods used by households. Results from both surveys show that over seventy percent of households did not use any form of household drinking water treatment. Of those who treated their water, camphor balls were the most common treatment method used for water in storage containers. Alum was also used for treatment of drinking water after collection in readiness for storage in households.

Table 6.6: Age at which children draw up water without help

Variables	Household survey (%)	School survey (%)
Age when children draw water without help		
Under 5 years	29	81
5-10 years	1	19
No specific age	36	-
Don't know	5	-
Whenever they are ready	29	-
Total	100	100

Sanitation behaviour

This section reports the results of defecation behaviour in the study area.

Urination behaviour

Results on Table 6.7 show that urination behind the home is the most common behaviour in the study area. Other urination places reported include outside bathroom. This is a place that provides some privacy when having a bath built behind the main household building but with no roof nor door. When away from home but still within the community, urination is mainly in nearby bushes. This indicates that most of the urine in the community goes directly into the environment.

Defecation behaviour

The results show that people have varying defecation behaviours depending on where they are, the time of the day, if it is rainy or not among other factors. From Table 6.7, results from both surveys show that the most dominant defecation practice at home is direct defecation into the river for adults and children. The use of pit latrine is the least and almost non-existent in study community. Only 33% of households had access to a toilet at home. The remaining proportion practiced various forms of open defecation.

On the defecation behaviour of children when at school, results show that fifty percent defecate in the surroundings of the school toilet building and other buildings in the school environment, while thirty percent actually use the shared school toilet. Direct defecation into the river was not reported as an option for children when in school.

Table 6.7: Results for defecation practices in study communities

Variables	Household survey	School survey
Place of urination when at home		
Pour flush to pit/septic tank	136 (19)	9 (5)
In nearby bushes	99 (14)	62 (34)
Behind my home	340 (47)	106 (58)
Others	240 (33)	5 (3)
Place of urination when away from home but within community		
In nearby bushes	708 (98)	-
Behind any building	426 (59)	-
Go back home	8(1)	-
Defecation practices of adults and when at home		
Pit latrine	2 (0)	5 (3)
Pour flush to pit/septic tank	236 (33)	49 (27)
Poo and dispose with household waste into the river	226 (31)	7 (4)
Poo and dispose in nearby bushes	120 (17)	22 (12)
Direct open defecation in nearby bushes	135 (19)	26 (14)
Direct defecation into the River	462 (64)	73 (40)
Defecation practices of children when at home		
Pit latrine	-	5 (3)
Pour flush to pit/septic tank	-	35 (19)
Poo and dispose with household waste	-	7 (4)
Poo and dispose in nearby bushes	-	7 (4)
Direct open defecation in nearby bushes	-	31 (17)
Direct defecation into the River	-	97 (53)
Defecation practices of children when at school		
Open defecation behind shared school toilet	-	64 (35)
Use shared school toilet	-	55 (30)
Nearby bush	-	36 (20)
Open defecation behind any building	-	27 (15)

No. of Respondents (%)

This study also explored the management of the faeces of children under age five by asking participants questions on defecation practices for this age group. Table 6.8 shows that disposal of child faeces in nearby bushes was the most common practice as reported by sixty five percent of participants in household surveys and seventy six percent from school surveys. Fifty four percent of households also reported disposing children faeces with household waste into the river. These proportions excludes households where there was no child under the age of five years.

When away from home, defecation was reportedly different. 507 participants reported defecation in nearby bushes when away from their homes but within community space (see Figure 6.4). This results indicates that the location of a person at the time when they need to defecate plays a role in their choice of a defection place.

Table 6.8: Child faeces disposal practices

Variables	Household survey	School survey
Faeces disposal practices for children under 5 years at home		
In a potty or equivalent emptied into a toilet	98(24)	16(9)
Anywhere on the ground within compound then disposed in nearby bush	260(65)	139(76)
Anywhere on the ground within compound then wrapped and disposed with household waste into the river	213(54)	22(12)
Others	3(1)	5(3)

No. of Respondents (%)

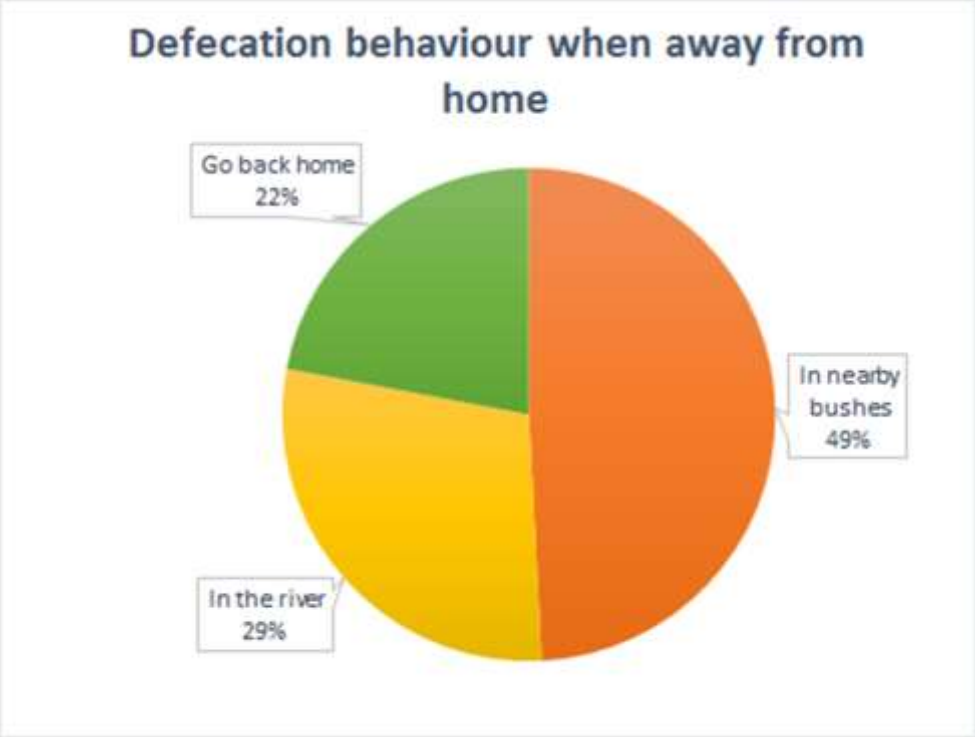


Figure 6.4: Defecation behaviour when away from home

Toilet sharing

In this study, the most common place where toilet facility was provided for people to share was in churches. The toilets are built and managed collectively by church members. Seventy two present of respondents in household survey reported having a shared toilet in their church premises. According to the results on Table 6.9, forty one percent of household survey participants and forty two percent of school survey participants reported using the shared toilets within their church premises when they are in the church. However, participants stated that this access was only available when a church activity or programme is ongoing in the church.

Table 6.9: Toilet sharing behaviour

Variables	Household survey	School survey
Defecation practices at place of worship		
Go back home	231(32)	18(10)
Open defecation in nearby bushes	338(47)	60(33)
Open defecation directly into the river	144(20)	27(15)
Use shared toilet within church premises	296(41)	77(42)
Others	37(5)	-
Toilet sharing at home		
Do not share	434(60)	66(36)
Share with one household	22(3)	38(21)
Share with two households	51(7)	47(26)
Share with three to five households	202(28)	15(8)
Share with more than 5 households	14(2)	16(9)

No. of Respondents (%)

Of the participants who reported having access to a toilet at home sixty percent from household surveys and thirty six percent from school surveys did not share their toilets with any other household. About thirty five percent from both surveys shared with two to five households.

Hand washing behaviour

This study also explored existing hand washing behaviour within the community. As shown on Table 6.10, more than eighty percent of participants in both surveys reported washing their hand with water only always or most of the time. No participant in the household survey reported washing their hands with soap always. About ten percent of participants from both surveys reported washing their hands with soap most of the time.

Table 6.10: Hand washing behaviour

Variables	Household survey	School survey
Hand washing material		
Water only always	217(30)	115(63)
Water only most of the time	441(61)	38(21)
Water and soap most of the time	65(9)	20(11)
Soap and water always	-	9(5)
Activity times when hands are reportedly washed		
By children under age 5		
Before eating	270(68)	-
After defecation	45(11)	-
When hands are visibly dirty	79(19)	-
Before cooking	-	-
Others	35(9)	-
By adults and others		
Before eating	721(100)	-
After defecation	178(25)	-
When hands are visibly dirty	237(33)	-
Before cooking	96(13)	-
Others	-	-
Hand washing technique used		
Wash one hand in a bowl of water rubbing fingers against each other.	116(16)	
Rub both hands together in a bowl of water	268(37)	
Rub both hands together in a bowl of water then rinse with a fresh portion of water	318(44)	
Others	21(3)	

No. of Respondents (%)

Knowledge of diarrhoea

The study used the household survey to explore existing knowledge of the causes of diarrhoea and how people in the study community manage diarrhoea cases. Results on Table 6.11 shows that sixty seven percent pf participants identify frequent lose stools in a day as a major symptom of diarrhoea. Twenty six percent of respondents did not know what the symptoms of diarrhoea was.

Table 6.11: Knowledge of diarrhoea

Variable	Household survey
Main symptoms of diarrhoea	
Frequent loose stools in a day	487(67)
Stomach cramps	246(34)
Body weakness	21(3)
I don't know	184(26)
Causes of diarrhoea	
Using a toilet	109(15)
Eating spoilt or decaying food	174(24)
Drinking dirty water	122(17)
Flies and dirty surroundings	88(12)
Teething in children	65(9)
Formula milk	57(8)
I don't know	197(27)
What is done when there is a diarrhoea case in a household	
Take the person to the health centre	59(8)
Treat the sick at home using traditional home remedies	44(6)
Give ORS (Oral Rehydration Salt)	116(16)
Take the person to the local chemist	459(64)
Pray for healing	42(6)
Don't do anything	3(0)

No. of Respondents (%)

Also, twenty seven percent of participants did not know the causes of diarrhoea. Interestingly, some participants (15%) believed that the use of toilets causes diarrhoea. The main management for diarrhoea in the study area as shown in the results is the local chemist. Sixty four percent of participants reported they would take the person to the local chemist and get medication to help them cope

with the sickness. Only eight percent of respondents mentioned that they would take the person to the health centre.

6.3 Observed state of septic tanks and sewage in community

The physical condition of some septic tanks in the study area were inspected. The figure below shows some of them. Sewage was observed leaking into stagnant water pooling around homes. Children were seen playing in the pooling water and people walking through it. This is a major contamination source located very close to homes.

Figure 6.5: Poorly functioning septic tanks

6.4 Summary of key findings

Water supply

The average household size reported in this study is 4.03. This compares well with the average household size of 4.77 for Kolokuma Opukuma Local Government Area, LGA, where Odi and Kaiama belong and 4.65 for Bayelsa State (NPC, 2007). In 2010, 95% of youths and 75% of adults in Bayelsa State were literate (NBS, 2014a). This is consistent with 89% literacy for this study.

Odi and Kaiama are typical of communities in Bayelsa State in terms of average household sizes rate of literacy and poverty.

Both communities depend on point sources and surface water, there is no piped water supply and no water utility company operating in the area. Most households (93%) get their water off premises. Drinking water is mainly obtained from boreholes operated by private owners who sold water to members of the community. In Kaiama members of the community can collect water at no cost, from a solar-powered borehole provided at the Kaiama Grammar School. This serves the Bayelsa National Youth Service Corps, NYSC, camp which may explain why it is better maintained when compared to the numerous non-functional water projects observed by the researcher during the study in both communities.

Participants expressed their preference for water from boreholes because of the ease of collection and the colour of the water. However, they explained that some boreholes have brownish coloured water. This could probably be due to the presence of iron which is common in the study area (Nwankwoala et al., 2016).

Water from the river was also used for drinking purposes. Participants preferred this because of its taste, healing powers and its continuous availability. They also reported that the trip to the river to collect water was rewarding as they can defecate and have a bath on the same trip. The use of surface water as the primary source of drinking water is predominant in Bayelsa State where almost 60% of households use this source (NBS, 2013b). We speculate that the high use of boreholes in Odi and Kaiama could be because they are both accessible by road when compared to majority of the communities of Bayelsa state where there is no road access. This access help enhance development. Also, Kaiama is the LGA headquarters hence it is better developed than other communities in the LGA.

Participants explained that they could do more than one task on a trip to collect water from the river. For example, they can wash and even have a bath. They also stated that they had concern about the cleanliness of water storage tanks used by private borehole providers. They stated incidences where the cover of tanks were blown off by wind during torrential rainfall and the remains of birds were later seen in the drinking water.

All households reported storing drinking water. Plastic buckets and drums were the most commonly used storage containers. According to participants, these wide-mouth containers were preferred because of the ease with which all family members can collect water from it. They explained that children and the elderly were very comfortable with collecting water to drink out of a bucket rather than from a jerry can. This meant they can be independent. Dipping was the most commonly reported method for collecting water from storage. No household had

a dedicated dipper but plates or cups with or without handles were dipped into the drinking water storage container to collect water.

It was uncommon for household drinking water to be treated in the study area. The most common treatment for the few who did treat was adding camphor balls to the drinking water storage container. Alum was also used but this was more common when the water source was the river. The use of Alum for water treatment has been reported elsewhere in riverine communities of other countries (Curry et al., 2015).

Sanitation and hand washing

Open defecation into the river was the most commonly practiced form of defecation in the study communities. The use of pit latrines was rare. This is consistent with the general practice in Bayelsa state where over 39% of households use hanging latrines built for direct defecation into the river, 32% have no facility and only about 3% use pit latrines (NBS, 2013b). In the study communities, flush toilets referred to as ‘modern toilets’ were the preferred sanitation option irrespective of social or financial status of participants. Children faeces were seen as harmless and were disposed of without much caution.

Open defecation in the river was widely accepted as a cultural practice. The absence of financial cost for construction and maintenance, absence of smell, fresh air at the shoreline were some of the reasons for preferring open defecation in the river. Also, the cultural practice of anal cleansing with water and the taboo of having poo on the body (from not wiping clean) made the river the preferred place. Participants stated that they often have a bath following defecation and

go home feeling clean and fresh, something they will not get if they used a ‘smelly air-tight’ toilet at home.

Some participants view a toilet as a source of disease pointing to its use as the main cause of diseases in cities when compared to rural areas. Also, the challenge of having very high water table and poorly constructed septic tanks resulting in the backflow of sewage into homes and the leakage of septic tanks into the immediate environs reportedly discouraged consistent use of toilets all year.

Participants reported adopting multiple defecation practices depending on their location when they need to defecate. Defecation in nearby bushes commonly happened when participants were away from their homes but still within their community. There were no functioning public toilets in both communities but abandoned public toilets near a school in Odi and within the community in Kaiama were observed.

Hand washing with soap was not a common practice in the study area. Participants reported what washing hands in a bowl of water was the most common method for washing hand. They also reported that most of their meals were eaten using hands rather than any cutlery, they are required to wash their hands before eating. Participants reported that they were sceptical about drinking water from rain because of warnings of acid rain in previous years but that rainwater was collected in big plastic containers outside and serves for hand washing and other household chores. Overall, participants reported washing their hands before eating more than at any other activity time.

Overall, for water supply service levels:

- There is no utility provider of water supply and households in the community have no piped connections.
- Private borehole operators are the main providers of water supply services.
- Boreholes used by 71% of households and river water used by 26% of households are the primary sources of drinking water in the study communities.
- Drinking water is not commonly treated as 73% of households never treat their water.
- Of the households who treat their water (mainly river water), Alum and camphor balls were the treatment methods used.

For perspectives and behaviours on water supply:

- Households are happy with their water quality
- Households are not satisfied with intermittent public power supply which results in a hike in price
- Borehole water preferred for drinking because of the convenience of collection.
- River water preferred for its taste and perceived healing powers.
- Participants were pleased to have the river as a reliably available source

For sanitation service levels;

- Flush toilets and open defecation are the main sanitation options used.
- Households are responsible for the provision of their sanitation at home.

- Community provide delineated open defecation space for males and females respectively along the shoreline.

For perceptions and behaviours on sanitation:

- Open defecation accepted as a cultural way of life so community members expressed no shame in the practice.
- Only few people with the right skills to build toilets because the job is seen as degrading and unattractive for young people to learn.
- Toilet is perceived by some as a source of disease because it brings faeces closer to home.
- Open defecation in bushes and nearby building is predominantly done when people are within community spaces away from their homes.
- Anal cleansing with water, the preferred method. Having any faeces left on the body after defecation seen as a taboo.
- Open defecation in the river seen as ‘unharmful’ because the river is flowing and therefore taking all the waste away.
- Flush toilets referred to as ‘modern’ toilets were the preferred sanitation option by all irrespective of financial or social status.
- Pit latrine not accepted as a good sanitation option.

Chapter 7 : Assessing contamination of drinking water from existing sanitation and drinking water management behaviour

7.1 Chapter introduction

The previous chapter showed access to water supply, water collection and management methods and sanitation behaviour. It showed widely practiced behaviour of open defecation. This chapter focuses on evaluating the impact of practiced sanitation behaviour on drinking water quality. In particular, it will assess the impact of having access to a toilet at home on stored household drinking water quality. Details of the methods used for sampling and analysis can be found in chapter 5.

7.2 Results

7.2.1 Detection of indicator Bacteria E.coli in samples

E.coli was detected in all samples collected (water and hand rinse samples). Table 7.1 provides a summary of the concentration of the indicator bacteria in all samples. Water quality here is measured by the concentration of the indicator bacteria, E.coli.

Table 7.1: Summary of E.coli concentrations for different sample types

Sample Type	N	E.coli CFU per 100ml		
		Mean	Standard Deviation	Median
Source water	30	704.67	570.691	550.00
Stored household drinking water	60	2179.00	1072.194	2300.00
Adult hand rinse (2-hands) sample	60	295.00	117.408	300.00
Child hand rinse (2-hands) sample	60	387.00	154.824	375.00

N= Number of samples; CFU = Colony Forming Units

All source water and stored household drinking water samples had E.coli concentrations above allowable limits permitted by World Health Organisation and the Standards Organisation of Nigeria Drinking Water Standard which is 0CFU/100ml (WHO, 2011, SON, 2007). However, this study is interested in how these contamination levels vary between households with toilet access and those without. This study is exploring access because it is the main focus of SDG 6 and people in hard to reach locations like riverine communities without road access are part of the main targets.

7.2.2 Drinking water source samples

The drinking water sources used in Odi and Kaiama were Boreholes, river water and rainwater. Of these sources, boreholes were the most commonly used source. Table 7.2 shows the distribution of all source water samples collected. Samples collected from wells were not included in the analysis for two reasons. Firstly, none of the stored household drinking water collected from households came from a well, therefore including the results for the wells in the sources that were compared with the stored water quality would be misleading. Secondly, the

well water samples very extremely polluted with mean E.coli concentration per millilitre higher than for other sources by 10E6 as shown on Table 7.2. Including these would greatly skew the data.

As shown in chapter 6, as a primary source of drinking water, 71% of households use boreholes, 26% use the River and only 2% use wells. The pollution levels in wells could be attributed to the very high ground water levels in both communities. At the time of the study, it was observed that ground water was above ground in some part of the communities and participants reported it stays so for several months of the rainy season. This means storm water runoff and other household wastewater disposed just around households could end up in the wells. Keeping of livestock was not mentioned by any participant and was not observed by the researcher.

Also, 19% of adults defecated in nearby bushes and 65% of child faeces is disposed in nearby bushes (see chapter 6). This could be a major source of contamination for wells during rainfall events and floods.

Table 7.2: Distribution of source water samples by source type

Source water type	No. of sample collection points	No. of sampling Episodes	No. of samples collected	Mean concentration of E.coli (CFU/ml)	Median concentration of E.coli (CFU/ml)
Boreholes	4	3	12	4.44×10^2	4.00×10^2
River Water	4	3	12	1.29×10^3	1.35×10^3
Wells	4	3	12	2.36×10^9	6.05×10^8
Rainwater	2	3	6	5.00×10^1	5.20×10^1

The water taken from boreholes was more polluted than expected. However, studies have shown that the use of improved sources does not necessarily mean safe water. Note that borehole water samples were collected from taps from which members of the community collect their water. This water is pumped from groundwater using motorised pumps into overhead plastic water tanks and supplied to the taps from the tanks as described in the previous chapter.

Water tanks used were designed and installed in a way that makes it difficult or near impossible to clean. All participants at water sources (private borehole owners) reported that their boreholes were more than 6 years old and they had never cleaned their storage tanks. The conditions under which water is stored can affect its quality through the growth of biofilms (Jagals et al., 2003). Studies have shown that plastic water storage containers were more likely to incorporate bacteria like faecal coliforms into biofilms on their internal surfaces than metallic

containers (Momba and Kaleni, 2002, Momba and Notshe, 2003). These biofilms could detach and flow in the stream of water discharged to the taps from these storage tanks.

Some storage tanks were observed without the lid. This means bird faeces, leaves, dust and other debris can enter the tanks. This was also a concern raised by participants in the qualitative study (see chapter 6). Flow in the pipes connecting the tanks to ground water and the taps is intermittent. This impacts on the quality of the water (Kumpel and Nelson, 2014).

7.2.3 Stored household drinking water samples

Source of stored household drinking water samples

Water was mainly stored in plastic and metallic drums. Storage duration of household drinking water ranged from 1 to 7 days on the day of sample collection. Table 7.3 shows details of the characteristics of stored household water samples in terms of the source where they were collected. About 72% of samples were collected from boreholes for storage. Results suggest that households without a toilet access are more likely to use alternative sources of water. This could be that households with toilets are wealthier and can always afford to buy water from a borehole or own one in their compound or have larger storage containers.

Table 7.3: Percentage distribution of source of stored drinking water by toilet access

Access to a household toilet	Source of stored household drinking water			Total
	Borehole	Rainwater	River water	
No	64 (19)	23(7)	14(4)	100(30)
Yes	80(24)	7(2)	13(4)	100(30)
Total	72(43)	15(9)	13(8)	100(60)

Note: X(N) = Percentage (No.of Samples). Percentages are rounded off to the nearest whole number

Storage duration of stored household drinking water

Table 7.4 shows that 60% of water samples from households with no access to a toilet were stored for 3 days or less when compared with just 23% for households with toilet access.

Table 7.4: Classification of samples by toilet access and storage duration

Access to a household toilet	Storage duration for stored drinking water samples in days							Total
	1	2	3	4	5	6	7	
No	27(8)	27(8)	7(2)	20(6)	7(2)	10(3)	3(1)	100(30)
Yes	3(1)	10(3)	10(3)	30(9)	33(10)	10(3)	3(1)	100(30)
Total	15(9)	18(11)	8(5)	25(15)	20(12)	10(6)	3(2)	100(60)

Note: X(N) = Percentage(No.of Samples). Percentages are rounded off to the nearest whole number. Average storage duration for all households= 4 days

Treatment of stored household drinking water

Table 7.5: Percentage Distribution of Stored household drinking water samples by treatment method and access to toilet

Access to a household toilet	Stored household drinking water treatment method			
	No treatment	Use of Alum	Use of camphor	Total
No	77 (23)	3(1)	20(6)	100(30)
Yes	90(27)	0(0)	10(3)	100(30)
Total	83(50)	2(1)	15(9)	100(60)

Note: X(N) = Percentage(No.of Samples). Percentages are rounded off to the nearest

83% of samples did not receive any form of household drinking water treatment. However water from the river is twelve times more likely to be treated than water from boreholes (see Table 7.5 and Table 7.6). The use of alum and camphor were the only forms of household drinking water treatment reported by some participating households. Drinking water treatment depends on the source of the stored water as shown on Table 7.6. Alum is reportedly used to stir collected river water prior to storage. The water is then allowed to stand and the clear part poured into storage. Camphor is then added to storage containers in the household.

Table 7.6: Percentage Distribution of Stored household drinking water samples by treatment method and source of stored water.

Source of stored drinking water sample	Stored household drinking water treatment method			
	No treatment	Use of Alum	Use of camphor	Total
Borehole	93(40)	0(0)	7(3)	100(43)
Rainwater	100(9)	0(0)	0(0)	100(9)
River water	13(1)	13(1)	75(6)	100(8)
Total	83(50)	2(1)	15(9)	100(60)

Note: X(N) = Percentage (No.of Samples). Percentages are rounded off to the nearest

Quality of stored household drinking water

Water samples that were collected from rainwater and stored had the lowest levels of faecal contamination. Samples were not compared to see if there was any statistically significant difference in the contamination levels for stored water from the different sources. This was mainly because of the size of the sample from rainwater and river. However, Table 7.7 shows the mean and median concentrations of E.coli in the stored household drinking water samples which gives an indication of the contamination levels of the different sources in storage.

Table 7.7: Summary statistics for E.coli concentrations in stored household drinking water samples

Source of stored drinking water	N	E.coli concentration CFU/ml	
		Mean	Median
Borehole	43	2.47×10^3	2.40×10^3
Rainwater	9	2.38×10^2	2.60×10^2
River water	8	2.83×10^3	2.70×10^3

N= Number of samples; CFU = Colony Forming Units

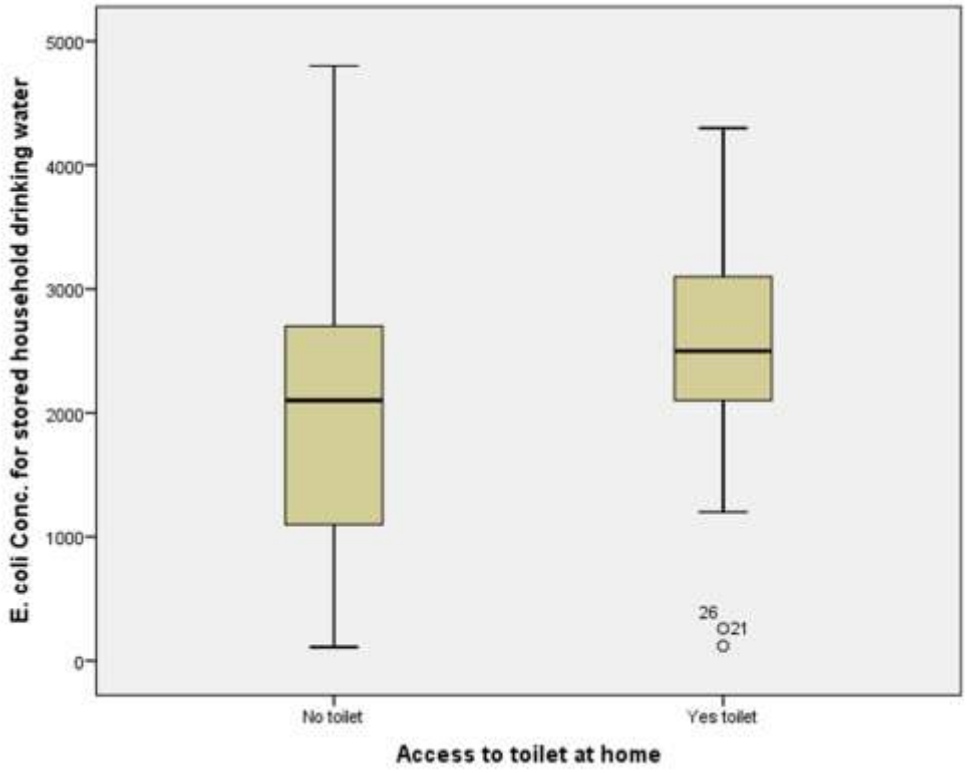


Figure 7.1: Comparison of households by toilet access and concentration of E.coli in stored drinking water

Pearson Chi-square test of independence was carried out to determine if there is a relationship between access to a household toilet and duration of storage. To carryout Chi-square test, the variables must be measured in ordinal or nominal scale and have two or more independent groups with each of the variables (Bryman and Cramer, 2011, Pallant, 2013). Given that the average storage duration was 4 days (see Table 7.4), households were divided into two groups; those who stored water for 4 days or less and those who stored water for more than 4 days. A Chi-square test for independence indicated a significant association between access to a household toilet (yes/no) and duration of storage (4 days or less/ more than 4 days), χ^2 (1, n = 60) = 4.80, p = .03, phi =

.28. The phi value indicates the effect size. It tell how much effect the independent variable has on the dependent variable.

This variability in storage duration between household groups could be attributed to various factors. This data shows that households with toilets are more likely to use boreholes. As already reported in results in the previous chapter, there is intermittent power supply in the study communities and this affects the cost of water from the private borehole operators. It is assumed that households would tend to collect more water when there is public power supply so they can store up more in order to avoid the price hike during periods of power outage when power generating sets are used to pump water by the borehole operators.

To assess if households with toilets differ from those without toilets in terms of their stored household drinking water quality, a Mann-Whitney test was carried out. This test compares values between groups and requires a categorical independent variable with two groups and a continuous dependent. (Pallant, 2013). The test revealed no statistically significant difference in stored household drinking water quality between households with toilets (N=30) and those without toilets (N=30), U = 334, Z = -1.72, p=0.09, r = 0.22. The effective size, r, is given by the express

$$r = \frac{z}{\sqrt{N}}$$ where Z = and N = Number of samples

It quantifies the size of the difference in E.coli concentrations between the two groups of households (Coe, 2002). Although there is no statistically significant difference in contamination concentrations, an effective size of 0.22 shows that there is a ‘small’ difference between the groups. Though it does not tell us which

group has higher contamination levels, Figure 7.1 shows that household with no toilet access had stored household drinking water with lower mean contamination levels. The mean and median contamination values are lower for households with no toilets when compared to household with toilet access at home.

Also a correlation analysis was carried out to test if there was a relationship between source water quality and stored household drinking water in the two group of households. For households with toilets and those without, there was a positive correlation between their stored household drinking water quality and source water quality. This means that an increase in contamination levels at source would lead to an increase in contamination levels in stored household drinking water for all households.

The strength of the relationship between variables is indicated by the value of the correlation coefficient (Pallant, 2013). When the correlation coefficient, r = 0.10 to 0.29, there is a small correlation, r=0.3 to 0.49, there is a medium correlation and when r=0.5 to 1.0 and there is a large correlation (Cohen, 1988). The correlation coefficients shown on Table 7.8 indicates a small correlation hence a weak relationship between source water and stored household drinking water quality in both household groups.

The coefficient of determination indicates the amount of variance shared between variables (Pallant, 2013). This is estimated using the formula; *Coefficient of determination* = $100r^2$, where r is the correlation coefficient. In both household groups, the coefficient of determination was small. It indicates that contamination levels in source water helps explain or predict only 4-8% of the

mean contamination levels in stored household drinking water. Therefore other factors account for a greater proportion of contamination levels in stored household drinking water in the study context than source water quality. Note that correlations indicate only the presence of a relationship and not a causation relationship. The p values are greater than 0.05 which indicates that there is no statistically significant difference in contamination levels between source water and stored household drinking water irrespective of household toilet access status.

Table 7.8: Results for correlation analysis

Variables	No. of cases	P value	Correlation coefficient, r	Coefficient of determination (%)
E.coli concentration in source water	30			
vs		0.137	0.278	8
E.coli concentration in stored household drinking water - toilet access at home	30			
E.coli concentration in source water	30			
vs		0.309	0.192	4
E.coli concentration in stored household drinking water - no toilet access at home	30			

The concentration of E.coli in source water was the independent variable while the concentration of E.coli in stored household drinking water was the dependent variable.

7.2.4 Hand rinse samples

Hand rinse samples were collected from a female adult (mother or main carer) and one child under 5 in all participating households. Hand rinse sample contamination levels is used here as a proxy to measure hand hygiene behaviour. Table 7.9 shows summary statistics for hand rinse samples for both groups of household. This shows almost similar levels of hand contamination in households with toilets access and those without.

To further examine the hand rinse samples for any difference between both groups, a Mann-Whitney test was carried out. The test had E.coli concentrations in hand rinse for adults and children as continuous dependent variables respectively and access to a household toilet as the independent categorical variable to meet the requirements for the test. Table 7.9 below shows the results of the test. The p values are both greater than 0.05 which means that there was no statistically significant difference in the level of faecal contamination on the hands of adults and children living in households with access to a household toilet and those without.

Table 7.9: Results of Mann-Whitney test for hand rinse samples

Test variables	U	Z	N	p	r
Child hand rinse vs toilet access	425.50	-0.36	60	0.72	0.05
Adult hand rinse vs toilet access	442.5	-0.11	60	0.91	0.05

U in CFU/ml; N = No. of samples

The effective size is very small and the same for both adult and child hand rinse samples. This suggest that there is no difference in hand contamination levels in adults and children in households with toilets and those without toilets.

7.3 Summary of chapter

In this chapter, we found that there was no statistically significant difference in the levels of faecal contamination in stored household drinking water between households with access to a toilet at home and those without. However, households with access to a toilet had higher mean and median faecal contamination levels. There was no statistically significant difference in hand contamination levels between adults in households with toilet access when compared with those in households without toilet access. This was the same for children under five years of age. In summary, it appears that having a household toilet does not reduce the risk of drinking faecal contaminated water in these communities.

Chapter 8 : Discussions

8.1 Introduction

The SDG 6 places particular emphasis on hard-to-reach areas such as riverine areas. However, there are mixed outcomes reported in literature for sanitation interventions which primarily focus on increasing access to sanitation. The health impact of interest here is reported diarrhoea rates.

This study evaluates the apparent anomaly that the riverine communities of Bayelsa State, Nigeria, have very poor access to sanitation but relatively low rates of diarrhoea when compared to other states. The objective is to help understand the need for and potential of new, targeted, interventions which have the potential of intercepting faecal contamination transmission pathways. In doing this, the following were examined:

- Access to water and sanitation infrastructure in the study communities.
- Perceptions, behaviours and attitude to water and sanitation in study communities.
- Resultant faecal contamination levels in stored household drinking water and how this differs between households with access to a toilet and those without.
- Plausible faecal contamination transmission pathways resulting from current sanitation conditions and behaviour.

This chapter discusses key findings reported in chapter 6 and 7.

8.2 Faecal contamination transmission pathway

Figure 2.1 in chapter 2 showed from literature, the standard F-diagram indicating pathways of faecal contamination. In this study, the contamination source of interest is human faeces. Livestock keeping was not observed or reported in the study area.

The logic of the F diagram suggests that in areas with high rates of open defecation and in the absence of effective latrines, rates of diarrhoeal disease should be relatively high. However, the results in Chapter 3 shows that in Bayelsa State, where open defecation rates are amongst the highest in Nigeria, reported rates of diarrhoea are not higher than average, and in fact are well below those in other states. This suggests that some aspects of defecation and hygiene practices in Bayelsa may be creating barriers to transmission.

In the study area, there were three principal defecation behaviours: open defecation into surface water bodies; open defecation in nearby bushes; and the use of household flush toilets which are observed to be generally poorly constructed and poorly managed. Chapter 7 shows the presence of faecal indicator bacteria in drinking water stored inside households and on hands. Levels of this contamination were higher within households with a toilet. Faecal indicator bacteria were also found in samples taken from boreholes, the river and rainwater collected from roofs. So let us think about these three defecation behaviours and how they might plausibly be contributing or not to contamination in households.

Open defecation into surface water.

Open defecation into River Nun was the most prominent defecation practice noted in the study. This means that the bulk of human faeces generated in these communities are deposited into surface water. This is similar to the practice in the wider Bayelsa State where nearly sixty percent of households defecate into the river using hanging latrines and more than thirty two percent had no facility and is assumed to defecate into water bodies too (NBS, 2013b, NPC and ICFI, 2014). As a general observation, defecation in surface water is often associated with direct transmission of pathogens, when households are also reliant on surface water for drinking. There is also the potential for contaminated surface water to infiltrate aquifers and impact on shallow groundwater which might also be used for drinking. The general belief amongst study participants was that this route was mitigated by dilution in the flowing river. Because of the high volume of water flowing in the River Nun it seems plausible to assume that there is relatively effective dilution in the river, and that contamination of shallow groundwater would be low. Impacts on water collected directly for drinking may be more significant if collection points are close to defecation points, but the most likely transmission route may be direct contact with faecal contamination in the water at the point of defecation while the person practices personal hygiene or cleans laundry. Figure 8.1 shows a revised pathway map indicating the most plausible routes for faecal contamination to reach individuals from open defecation into surface water. Dotted lines show non-plausible routes.

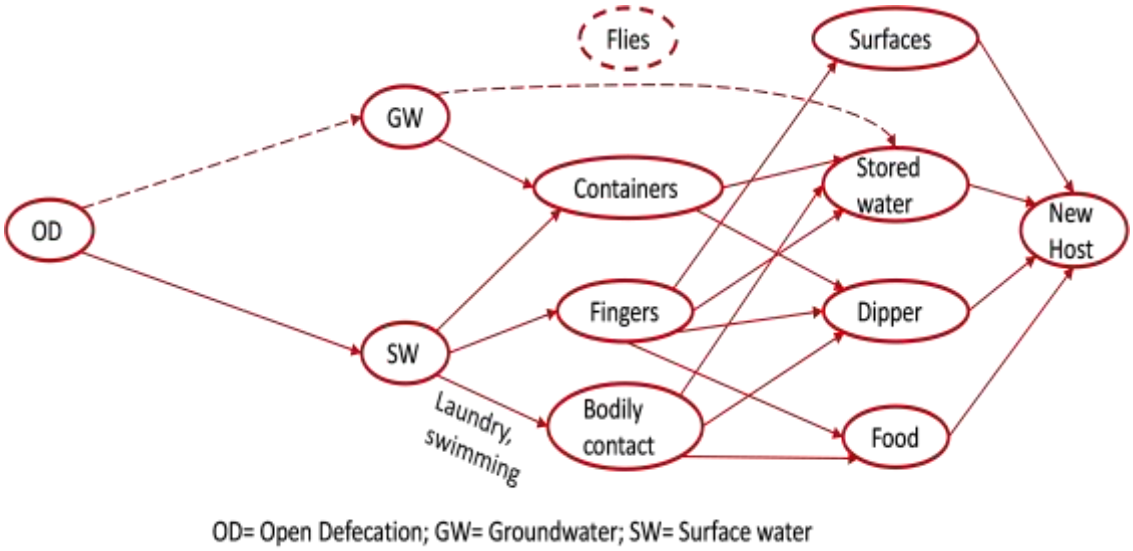


Figure 8.1: Faecal contamination transmission pathway for defecation in surface water

The high rates of open defecation into the river suggest that some at least of these pathways could be significant, and indeed, there is evidence of contamination of the shallow aquifer although the source of this contamination could not be ascertained in this study. There is some evidence that surface water may be more contaminated than other sources when looking at samples taken at source but this effect disappears when comparing samples of stored water from surface sources with boreholes.

Open defecation in nearby bushes

This was reported to take place mainly when people were away from home. Child faeces were reportedly disposed in nearby bushes. Overall it seems likely that the volume of faeces deposited in the bushes is lower than that in the river. Open defecation has the potential to create significant contamination via

‘environmental’ pathways such as pooled water near to the house, and via vector-borne transmission. During rainfall events, faecal matter on the ground could be washed into surface water bodies and potentially to groundwater via poorly-maintained, and inadequately sealed water points as well as by direct infiltration through the soil.

Figure 8.2 shows plausible transmission pathways defecation in nearby bushes.

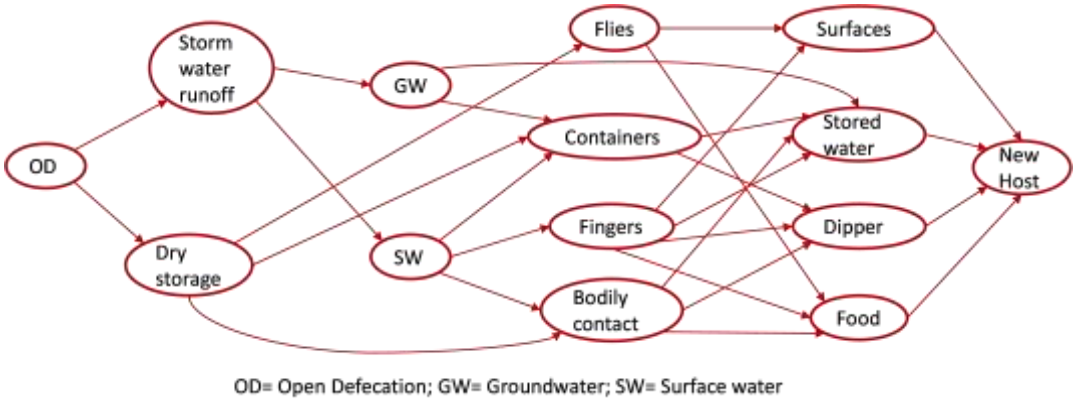


Figure 8.2: Faecal contamination transmission pathway for defecation in bushes

Open defecation of this kind might be expected to be associated with high rates of transmission, particularly via flies, and also from fingers when it is not accompanied by adequate hygiene.

Use of poorly constructed and poorly managed toilets

A third of households use poorly-functioning toilets at home. These included broken and leaking “septic tanks” (which may actually be sealed vaults rather than true septic tanks). Most households reported backflow of sewage into the

home. This type of toilet is a continuous source of pollution near homes. The water table is high and above ground for several months in some parts of the community. These poorly functioning ‘septic tanks’ introduce a constant stream of sewage into the environment resulting in stagnant water pooling around homes and the community. People walk through these areas of stagnant water, and children can often be seen to play in them as they are close to home. Figure 8.3 shows plausible faecal contamination transmission pathways resulting from the use of poorly constructed and poorly maintained toilets. Because of the high rates of flooding the concentration of contaminated material in these types of toilets could potentially contribute to transmission through a wide variety of routes.

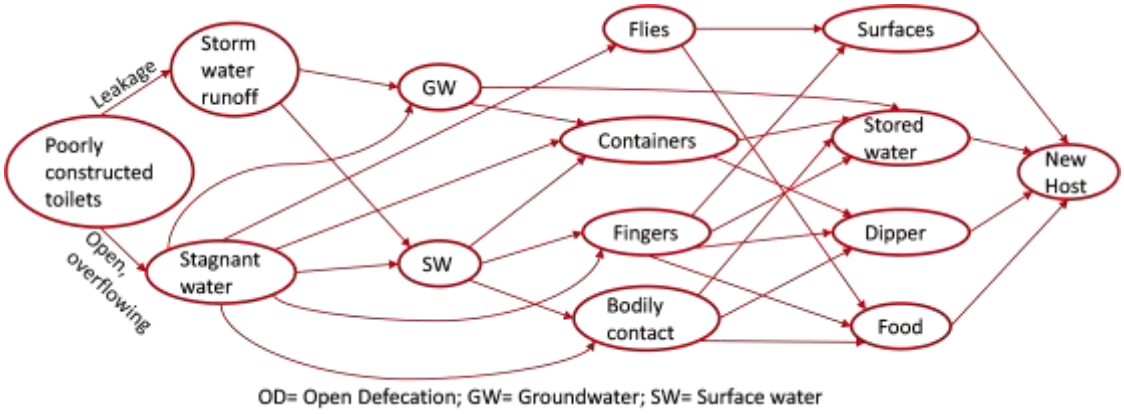


Figure 8.3: Faecal contamination transmission pathways from poorly constructed toilets

With poorly functioning toilets, more people are exposed to faecal contamination and at a higher frequency than with the two behaviours discussed above. This source of faecal contamination therefore constitutes a bigger risk of exposure. This is evidenced by a higher faecal contamination concentration recorded in households with to access to toilets. The use of

poorly constructed toilets is the primary source of contamination in the community. This study speculates that having access to these kind of toilet is worsening exposure to faecal contamination rather than improve it.

8.3 Overall faecal flows in study area

Figure 8.4 below shows a consolidated F- diagram for the study area. There are interesting points to note about this.

Firstly, open defecation as practiced in the study area might be expected to be a significant source of faecal contamination but this is not borne out by the evidence. There is no strong correlation between the places linked to open defecation and surface water.

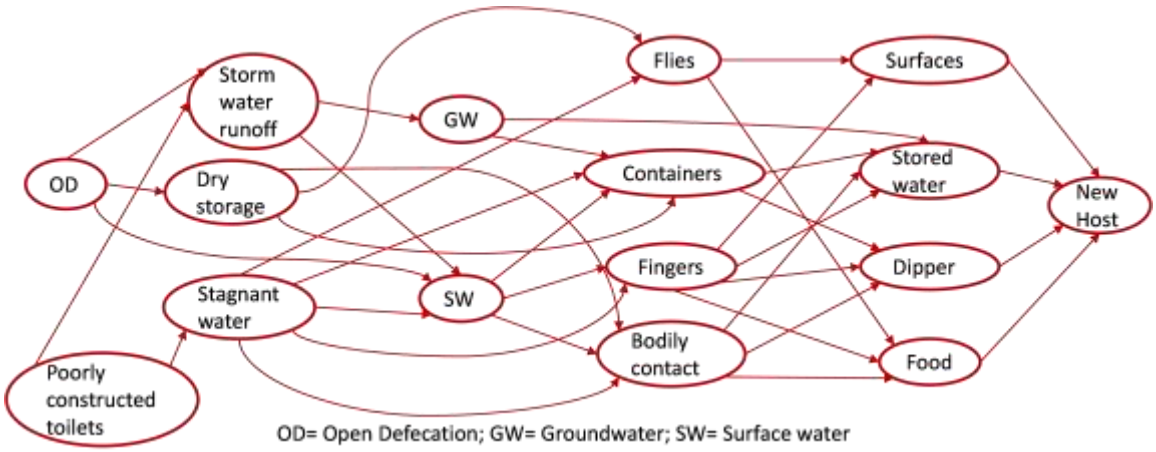


Figure 8.4: Modified F-diagram for riverine communities

This could primarily be due to dilution of surface waters. The River Nun is very large (more than 20m wide) hence has capacity for dilution of the concentration of faecal contamination. UV radiation from the sun and temperature contribute to reduce the concentration of pathogens in surface water. Water collected from

the river is twelve times more likely to be treated than water from boreholes. There is evidence that the treatment method adopted which is the use of Alum, is efficient in the reduction of coliforms in water (Wrigley, 2002). Alum is a well know coagulant/flocculants used in water treatment processes (Jiang et al., 2006). A study in Vietnam reported the use of Alum in riverine communities for the treatment of surface water used for drinking (Wrigley, 2002). Also, the efficiency of Alum for water treatment at household level has been demonstrated to be effective in the reduction of indicator bacteria and pathogens using evidence from Myanmar, Cambodia, Kenya and Vietnam (Khan et al., 1984, Oo et al., 1993, Karanis and Kimura, 2002, Chowdhury et al., 1997). Camphor balls were also used by some households to treat water in storage but there is no evidence of any possible treatment from this practice.

The norm of having a bath after defecation into the river before returning home as reported by most participants suggest that faecal matter is washed off the body and hands before returning home, hence reducing the chance of faecal contamination at home. Therefore, it is plausible that open defecation into the river as practised in the study area is of minimal risk in terms of exposing the population to faecal contamination.

Secondly, there is open defection in bushes, commonly practiced when people are away from their homes, but still within the community. However, the frequency with which this happens is appears to be low Child faeces were disposed in multiple ways with some disposed in the bushes. This defecation behaviour would plausibly not deposit large volumes of faeces into the environment although it would be considered as potentially contributing to more widespread contamination in situations where local flooding or high water

tables at the ground level result in mobilisation of faeces into the wider environment.

The highest level of contamination is found in households with toilets suggesting that this direct route from toilets to future hosts is really very significant. Figure 8.3 indicates that the routes might plausibly be indirect through leakage into ground water but much more significantly, direct due to the pooling of stagnant water near homes. People, particularly children, have regular direct contact with the contamination near the home hence the observed higher contaminations in homes with toilets. These toilets in effect result in the same outcome as would be expected from direct open defecation, but in this case, defecation is concentrated close to the home. This 'effective open defecation' is generally not considered when health risks are being assessed but is likely the main cause of higher rates of contamination in affected households.

The high rate of faecal contamination in households with toilets could be associated with higher rates of diarrhoeal disease but this was not investigated in this study. Overall however, the low rate of usage of these toilets suggests that much faecal matter is removed from the community by transport in the river Nun which could plausibly account for the lower-than-expected rates of diarrheal disease in the community as a whole.

This is a first attempt to describe faecal contamination transmission pathways resulting from existing sanitation behaviour in riverine communities particularly in Nigeria.

8.4 Factors influencing open defecation and current sanitation behaviour

Open defecation especially in rivers in these communities was seen as the norm and culturally accepted. This is not unique to the study area as communities in other countries, including for example India, have reported similar defecation behaviour (Rajgire, 2013). This means a sanitation intervention which aims to reduce or eliminate the practice of defecation into the river has to consider how to break this age-long acceptable behaviour so as to encourage the proposed new behaviour introduced by the intervention.

There was strong believe that because the river is flowing, any faeces deposited in it is taken away by the flowing water. Because of this it was perceived that water collected from the river, upstream of the defecation point is free from faecal contamination. There is evidence that factors such as self-cleansing property of rivers, dilution, flow velocity and the effect of UV radiation from the sunlight reduce the concentration of microorganism like bacteria in surface water (Maraccini et al., 2016, Peng et al., 2017, Oppezzo, 2012, Nyeleti et al., 2004, Burkhardt et al., 2000). However, it is unclear to what extent this happens and how factors like depth and breadth of river, turbidity, and temperature among other factors affect faecal contamination in surface water. It can be inferred that exactly what happens with faeces when it goes into large water bodies is not clear. It is also unclear what size of surface water is classed as small or large and what flowrates is required to achieve what level of dilution.

Open defecation in bushes was mainly reported when people were away from their homes. This gives an indication that the location where people are at the

time when they need to defecate influence their defecation behaviour. There were no toilets in public places like markets. This is common even in cities in developing countries. The provision of sanitation facilities in public places is key to ending all open defecation in this setting. However, in one of the study communities, a public toilet which was a VIP latrine was abandoned and people including children reported that they would rather open defecate around it than go inside and use it. This indicates that the type of sanitation facility provided in public places should be such that is acceptable to the people and they are happy to use else the purpose of such provision will be defeated. Regular well-funded and well-managed operation and maintenance of public facilities is essential for their operation and to ensure that they are providing a service that is attractive to users.

Child faeces was believed to be 'harmless' and so could be disposed anywhere. In the study communities, child faeces were disposed of mainly in nearby bushes. Community members were unaware that child faeces pose the same danger as that from adults. Addressing this behaviour would require specific targeted behaviour change interventions, including possibly the simple one of providing information on the proper disposal of child faeces and the need to dispose it as appropriate as adult faeces.

Results from this study show a strong desire for flush toilets referred to as "modern" toilets in the study area. Community members reported that they would rather continue defecating in the open than use any other form of toilet. Only two out of seven hundred and twenty three households reported having a pit latrine. A previous study in Tambiri II, a community in Bayelsa State also reported the absence of pit latrines (Kilakime et al., 2015). This reflects the belief reported in

these communities that ‘heat’ from pit latrines results in infertility and miscarriages. This desire for so-called “high-end” sanitation options despite the fact that the existing flush toilets are both expensive and generally not functioning adequately, presents a significant challenge in these communities. Essentially, the lack of a desirable and functional solution is what ensures that both direct open defecation and effective open defecation to continue.

They reported the absence of direct financial cost as a motivation for open defecation. Given that there was no maintenance or building cost that goes with open defecation especially in rivers, households saw no need in going out of their way to build a toilet which comes with financial cost. Also, the ‘high end’ preference of the flush toilet as expressed by participants would mean the cost of building a toilet is higher that where simple options like pit latrines preferred. Also, the challenge of backflow of sewage into the house during the rainy season making it impossible for continuous use was reported in the study communities. It is plausible that this could deter households from investing in a toilet if they still need to defecate in the open due to the toilets non functionality in the rainy season, a time when the toilet would prevent them from walking in the rain to defecate in the open.

The perception reported in these communities that the job of building toilets is ‘degrading’ hence should be left to people of low social status and the very poor. This poses a challenge for training people to take on the skills required to build appropriate toilets suitable to overcome the physical challenges in the environment.

8.5 Impact of sanitation access on stored household drinking water quality

Improving sanitation access is one of the key objectives of Sustainable Development Goals. This study compared the concentration of faecal contamination in stored household drinking water for household with access to a toilet and those without access in the study area. This result supports the contention that the use of improved sanitation does not directly protect the user but their neighbours. (Hunter and Pruss-Ustun, 2016). Households with toilets are exposed to their own faecal contamination as well as that resulting from open defecation of their neighbours. This exposure is made worse by the use of poorly constructed toilets as is the case in our study community. With reported backflow of sewage during the rainy season when the water table is very high and even above ground in some parts of the community, toilets becomes a major source of contamination. In this situation, it is plausible that there are more opportunities for faecal contamination in households with toilets when compared with those without a toilet.

Also, when the focus of an intervention programme is just on access, once household have gained access, it is assumed that the risk of exposure to faecal contamination is removed. Households need to understand behaviours that could make the new toilet a potential source of contamination, creating a new pathway of exposure.

Results from this study showed an increase in contamination rate between water sources and stored household drinking water. Some studies report that for highly contaminated sources, die-off rate between source and point of use resulted in

lower contamination levels as indicator bacteria compete for oxygen and nutrients in (Momba and Notshe, 2003). However, other studies suggest increase in contamination for water from safe sources due to unwashed water collection containers, dippers and contact with hands (Wright et al., 2004). This study shows that where open defecation is practiced and hand hygiene is poor, irrespective of source water quality, if households collect, transport and store their drinking water, multiple interactions occur in the process and this leads to increase in contamination levels in the stored drinking water. This is the case irrespective of toilet access in the household.

This research adds to existing knowledge that community level access to sanitation is essential for sustainable gains from sanitation access. Although studies have shown decrease in diarrhoea from individual household level improvements in sanitation access, ignoring the wider community sanitation behaviour may significantly underrate the impact that sanitation has on health (Wolf et al., 2014b, Strunz et al., 2014, Ziegelbauer et al., 2012, Fink et al., 2011, Larsen et al., 2017). Also research suggest that family members exposed to pathogens commonly encountered within their household would develop immunity to those pathogens (Vanderslice and Briscoe, 1993). This makes it unclear if the decrease in diarrhoea rates observed in studies were solely due to sanitation access.

Because household members collect water by themselves and transport it home, interactions between their hands and the drinking water would probably introduce pathogens which already exist within the household into the water. In this case, the family already have immunity to these pathogens and so are less likely to develop diarrhoea from repeated exposure to their own pathogens. This

explains why households our study communities still have low diarrhoea rates despite high contamination concentrations in their drinking water. Studies would be required to assess how diarrhoea rates vary between households where different water vendors deliver water to the household and those that collect their water themselves.

8.6 Implication for the design of intervention programmes

With the target of achieving the SDG 6, the focus, as has been the case is on increasing access especially in areas that are deprived of sanitation infrastructure like hard-to-reach riverine area. This research provides evidence that increasing access only may in fact have a negative effect if it creates additional pathways for faecal contamination transmission. While improving access, existing behaviour and transmission pathways need to be assessed to help focus the design of interventions. A “one size fits all” approach is inappropriate as the challenges in different context are different even within the same country.

The SDGs also signal the importance of this since SDG 3 on good health and wellbeing calls for an end to preventable deaths and reduce maternal mortality and SDG 1 on ending poverty and the provision of basic services.

For riverine communities in Bayelsa State and the Niger Delta region, data on available infrastructure paints a frightening picture. However, reported diarrhoea rates in the region is better than expected with Bayelsa having one of the lowest rates in Nigeria. Existing faecal contamination pathways, water treatment

method, adopted sanitation practices do not present an enormous risk. On the contrary, households with toilets have higher faecal contamination levels.

Currently, defecation is mainly in the river which means faeces are generally far from homes Therefore, interventions must be designed to perform better than existing behaviour in truncating transmission pathways and not creating new ones from inappropriate toilet access and use.

Given the attitude towards toilet building skills, sanitation marketing and business schemes could be useful in encouraging young people to develop the skills required for sustainable provision of sanitation services to communities. Also, the provision of toilets in public places would reduce defecation in bushes. Although public toilets have failed in the study communities in the past (these were pit latrines which community members do not like), lessons on the reasons for the failure should be incorporated into designs and operations plans for sustained use. Modern container-based toilets that prevents leaking and allows faeces to be moved away from where the people is a feasible option.

Revitalizing existing non-functional water projects in the study community and elsewhere will reduce dependence on surface water as a source of drinking water. It is necessary to introduce policy on monitoring and regulating water quality from privately owned boreholes that sell water to the public to ensure water safety.

8.7 Policy implication of findings

Key policy point is to clarify and generate a collective agreement on the objective of any national or local sanitation policy. As it currently stands, and possibly rightly so, there is a strong focus on the elimination of open defecation and the construction of toilets. However, in riverine areas it may be more useful to develop a focus on the outcome, which is an environment free of faecal contamination rather than on mechanistic delivery of infrastructure or behaviour change programmes.

To effectively improve drinking water and sanitation in multiple interventions would be needed to;

I. Get faeces out of the environment by ending open defecation and using sanitation systems that ensure safe collection, treatment and disposal/reuse of faecal matter.
II. Keep faeces out of water sources and clean water storage tanks at source to reduce the risk of multiplication of contaminants.
III. Keep drinking water collection and transporting containers and household storage containers free from faecal contamination by cleaning them with water and soap regularly.
IV. Wash hands with soap and water regularly especially before collecting and transporting drinking water.
V. Good indoor sanitation and cleaning fomites to reduce the risk of spreading faecal contamination within the household.

The most effective of these is likely to be (I) but we will need a lot more research to be sure. This study provides a first cut of evidence that individual household

toilets are not sufficient to make a significant impact on stored household drinking water quality.

In addition there are some specific issues that this study has drawn to light: The study area had no municipal water supply hence privately owned boreholes provided water supply. It was reported that privately owned water sources accessed by members of the public whether free or paid for were classed as 'public' water supply. These privately owned boreholes are maintained and managed by their owners as a business. This raises a question about the definition of 'public water supply' in different context. The Nigerian standard for drinking water quality states that its scope covers privately owned water supplies used solely by the family residence but did not mention any application to privately owned boreholes which provide water to the public despite this being a common practise in the country (SON, 2007). Therefore, it is unclear if any regulations for the operation of these private public servicing boreholes.

Microbial analysis showed high concentration of faecal contamination in borehole sources. This is not just common to the study area as other research have shown contamination of improved water sources. Since the treatment with Alum is efficient and is proven to reduce the concentration of indicator organisms in surface water, its use can be extended to water from boreholes.

Having policy documents in place is necessary for improvements in service. However, until policies are fully implemented, the overriding benefits of its existence would not be achieved. The new Partnership for Expanded Water Supply, Sanitation and Hygiene (PEWASH) programme aims to eradicate poverty and improve public health through sustainable sanitation interventions

(FGN, 2016). To date, there is no sanitation approach adopted as policy in Nigeria that has been successful in ending open defecation in riverine communities of Bayelsa State and the Niger Delta region. This research provides insight into the sanitation behaviour of riverine communities, potential existing faecal contamination transmission pathways and how current behaviour impacts on faecal contamination concentration levels in stored household drinking water.

Although this study found higher faecal contamination levels in drinking water for households with toilets, it does not undermine the importance of toilet access. Rather it shows that interventions should be designed such that toilet access does not introduce a new faecal contamination pathway closer to home. It also highlights the need for universal access at community level so that households with toilet access will not be in a disadvantaged position in terms of their exposure to faecal contamination.

8.8 Chapter summary

This chapter discussed key findings of this thesis. It also highlights implication of findings for policy. The next chapter would be a brief conclusion of the findings of the research.

Chapter 9 Conclusions

9.1 Chapter introduction

This chapter presents overall conclusions of this thesis based on the aims and objectives set out in chapter one. Key findings are discussed followed by a discussion of limitations of the study. A description of the application of the research finding is given and recommendations for further research.

9.2 Research conclusions

The main aim of this research was to assess the impact of current sanitation behaviour on drinking water quality. The research focused on riverine communities of Bayelsa State, Niger Delta, Nigeria where ending open defecation is still a challenge yet reported diarrhoea rate is the lowest in Nigeria. The overall conclusions for the set objectives are discussed below.

The first objective was to explore access to water and sanitation infrastructure in the study community. Primary research using mixed methods showed that water from privately owned boreholes and the River Nun were the primary sources of drinking water. Water from the boreholes were purchased at a price which was dependent on power supply conditions which in itself was often interrupted. Direct defecation into the river and the use of flush toilets were the most common sanitation in use. Flush toilets were often not in use all year round due to the backflow of sewage from ‘septic tanks’ into household. Open defecation in bushes was commonly practised when people were away from home. This study concludes that existing water and sanitation facilities in these communities are

inadequate. To achieve SDG 6, investments and interventions in the provision of water and sanitation facilities in these communities is required.

The second objective assessed perceptions, behaviors and attitude to water and sanitation in study communities. Evidence from primary research using a mixed method design revealed that water from borehole was the most commonly used drinking water source because of the ease of collection while water from the river was preferred for its taste and perceived ‘healing powers’. Desire for water from boreholes was expressed in the displeasure for non-functional water projects in the study area. Open defecation into the river was culturally accepted as the norm. Findings also showed that anal cleansing with water was the dominant behavior. This was influenced by believe, that carrying fecal matter on the body after defecation was a taboo. Ownership of a flush toilet was the preferred sanitation option and associated with being ‘modern’. Defecation into the river was seen as harmless to health because the river was flowing and takes away anything dropped into it. Child faeces was seen as harmless and can therefore requires little or no caution in its disposal. Pit latrines were nearly absent as it was perceived that ‘heat’ from it causes infertility and miscarriage in women and its use represents economic retrogression when compared with their ancestors. This study concludes that the current sanitation behavior. This study concludes that riverine communities are happy with their current behavior of defecating in the river and improved water sources were preferred especially for ease of access. These perceptions are make useful contribution to inform the selection and design of appropriate interventions programs for these and similar communities.

The third objective was to assess plausible faecal contamination transmission pathways resulting from current sanitation practices. The findings show three main sources of faecal contamination in the study area; the collection of drinking water from the same river here open defecation takes place; defecation and disposal of child faeces in bushes; and the use of poorly constructed and poorly managed toilets at home. Two main transmission routes were identified; interactions between contamination sources, fingers and the path of water from source, through transportation to household drinking water storage; and interactions between fingers, dippers stored drinking water and food within the household. This study concludes that proximity of a poorly constructed, poorly functional and poorly maned toilet to a household is probably the most significant source of contamination and a potential overlooked source of faecal contamination.

The last objective was to examine resultant faecal contamination levels in stored household drinking water and how this differs between households with access to a toilet and those without. Evidence from microbiological analysis of stored household drinking water surprisingly revealed that households with access to a toilet had higher concentrations of faecal contamination. This suggest that though access is the main focus of many countries as they strive to meet SDG 6, access only is not sufficient to protect households from faecal contamination especially where open defecation I still practiced.

The overall conclusion from the study is that in these communities, the presence of toilets in the house represents potentially the most significant route of transmission of faecal contamination and that, by contrast, open defecation in the river and even in bushes may be less significant in terms of poor health

outcomes. In effect the toilets which are present, which rely on septic systems which are not regularly emptied or maintained and which are impacted by frequent flooding represent the biggest health risk. The policy implications are profound since, in the absence of a plausible alternative which could provide 'safely managed sanitation' it may be better not to increase access to a 'basic' level of service for people currently using the river as their defecation point.

9.3 Limitations of Study

This research is the first attempt at exploring the anomaly of low sanitation access yet low reported diarrhoea rates in riverine communities in Nigeria and possibly globally. It makes an important contribution to understanding sanitation behaviours, resultant faecal contamination and impact on reported diarrhoea rates. Despite this, some limitations are recognised.

First is the sample size. This study took place in two riverine communities. This number was selected because of the financial and time constraints and the challenge of working as a lone researcher in remote locations in Niger Delta Nigeria. However, these two communities were studied in depth and the behaviours observed in the study communities are typical of riverine communities in the region.

Secondly, the selected communities were communities that had road access. Majority of communities in Bayelsa State can only be access by river or sea travel. At the time of this study, the foreign and commonwealth office only allowed travel to riverine communities with road access in Bayelsa State. As a result, the level of infrastructure access reported for these communities may not represent

access in riverine communities with no road access. This is because for communities with road access it is less challenging to transport material to carryout infrastructure projects when compared with communities that can only be access boats.

The water quality analysis was carried out at a preliminary level and the absence of sophisticated source tracking means that it is not possible to conclude absolutely that the source of measured faecal contamination is human excreta. More detailed microbial source tracking analysis in typical communities where defecation in water bodies is common would enable a more sophisticated and quantifiable analysis of the burdens associated with the different transmission pathways posited here.

9.4 Application of research

This research makes contribution to existing knowledge in many ways especially for riverine communities of Bayelsa State and the Niger Delta Region and the wider water and sanitation sector. Based on primary evidence, the research identifies the role of privately owned borehole in the provision of water supply from improved sources to members of the public. Despite the important service provided by these privately owned boreholes they are not currently regulated and are not mentioned in the Nigerian standard for drinking water quality. This finding can be applied when considering options for improving drinking water supply. Rather than start new water projects that may not be sustainable on the long term (non-functional water projects exist in study communities), existing privately owned boreholes could partner with intervention organisations and government in the provision of regulated water supply services at community level.

Also, contrary to expectations, this research provides empirical evidence that the provision of access to toilet alone in riverine communities does not reduce the exposure of households to faecal contamination and rather is associated with higher faecal contamination levels in stored household drinking water. This finding can be applied in the design of sanitation interventions for riverine communities by focusing on intercepting existing faecal contamination transmission pathways and promote universal access to enhance impact of intervention. Therefore, investment in sanitation must be as good as or better than current practice in terms of the amount of faecal contaminants in the environment resulting from the use of the new sanitation.

The research also explored sanitation behaviour both when people are at home and when they are away from home. Based on the finding of this research sanitations interventions that focus only on the provision of sanitation at household level will not end all open defecation. This is because this research shows that people have different defecation behaviours depending on where they are at the time they need to defecate. Hence in the design of interventions to end all open defecation as proposed by SDG 6, sanitation in public places should be included in interventions.

9.5 Recommendations for further research

This study has revealed a number of important features of water supply and sanitation which merit further examination, particularly since they can plausibly be assumed to occur elsewhere in Nigeria and in other similar geographies. These are:

- Further detailed research including Microbiological Source Tracking to establish and confirm the flow of faecal contamination.
- More extensive studies of riverine communities to ensure that the findings are not anomalous to the two communities in this study.
- Investigation or Randomised Controlled Trial to design and test new approaches to achieving ODF outcomes, including no faeces in the environment, in riverine communities.
- Research is required to establish the effect of Alum use in combination with Camphor balls on the chemical and bacteriological quality of water.
- Study on the functionality of septic tanks in riverine communities in Nigeria is needed.

List of References

ABDEL-RAZIK, M. S. M., EL RABBAT, M., ELDEN, N. M. K. & ALI, H. Y. 2015. Ecological Study to Set Alternative Strategies for Reducing Child Mortality. *Epidemiology Biostatistics and Public Health,* 12**,** 9.

ABOSSIE, A. & SEID, M. 2014. Assessment of the prevalence of intestinal parasitosis and associated risk factors among primary school children in Chencha town, Southern Ethiopia. *Bmc Public Health,* 14**,** 8.

ABOUTEIR, A., EL YAAGOUBI, F., BIOH-JOHNSONA, I., KAMEL, A., GODARD, N., CORMERAIS, L., ROBIN, F. & LESENS, O. 2011. Water access and attendance for diarrhea in primary health care centers, Gaza strip. *Transactions of the Royal Society of Tropical Medicine and Hygiene,* 105**,** 555-560.

ABU-ELYAZEED, R., WIERZBA, T. F., MOURAD, A. S., PERUSKI, L. E., KAY, B. A., RAO, M., CHURILLA, A. M., BOURGEOIS, A. L., MORTAGY, A. K., KAMAL, S. M., SAVARINO, S. J., CAMPBELL, J. R., MURPHY, J. R., NAFICY, A. & CLEMENS, J. D. 1999. Epidemiology of enterotoxigenic Escherichia coli diarrhea in a pediatric cohort in a periurban area of lower Egypt. *Journal of Infectious Diseases,* 179**,** 382-389.

AHMED, S. A. Community Led Total Sanitation in Bangladesh: Chronicles of a People's Movement. IDS Conference paper, 2008.

ALEXANDER, D., WILSON, N., GIESEKER, R., BARTLETT, E., ROSSEAU, N. A., AMUZU, E. X., ANSONG, D., OLOPADE, O. I. & OLOPADE, C. O. 2015. Drinking water infrastructure in the Ashanti Region of Ghana: developing a model for sustainable interventions by non-governmental organizations. *Journal of Water Sanitation and Hygiene for Development,* 5**,** 127-135.

ARNOLD, B. F., KHUSH, R. S., RAMASWAMY, P., LONDON, A. G., RAJKUMAR, P., RAMAPRABHA, P., DURAIRAJ, N., HUBBARD, A. E., BALAKRISHNAN, K. & COLFORD, J. M. 2010. Causal inference methods to study nonrandomized, preexisting development interventions. *Proceedings of the National Academy of Sciences of the United States of America,* 107**,** 22605-22610.

ARNOLD, M., VANDERSLICE, J. A., TAYLOR, B., BENSON, S., ALLEN, S., JOHNSON, M., KIEFER, J., BOAKYE, I., ARHINN, B., CROOKSTON, B. T. & ANSONG, D. 2013. Drinking water quality and source reliability in rural Ashanti region, Ghana. *Journal of Water and Health,* 11**,** 161-172.

BARBOUR, R. S. 2001. Checklists for improving rigour in qualitative research: a case of the tail wagging the dog? *BMJ: British Medical Journal,* 322**,** 1115.

BARNARD, S., ROUTRAY, P., MAJORIN, F., PELETZ, R., BOISSON, S., SINHA, A. & CLASEN, T. 2013. Impact of Indian Total Sanitation Campaign on Latrine Coverage and Use: A Cross-Sectional Study in Orissa Three Years following Programme Implementation. *Plos One,* 8**,** 8.

BARTRAM, J., LEWIS, K., LENTON, R. & WRIGHT, A. 2005. Focusing on improved water and sanitation for health. *The Lancet,* 365**,** 810-812.

BOISSON, S., SOSAI, P., RAY, S., ROUTRAY, P., TORONDEL, B., SCHMIDT, W. P., BHANJA, B. & CLASEN, T. 2014. Promoting latrine construction and use in rural villages practicing open defecation: Process evaluation in connection with a randomised controlled trial in Orissa, India. *BMC Research Notes,* 7.

BOSCHI-PINTO, C., VELEBIT, L. & SHIBUYA, K. 2008. Estimating child mortality due to diarrhoea in developing countries. *Bulletin of the World Health Organization,* 86**,** 710-717.

BRICEÑO, B., COVILLE, A. & MARTINEZ, S. 2015. Promoting handwashing and sanitation: evidence from a large-scale randomized trial in rural Tanzania. In: Policy Research Working Paper. World Bank.

BROWN, J., PROUM, S. & SOBSEY, M. D. 2008. Escherichia coli in household drinking water and diarrheal disease risk: evidence from Cambodia. *Water Science and Technology,* 58**,** 757-763.

BROWN, M., SODANEATH, H., SMITH, J., HAGAN, J. & BUNTHAN, K. 2010. Sanitation in Floating Communities in Cambodia - Live & Learn Environmental Education Cambodia Engineers Without Borders Australia. Live & Learn Environmental Education Cambodia Engineers Without Borders Australia,

.

BRYMAN, A. & CRAMER, D. 2011. *Quantitative data analysis with IBM SPSS 17, 18 and 19*, Routledge.

BURKHARDT, W., CALCI, K. R., WATKINS, W. D., RIPPEY, S. R. & CHIRTEL, S. J. 2000. Inactivation of indicator microorganisms in estuarine waters. *Water Research,* 34**,** 2207-2214.

BYERS, K. E., GUERRANT, R. L. & FARR, B. M. 2001. Fecal-oral transmission. *Epidemiologic Methods for the Study of Infectious Diseases.* Oxford University Press.

CAIRNCROSS, S. 2004. The case for marketing sanitation. *WSP-AF (Water and Sanitation Program for Africa) Field Notes, Nairobi, Kenya, digitally available at:* *www.wsp.org/sites/wsp.org/files/publications/af_marketing.pdf* [Online]. [Accessed 13th December, 2015].

CAMERON, L. & SHAH, M. 2010. Scaling up rural sanitation: findings from the impact evaluation baseline survey in Indonesia.

CGSW 2014. Rapid Assessment Tool Manual. Atlanta,USA: Centre for Global Safe Water, Emory University.

CHAMBERS, R. 1994. The origins and practice of participatory rural appraisal. *World development,* 22**,** 953-969.

CHAMBERS, R. 2009. Going to Scale with Community-Led Total Sanitation: Reflections on Experience, Issues and Ways Forward. *IDS Practice Papers,* 2009**,** 01-50.

CHATTERJEE, L. 2011. *Time to acknowledge the dirty truth behind community-led sanitation* [Online]. The guardian. Available: http://www.theguardian.com/global-development/poverty-matters/2011/jun/09/dirty-truth-behind-community-sanitation [Accessed 30/04/2014 2014].

CHOWDHURY, M., HUQ, A., XU, B., MADEIRA, F. & COLWELL, R. R. 1997. Effect of alum on free-living and copepod-associated Vibrio cholerae O1 and O139. *Applied and environmental microbiology,* 63**,** 3323-3326.
CLASEN, T., BOISSON, S., ROUTRAY, P., CUMMING, O., JENKINS, M., ENSINK, J. J., BELL, M., FREEMAN, M. C., PEPPIN, S. & SCHMIDT, W. P. 2012. The effect of improved rural sanitation on diarrhoea and helminth infection: Design of a cluster-randomized trial in Orissa, India. *Emerging Themes in Epidemiology***,** 7.
CLASEN, T., BOISSON, S., ROUTRAY, P., TORONDEL, B., BELL, M., CUMMING, O., ENSINK, J., FREEMAN, M., JENKINS, M. & ODAGIRI, M. 2014. Effectiveness of a rural sanitation programme on diarrhoea, soil-transmitted helminth infection, and child malnutrition in Odisha, India: a cluster-randomised trial. *The Lancet Global Health,* 2**,** e645-e653.
CLASEN, T. F. & BASTABLE, A. 2003. Faecal contamination of drinking water during collection and household storage: the need to extend protection to the point of use. *Journal of water and health,* 1**,** 109-115.
CLASEN, T. F., BOSTOEN, K., SCHMIDT, W. P., BOISSON, S., FUNG, I. C., JENKINS, M. W., SCOTT, B., SUGDEN, S. & CAIRNCROSS, S. 2010. Interventions to improve disposal of human excreta for preventing diarrhoea. *Cochrane database of systematic reviews (Online),* 6.
COE, R. 2002. It's the effect size, stupid: What effect size is and why it is important. *Annual Conference of the British Educational Research Association.* University of Exeter, England.
COHEN, J. 1988. *Statistical power analysis for the behavioral sciences,* Hillsdale, N.J, L. Erlbaum Associates.
COLE, B., PINFOLD, J., HO, G. & ANDA, M. 2012. Investigating the dynamic interactions between supply and demand for rural sanitation, Malawi. *Journal of Water, Sanitation and Hygiene for Development,* 2**,** 266-278.
COLE, B., PINFOLD, J., HO, G. & ANDA, M. 2014. Exploring the methodology of participatory design to create appropriate sanitation technologies in rural Malawi.
COTTON, A., FRANCEYS, R., PICKFORD, J. & SAYWELL, D. 1995. On-Plot Sanitation in low-income urban communities. *WEDC Loughborough Univ. of Technology, Loughborough*.
CRESWELL, J. W. 2014. *Research design: qualitative, quantitative, and mixed methods approaches,* Los Angeles, Calif;London;, Sage.
CRESWELL, J. W. & PLANO CLARK, V. L. 2011. *Designing and conducting mixed methods research,* Los Angeles, CA;London;, SAGE.
CURRY, K. D., MORGAN, M., PEANG, S. H. & SEANG, S. 2015. Biosand water filters for floating villages in Cambodia: safe water does not prevent recontamination. *Journal of Water Sanitation and Hygiene for Development,* 5**,** 213-219.
DE VREEDE, E. 2004. CHAST “Children hygiene and sanitation training” in Somalia. *School Sanitation & Hygiene Education***,** 72.
DEVINE, J. 2010. Sanitation marketing as an emergent application of social marketing: experiences from East Java. *Cases in Public Health Communication & Marketing,* 4**,** 38-54.
DEVINE, J. & KULLMANN, C. 2012. Introductory Guide to Sanitation Marketing. World Bank Water and Sanitation Programme.

DEVINE, J. & SIJBESMA, C. 2011. Sustainability of Rural Sanitation Marketing in Vietnam: Findings from a new case study. *Waterlines,* 30**,** 52-60.
DJONOPUTRO, E. R., BLACKETT, I., ROSENBOOM, J. W. & WEITZ, A. 2010. Understanding sanitation options in challenging environments. *Waterlines,* 29**,** 186-203.
DONOVAN, R. J. & HENLEY, N. 2003. *Social marketing: Principles and practice*, Ip Communications Melbourne.
DUFOUR, A. 1977. Escherichia coli: the fecal coliform. *Bacterial indicators/health hazards associated with water.* ASTM International.
EGBERONGBE, F. O., NWILO, P. C. & BADEJO, O. T. Oil Spill Disaster Monitoring along Nigerian Coastline". Paper presented at. 5th FIG Regional Conference: Promoting Land Administration and Good Governance, 2006. Citeseer.
ENGELL, R. E. & LIM, S. S. 2013. Does clean water matter? An updated meta-analysis of water supply and sanitation interventions and diarrhoeal diseases. *Lancet,* 381**,** 44-44.
ESHCOL, J., MAHAPATRA, P. & KESHAPAGU, S. 2009. Is fecal contamination of drinking water after collection associated with household water handling and hygiene practices? A study of urban slum households in Hyderabad, India. *Journal of water and health,* 7**,** 145-154.
ESREY, S. A., POTASH, J. B., ROBERTS, L. & SHIFF, C. 1991a. Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma. *Bulletin of the World Health Organization,* 69**,** 609-621.
ESREY, S. A., POTASH, J. B., ROBERTS, L. & SHIFF, C. 1991b. Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma. *Bulletin of the World Health organization,* 69**,** 609.
EVANS, B., HALLER, L. & HUTTON, G. 2004. Closing the sanitation gap: the case for better public funding of sanitation and hygiene.
FAWZI, A., JONES, H. 2010. Community-Led Total Sanitation (CLTS) for people in vulnerable situations Identifying and supporting the most disadvantaged people in CLTS A case study of Bangladesh. WaterAid.
FENN, B., BULTI, A. T., NDUNA, T., DUFFIELD, A. & WATSON, F. 2012. An evaluation of an operations research project to reduce childhood stunting in a food-insecure area in Ethiopia. *Public Health Nutrition,* 15**,** 1746-1754.
FEWTRELL, L., KAUFMANN, R. B., KAY, D., ENANORIA, W., HALLER, L. & COLFORD JR, J. M. 2005. Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis. *The Lancet infectious diseases,* 5**,** 42-52.
FGN 2000. Water Supply & Sanitation Interim Strategy Note. Federal Republic of Nigeria.
FGN 2004. DRAFT FINAL NATIONAL WATER SANITATION POLICY. Nigeria: Department of Water Supply and Quality Control. Federal Ministry of Water Resources.
FGN 2016. Partnership for Expanded Water Supply, Sanitation& Hygiene (PEWASH) Programmed Strategy (2016 – 2030). Nigeria: Federal Ministry of Water Resources.

FINK, G., GUNTHER, I. & HILL, K. 2011. The effect of water and sanitation on child health: evidence from the demographic and health surveys 1986-2007. *International Journal of Epidemiology,* 40**,** 1196-1204.
FLICK, U. 2013. *The SAGE Handbook of Qualitative Data Analysis*.
FOWLER, F. J. 2008. *Survey research methods*, Sage publications.
FREEMAN, M. C., GARN, J. V., SCLAR, G. D., BOISSON, S., MEDLICOTT, K., ALEXANDER, K. T., PENAKALAPATI, G., ANDERSON, D., MAHTANI, A. G. & GRIMES, J. E. 2017. The impact of sanitation on infectious disease and nutritional status: a systematic review and meta-analysis. *International Journal of Hygiene and Environmental Health*.
FREUDENBERG, K. S. unknown.
Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal (PRA) - A manual for CRS Field Workers and Partners. Baltimore, Maryland.
FRIAS, J. & MUKHERJEE, N. 2005. Harnessing Market Power for Rural Sanitation: Private Sector Sanitation Delivery in Vietnam. Water and Sanitation Program–East Asia and Pacific.
GALBRAITH, C. 2009. *COMMUNITY APPROACHES to TOTAL SANITATION Based on case studies from India, Nepal, Sierra Leone, Zambia*. New York: UNICEF.
GARN, J. V., SCLAR, G. D., FREEMAN, M. C., PENAKALAPATI, G., ALEXANDER, K. T., BROOKS, P., REHFUESS, E. A., BOISSON, S., MEDLICOTT, K. O. & CLASEN, T. F. 2016. The impact of sanitation interventions on latrine coverage and latrine use: A systematic review and meta-analysis. *International Journal of Hygiene and Environmental Health*.
GIBBS, A. 1997. Focus groups. *Social research update,* 19.
GODFREY, A. 2010. Documentation of CLTS experiences with ASNANI in NAMPULA Province. Water and Sanitation Programme.
GODFREY, A., HART, T. & ROSENSWEIG, F. 2010. Application of Total Sanitation and Sanitation Marketing (TSSM) Approaches to USAID. USAID.
GREASLEY, P. 2008. *Quantitative data analysis using SPSS: an introduction for health and social science,* Maidenhead, Open University Press.
GREENE, J. C., CARACELLI, V. J. & GRAHAM, W. F. 1989. Toward a Conceptual Framework for Mixed-Method Evaluation Designs. *Educational Evaluation and Policy Analysis,* 11**,** 255-274.
GREENE, L. E., FREEMAN, M. C., AKOKO, D., SABOORI, S., MOE, C. & RHEINGANS, R. 2012. Impact of a school-based hygiene promotion and sanitation intervention on pupil hand contamination in Western Kenya: a cluster randomized trial. *The American journal of tropical medicine and hygiene,* 87**,** 385-393.
GRIER, S. & BRYANT, C. A. 2005. Social marketing in public health. *Annu. Rev. Public Health,* 26**,** 319-339.
GUERRANT, R. L., DEBOER, M. D., MOORE, S. R., SCHARF, R. J. & LIMA, A. A. M. 2013. The impoverished gut-a triple burden of diarrhoea, stunting and chronic disease. *Nature Reviews Gastroenterology & Hepatology,* 10**,** 220-229.
GUION, L. A., DIEHL, D. C. & MCDONALD, D. 2011. Triangulation: Establishing the validity of qualitative studies.

HARDING, J. 2013. *Qualitative data analysis from start to finish*, Sage.
HARRIS, M., ALZUA, M. L., OSBERT, N. & PICKERING, A. 2017. Community-Level Sanitation Coverage More Strongly Associated with Child Growth and Household Drinking Water Quality than Access to a Private Toilet in Rural Mali. *Environmental Science & Technology,* 51**,** 7219-7227.
HEIJNEN, M., ROUTRAY, P., TORONDEL, B. & CLASEN, T. 2015. Shared Sanitation versus Individual Household Latrines in Urban Slums: A Cross-Sectional Study in Orissa, India. *American Journal of Tropical Medicine and Hygiene,* 93**,** 263-268.
HERBST, S., BENEDIKTER, S., KOESTER, U., PHAN, N., BERGER, C., RECHENBURG, A. & KISTEMANN, T. 2009. Perceptions of water, sanitation and health: a case study from the Mekong Delta, Vietnam. *Water Science & Technology,* 60.
HOE, J. & HOARE, Z. 2013. Understanding quantitative research: part 1. *Nursing Standard,* 27**,** 52-58.
HUMPHREY, J. H. 2009. Child undernutrition, tropical enteropathy, toilets, and handwashing. *Lancet,* 374**,** 1032-1035.
HUNTER, P. R. & PRUSS-USTUN, A. 2016. Have We Substantially Underestimated the Impact of Improved Sanitation Coverage on Child Health? A Generalized Additive Model Panel Analysis of Global Data on Child Mortality and Malnutrition. *Plos One,* 11**,** 17.
IHME. 2017. *Institute for Health Metrics and Evaluation (IHME). GBD Compare* [Online]. Seattle, WA, USA: University of Washington. Available: http://ghdx.healthdata.org/gbd-results-tool [Accessed 28 MAY 2017].
JAGALS, P., JAGALS, C. & BOKAKO, T. 2003. The effect of container-biofilm on the microbiological quality of water used from plastic household containers. *Journal of water and health,* 1**,** 101-108.
JENKINS, M. & SCOTT, B. 2010. Sanitation Marketing for Managers: Guidance Tools for Programme development. Washington: USAID Hygiene Improvement Project, HIP.
JENKINS, M. W. & CURTIS, V. 2005. Achieving the 'good life': Why some people want latrines in rural Benin. *Social science & medicine,* 61**,** 2446-2459.
JENKINS, M. W. & SCOTT, B. 2007. Behavioral indicators of household decision-making and demand for sanitation and potential gains from social marketing in Ghana. *Social science & medicine,* 64**,** 2427-2442.
JENKINS, M. W. & SUGDEN, S. 2006. Rethinking sanitation: Lessons and innovation for sustainability and success in the new millennium. Human Development Report Office (HDRO), United Nations Development Programme (UNDP).
JEWITT, S. 2011. Geographies of shit Spatial and temporal variations in attitudes towards human waste. *Progress in Human Geography,* 35**,** 608-626.
JIANG, J.-Q., WANG, S. & PANAGOULOPOULOS, A. 2006. The exploration of potassium ferrate (VI) as a disinfectant/coagulant in water and wastewater treatment. *Chemosphere,* 63**,** 212-219.
JOHNSON, R. B. & ONWUEGBUZIE, A. J. 2004. Mixed Methods Research: A Research Paradigm Whose Time Has Come. *Educational Researcher,* 33**,** 14-26.

JOSÉ BORREGO, J., TORANZOS, G. A., MCFETERS, G. A. & SAVILL, M. 2007. Detection of Microorganisms in Environmental Freshwaters and Drinking Waters. *Manual of Environmental Microbiology.* Washington DC: ASM Press.

KAKULU, I. I. & BRISIBE, W. G. 2014. INCREASING FLOOD RESILIENCE IN BUILDINGS THROUGH ADAPTABLE DESIGNS: LEARNING FROM THE BAYELSA EXPERIENCE. *2nd International Conference on flood and erosion prevention, protection and mitigation,.* Port Harcourt.

KAR, K. & BONGARTZ, P. 2006. Update on Some Recent Developments in Community-Led Total Sanitation. *University of Sussex, Institute of Development Studies, Brighton, UK*.

KAR, K. & CHAMBERS, R. 2008. *Handbook on community-led total sanitation*, Plan UK London.

KARANIS, P. & KIMURA, A. 2002. Evaluation of three flocculation methods for the purification of Cryptosporidium parvum oocysts from water samples. *Letters in applied microbiology,* 34**,** 444-449.

KARRA, M., SUBRAMANIAN, S. V. & FINK, G. 2017. Height in healthy children in low- and middle-income countries: An assessment. *American Journal of Clinical Nutrition,* 105**,** 121-126.

KENNEDY-WALKER, R., EVANS, B., AMEZAGA, J. & PATERSON, C. 2014. Challenges for the future of urban sanitation planning: critical analysis of John Kalbermatten's influence.

KHAN, M., KHAN, M., HOSSAIN, B. & AHMED, Q. 1984. Alum potash in water to prevent cholera. *The Lancet,* 324**,** 1032.

KILAKIME, J., AMADI, A. C., AZUAMAH, C., AMADI, N. & ZACCHAEUS, U. 2015. Assessment of Excreta Disposal and its Health Implications in Tambiri Ii Community Biseni Bayelsa State Nigeria. *International Journal of Research,* 2**,** 85-93.

KITZINGER, J. 1995. Qualitative research. Introducing focus groups. *BMJ: British medical journal,* 311**,** 299.

KUMPEL, E. & NELSON, K. L. 2014. Mechanisms affecting water quality in an intermittent piped water supply. *Environmental science & technology,* 48**,** 2766-2775.

KVALE, S. 1996. *Interviews: an introduction to qualitative research interviewing,* Thousand Oaks;London;, Sage.

LARSEN, D. A., GRISHAM, T., SLAWSKY, E. & NARINE, L. 2017. An individual-level meta-analysis assessing the impact of community-level sanitation access on child stunting, anemia, and diarrhea: Evidence from DHS and MICS surveys. *PLOS Neglected Tropical Diseases,* 11**,** e0005591.

LEVY, K. 2015. Does Poor Water Quality Cause Diarrheal Disease? *American Journal of Tropical Medicine and Hygiene,* 93**,** 899-900.

LEVY, K., NELSON, K. L., HUBBARD, A. & EISENBERG, J. N. 2008. Following the water: a controlled study of drinking water storage in northern coastal Ecuador. *Environ Health Perspect,* 116**,** 1533-1540.

LEVY, K., NELSON, K. L., HUBBARD, A. & EISENBERG, J. N. 2012. Rethinking indicators of microbial drinking water quality for health studies in tropical developing countries: case study in northern coastal Ecuador. *The American journal of tropical medicine and hygiene,* 86**,** 499-507.

LIAMPUTTONG, P. 2011. *Focus group methodology: principle and practice,* London, SAGE.
LIAMPUTTONG, P. 2013. *Qualitative research methods,* South Melbourne, Vic, Oxford University Press.
LOZANO, R., NAGHAVI, M., FOREMAN, K., LIM, S., SHIBUYA, K., ABOYANS, V., ABRAHAM, J., ADAIR, T., AGGARWAL, R. & AHN, S. Y. 2012. Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *The Lancet,* 380**,** 2095-2128.
LUXEMBURGER, C., DUC, C. M., LANH, M. N., WAIN, J., HIEN, T. T., SIMPSON, J. A., THUY, N. T. T., WHITE, N. J. & FARRAR, J. J. 2001. Risk factors for typhoid fever in the Mekong delta, southern Viet Nam: a case-control study. *Transactions of the Royal Society of Tropical Medicine and Hygiene,* 95**,** 19-23.
MACHARIA, P. W., YILLIA, P. T., MUIA, W. A., BYAMUKAMA, D. & KREUZINGER, N. 2015. Microbial quality of domestic water: following the contamination chain in a rural township in Kenya. *Journal of Water, Sanitation and Hygiene for Development,* 5**,** 39-49.
MARA, D. 2012. Sanitation: What's the Real Problem? *IDS Bulletin,* 43**,** 86-92.
MARA, D., LANE, J., SCOTT, B. & TROUBA, D. 2010. Sanitation and health. *PLoS medicine,* 7**,** e1000363.
MARA, D. D. 2003. Water, sanitation and hygiene for the health of developing nations. *Public Health,* 117**,** 452-456.
MARACCINI, P. A., MATTIOLI, M. C. M., SASSOUBRE, L. M., CAO, Y., GRIFFITH, J. F., ERVIN, J. S., VAN DE WERFHORST, L. C. & BOEHM, A. B. 2016. Solar inactivation of enterococci and Escherichia coli in natural waters: Effects of water absorbance and depth. *Environmental science & technology,* 50**,** 5068-5076.
MARSHALL, M. N. 1996. Sampling for qualitative research. *Family practice,* 13**,** 522-526.
MATTIOLI, M. C., BOEHM, A. B., DAVIS, J., HARRIS, A. R., MRISHO, M. & PICKERING, A. J. 2014. Enteric pathogens in stored drinking water and on caregiver's hands in Tanzanian households with and without reported cases of child diarrhea. *PloS one,* 9**,** e84939.
MAYS, N. & POPE, C. 1995. Rigour and qualitative research. *BMJ: British Medical Journal,* 311**,** 109.
MOE, C., SOBSEY, M., SAMSA, G. & MESOLO, V. 1991. Bacterial indicators of risk of diarrhoeal disease from drinking-water in the Philippines. *Bulletin of the World Health Organization,* 69**,** 305.
MOMBA, M. N. & KALENI, P. 2002. Regrowth and survival of indicator microorganisms on the surfaces of household containers used for the storage of drinking water in rural communities of South Africa. *Water Research,* 36**,** 3023-3028.
MOMBA, M. N. & NOTSHE, T. 2003. The microbiological quality of groundwater-derived drinking water after long storage in household containers in a rural community of South Africa. *Journal of Water Supply: Research and Technology-Aqua,* 52**,** 67-77.
MORGAN, D. L. & SPANISH, M. T. 1984. Focus groups: A new tool for qualitative research. *Qualitative sociology,* 7**,** 253-270.

MUKHERJEE, N. 2001. *Achieving Sustained Sanitation for the Poor: Policy and Strategy Lessons from Participatory Assessments in Cambodia, Indonesia, Vietnam*, Water and Sanitation Program for East Asia and the Pacific.
MUKHERJEE, N. 2009. Total Sanitation and Sanitation Marketing Project: Indonesia Country Update June 2009 Learning at Scale. World Bank Water and Sanitation Programme, WSP.
MUKHERJEE, N. 2011. Factors Associated with Achieving and Sustaining Open Defecation Free Communities: Learning from East Java. Water and Sanitation Programme, WSP.
NBS 2013a. Annual Abstract of Statistics 2011. National Bureau of Statistics, Federal Republic of Nigeria.
NBS 2013b. Nigeria Multiple Indicator Cluster Survey 2011. FEDERAL REPUBLIC OF NIGERIA, NATIONAL BUREAU OF STATISTICS.
NBS 2014a. Annual Abstract of Statistics 2012. NATIONAL BUREAU OF STATISTICS, Federal Republic of Nigeria.
NBS 2014b. Demograhpic Statistics Bulletin 2013. National Bureau of Statistics.
NDDC Niger Delta Regional Development Master Plan.
NELSON, K. L. & MURRAY, A. 2008. Sanitation for Unserved Populations: Technologies, Implementation Challenges, and Opportunities. *Annual Review of Environment and Resources,* 33**,** 119-151.
NIS 2009. General Population Census of Cambodia 2008: National Report on Final Census Results. National Institute of Statistics, Ministry of Planning, .
NJUGUNA, J. 2016. Effect of eliminating open defecation on diarrhoeal morbidity: an ecological study of Nyando and Nambale sub-counties, Kenya. *Bmc Public Health,* 16**,** 6.
NPC 2007. Priority table Vol 9 Size of Household. Nigeria: National Population Commission Nigeria.
NPC & ICFI 2014. Nigeria Demographic and Health Survey 2013. National Population Commission, Abuja, Nigeria and ICF International, Rockville, Maryland, USA.
NWANKWOALA, H., EGESI, N. & AGI, C. 2016. Analysis of the water resources of Kaiama area of Bayelsa State, Eastern Niger Delta. *International Journal of Environmental Science and Technology,* 1**,** 7-12.
NYELETI, C., COGAN, T. & HUMPHREY, T. 2004. Effect of sunlight on the survival of Salmonella on surfaces. *Journal of applied microbiology,* 97**,** 617-620.
ODAGIRI, M., SCHRIEWER, A., DANIELS, M. E., WUERTZ, S., SMITH, W. A., CLASEN, T., SCHMIDT, W.-P., JIN, Y., TORONDEL, B., MISRA, P. R., PANIGRAHI, P. & JENKINS, M. W. 2016. Human fecal and pathogen exposure pathways in rural Indian villages and the effect of increased latrine coverage. *Water Research,* 100**,** 232-244.
ODULARU, G. O. 2008. Crude oil and the Nigerian economic performance. *Oil and Gas Business***,** 1-29.
OGBONNA, D. N. & IDAM, D. Y. 2007. Appropriate sanitation systems for low-income coastal and water front communities in the Niger Delta, Nigeria. *Journal of Applied Sciences,* 7**,** 1116-1123.

OMEJE, K. 2004. The state, conflict & evolving politics in the Niger Delta, Nigeria. *Review of African Political Economy,* 31**,** 425-440.
OO, K. N., AUNG, K. S., THIDA, M., KHINE, W. W., SOE, M. M. & AYE, T. 1993. Effectiveness of potash alum in decontaminating household water. *Journal of diarrhoeal diseases research***,** 172-174.
OPPENHEIM, A. N. 2003. *Questionnaire design, interviewing and attitude measurement,* London, Continuum.
OPPEZZO, O. J. 2012. Contribution of UVB radiation to bacterial inactivation by natural sunlight. *Journal of Photochemistry and Photobiology B: Biology,* 115**,** 58-62.
PALINTEST® Potatest® 2 Advanced Portable Water Quality Laboratory (Microbiological).
PALLANT, J. 2013. *SPSS survival manual*, McGraw-Hill Education (UK).
PARKER, A. & TRITTER, J. 2006. Focus group method and methodology: current practice and recent debate. *International Journal of Research & Method in Education,* 29**,** 23-37.
PATIL, S. R., ARNOLD, B. F., SALVATORE, A. L., BRICENO, B., GANGULY, S., COLFORD, J. M. & GERTLER, P. J. 2014. The Effect of India's Total Sanitation Campaign on Defecation Behaviors and Child Health in Rural Madhya Pradesh: A Cluster Randomized Controlled Trial. *Plos Medicine,* 11**,** 17.
PATTON, M. Q. 2002. *Qualitative Research and Evaluation Methods*, Sage Publications.
PEAL, A., EVANS, B. & VAN DER VOORDEN, C. 2010. Hygiene and Sanitation Software: An Overview of Approaches.
PENG, X., NG, T. W., HUANG, G., WANG, W., AN, T. & WONG, P. K. 2017. Bacterial disinfection in a sunlight/visible-light-driven photocatalytic reactor by recyclable natural magnetic sphalerite. *Chemosphere,* 166**,** 521-527.
PICKERING, A. J., BOEHM, A. B., MWANJALI, M. & DAVIS, J. 2010. Efficacy of waterless hand hygiene compared with handwashing with soap: a field study in Dar es Salaam, Tanzania. *The American journal of tropical medicine and hygiene,* 82**,** 270-278.
PICKERING, A. J., DJEBBARI, H., LOPEZ, C., COULIBALY, M. & ALZUA, M. L. 2015. Effect of a community-led sanitation intervention on child diarrhoea and child growth in rural Mali: a cluster-randomised controlled trial. *Lancet Global Health,* 3**,** E701-E711.
PICKERING, A. J., JULIAN, T. R., MAMUYA, S., BOEHM, A. B. & DAVIS, J. 2011. Bacterial hand contamination among Tanzanian mothers varies temporally and following household activities. *Tropical Medicine & International Health,* 16**,** 233-239.
PRÜSS-ÜSTÜN, A., BOS, R., GORE, F. & BARTRAM, J. 2008. *Safer water, better health: costs, benefits and sustainability of interventions to protect and promote health*, World Health Organization.
PRÜSS-USTÜN, A., BARTRAM, J., CLASEN, T., COLFORD, J. M., CUMMING, O., CURTIS, V., BONJOUR, S., DANGOUR, A. D., DE FRANCE, J. & FEWTRELL, L. 2014. Burden of disease from inadequate water, sanitation and hygiene in low-and middle-income settings: a retrospective analysis of data from 145 countries. *Tropical Medicine & International Health*.

PRÜSS, A., KAY, D., FEWTRELL, L. & BARTRAM, J. 2002. Estimating the burden of disease from water, sanitation, and hygiene at a global level. *Environmental health perspectives,* 110**,** 537-542.
PUNCH, K. 2014. *Introduction to social research: quantitative & qualitative approaches,* London, SAGE Publications Ltd.
RAJGIRE, A. 2013. Open defecation: a prominent source of pollution in drinking water in villages. *International journal of life sciences biotechnology and pharma research,* 2**,** 238-246.
RAM, P. K., JAHID, I., HALDER, A. K., NYGREN, B., ISLAM, M. S., GRANGER, S. P., MOLYNEAUX, J. W. & LUBY, S. P. 2011. Variability in hand contamination based on serial measurements: implications for assessment of hand-cleansing behavior and disease risk. *The American journal of tropical medicine and hygiene,* 84**,** 510-516.
ROOT, G. P. M. 2001. Sanitation, community environments, and childhood diarrhoea in rural Zimbabwe. *Journal of Health Population and Nutrition,* 19**,** 73-82.
ROSENBOOM, J. W., JACKS, C., PHYRUM, K., ROBERTS, M. & BAKER, T. 2011. Sanitation marketing in Cambodia. *Waterlines,* 30**,** 21-40.
ROTHSCHILD, M. L. 1999. Carrots, Sticks, and Promises: A Conceptual Framework for the Management of Public Health and Social Issue Behaviors. *Journal of Marketing,* 63.
SABOORI, S., GREENE, L. E., MOE, C. L., FREEMAN, M. C., CARUSO, B. A., AKOKO, D. & RHEINGANS, R. D. 2013. Impact of Regular Soap Provision to Primary Schools on Hand Washing and E. coli Hand Contamination among Pupils in Nyanza Province, Kenya: A Cluster-Randomized Trial. *The American journal of tropical medicine and hygiene,* 89**,** 698-708.
SALTER, D. 2008. Identifying constraints to increasing sanitation coverage: sanitation demand and supply in Cambodia. *Phnom Penh: Water and Sanitation Program*.
SANAN, D. & MOULIK, S. G. 2007. Community-led total sanitation in rural areas: an approach that works.
SANTOS, A. C., ROBERTS, J. A., BARRETO, M. L. & CAIRNCROSS, S. 2011. Demand for sanitation in Salvador, Brazil: A hybrid choice approach. *Social Science & Medicine,* 72**,** 1325-1332.
SCHREIER, M. 2012. *Qualitative content analysis in practice*, Sage Publications.
SCLAR, G. D., PENAKALAPATI, G., AMATO, H. K., GARN, J. V., ALEXANDER, K., FREEMAN, M. C., BOISSON, S., MEDLICOTT, K. O. & CLASEN, T. 2016. Assessing the impact of sanitation on indicators of fecal exposure along principal transmission pathways: A systematic review. *International Journal of Hygiene and Environmental Health,* 219**,** 709-723.
SEYOUM, S. & GRAHAM, J. P. 2016. Equity in access to water supply and sanitation in Ethiopia: an analysis of EDHS data (2000-2011). *Journal of Water Sanitation and Hygiene for Development,* 6**,** 320-330.
SIJBESMA, C., TRUONG, T. X. & DEVINE, J. 2010. Case study on sustainability of rural sanitation marketing in Vietnam. *Water and Sanitation Program, Washington, DC and IRC International Water and Sanitation Centre, The Hague*.

SINGH, U., LUTCHMANARIYAN, R., WRIGHT, J., KNIGHT, S., JACKSON, S., LANGMARK, J., VOSLOO, D. & RODDA, N. 2013. Microbial quality of drinking water from groundtanks and tankers at source and point-of-use in eThekwini Municipality, South Africa, and its relationship to health outcomes. *Water Sa,* 39**,** 663-673.

SOMMER, M. & SAHIN, M. 2013. Overcoming the Taboo Advancing the Global Agenda for Menstrual Hygiene Management for Schoolgirls. *AMERICAN JOURNAL OF PUBLIC HEALTH,* 103**,** 1556-1559.

SON 2007. Nigerian Standard for Drinking Water Quality. *In:* NIGERIA, S. O. O. (ed.). Price group.

SORENSEN, J. P. R., SADHU, A., SAMPATH, G., SUGDEN, S., DUTTA GUPTA, S., LAPWORTH, D. J., MARCHANT, B. P. & PEDLEY, S. 2016. Are sanitation interventions a threat to drinking water supplies in rural India? An application of tryptophan-like fluorescence. *Water Research,* 88**,** 923-932.

SPEARS, D., GHOSH, A. & CUMMING, O. 2013. Open defecation and childhood stunting in India: an ecological analysis of new data from 112 districts. *PLoS One,* 8**,** e73784.

SPEICH, B., CROLL, D., FÜRST, T., UTZINGER, J. & KEISER, J. 2016. Effect of sanitation and water treatment on intestinal protozoa infection: a systematic review and meta-analysis. *The Lancet. Infectious diseases,* 16**,** 87-99.

STRUNZ, E. C., ADDISS, D. G., STOCKS, M. E., OGDEN, S., UTZINGER, J. & FREEMAN, M. C. 2014. Water, Sanitation, Hygiene, and Soil-Transmitted Helminth Infection: A Systematic Review and Meta-Analysis. *Plos Medicine,* 11**,** 38.

TILLEY, E. & GUNTHER, I. 2016. The Impact of Conditional Cash Transfer on Toilet Use in eThekwini, South Africa. *Sustainability,* 8**,** 16.

TONGCO, M. D. C. 2007. Purposive sampling as a tool for informant selection.

TORLESSE, H., CRONIN, A. A., SEBAYANG, S. K. & NANDY, R. 2016. Determinants of stunting in Indonesian children: evidence from a cross-sectional survey indicate a prominent role for the water, sanitation and hygiene sector in stunting reduction. *Bmc Public Health,* 16**,** 11.

UDDIN, S. M. N., MUHANDIKI, V. S., FUKUDA, J., NAKAMURA, M. & SAKAI, A. 2012. Assessment of social acceptance and scope of scaling up urine diversion dehydration toilets in Kenya. *Journal of Water Sanitation and Hygiene for Development,* 2**,** 182-189.

UN 2015a. Levels and trends in child mortality. Report 2015. Estimates developed by the UN Inter-agency Group for Child Mortality Estimation. New York: UNICEF.

UN. 2015b. *Sustainable Development Goals* [Online]. WASHINGTON DC.: UNITED NATIONS. [Accessed 04 JULY 2017].

UNICEF. 2012. *Maternal and child health* [Online]. UNICEF NIGERIA. Available: https://www.unicef.org/nigeria/children_1926.html [Accessed 28TH MAY 2017].

VAN HUU, B., HILL, C. & NARA, I. Very small floating structure in prek toal core area of tonle sap biosphere reserve.

VANDERSLICE, J. & BRISCOE, J. 1993. All coliforms are not created equal - a comparison of the effects of water source and in-house water contamination on infantile diarrheal disease. *Water Resources Research,* 29**,** 1983-1995.
WATERKEYN, J. & CAIRNCROSS, S. 2005. Creating demand for sanitation and hygiene through Community Health Clubs: A cost-effective intervention in two districts in Zimbabwe. *Social Science & Medicine,* 61**,** 1958-1970.
WATSON, R. 2015. Quantitative research. *Nursing standard (Royal College of Nursing (Great Britain) : 1987),* 29**,** 44.
WEAVER, E. R. N., AGIUS, P. A., VEALE, H., DORNING, K., HLANG, T. T., AUNG, P. P., FOWKES, F. J. I. & HELLARD, M. E. 2016. Water, sanitation, and hygiene facilities and hygiene practices associated with diarrhea and vomiting in monastic schools, myanmar. *American Journal of Tropical Medicine and Hygiene,* 95**,** 278-287.
WHO 1997. Participatory Hygiene And Sanitation Transformation - A new qapproach to working with communities. World Health Organisation.
WHO 2011. *Guidelines for Drinking-water Quality*, World Health Organization.
WHO 2016. World health statistics 2016: monitoring health for the SDGs, sustainable development goals. World Health Organization.
WHO/UNICEF 2013. Progress on Sanitation and Drinking-Water 2013 update. World Health Organisation and UNICEF.
WHO/UNICEF 2015. Progress on Drinking-Water and Sanitation–2015 Update and MDG Assessment.
WHO/UNICEF/WSSCC 10 Things you need to know about Sanitation. WHO.
WOLF, J., PRUSS-USTUN, A., CUMMING, O., BARTRAM, J., BONJOUR, S., CAIRNCROSS, S., CLASEN, T., COLFORD, J. M., CURTIS, V., DE FRANCE, J., FEWTRELL, L., FREEMAN, M. C., GORDON, B., HUNTER, P. R., JEANDRON, A., JOHNSTON, R. B., MAUSEZAHL, D., MATHERS, C., NEIRA, M. & HIGGINS, J. P. T. 2014a. Assessing the impact of drinking water and sanitation on diarrhoeal disease in low- and middle-income settings: systematic review and meta-regression. *Tropical Medicine & International Health,* 19**,** 928-942.
WOLF, J., PRÜSS-USTÜN, A., CUMMING, O., BARTRAM, J., BONJOUR, S., CAIRNCROSS, S., CLASEN, T., COLFORD, J. M., CURTIS, V. & FRANCE, J. 2014b. Systematic review: assessing the impact of drinking water and sanitation on diarrhoeal disease in low-and middle-income settings: systematic review and meta-regression. *Tropical Medicine & International Health,* 19**,** 928-942.
WRIGHT, J., GUNDRY, S. & CONROY, R. 2004. Household drinking water in developing countries: a systematic review of microbiological contamination between source and point-of-use. *Tropical Medicine & International Health,* 9**,** 106-117.
WRIGLEY, T. 2002. Low cost water treatment in the Mekong basin. *Water 21***,** 47-48.
WSP 2009. Market Research Assessment in Rural Tanzania for New Approaches to Stimulate and Scale up Sanitation Demand and Supply. Water and Sanitation Programme.
YIN, R. K. 2014. *Case study research: design and methods,* Los Angeles, SAGE.

ZIEGELBAUER, K., SPEICH, B., MÄUSEZAHL, D., BOS, R., KEISER, J. & UTZINGER, J. 2012. Effect of sanitation on soil-transmitted helminth infection: systematic review and meta-analysis. *PLoS medicine,* 9**,** e1001162.

Appendix A : Ethical Approval for field work

Performance, Governance and Operations
Research & Innovation Service
Charles Thackrah Building
101 Clarendon Road
Leeds LS2 9LJ Tel: 0113 343 4873
Email: ResearchEthics@leeds.ac.uk

UNIVERSITY OF LEEDS

Esther Sample
Civil Engineering
University of Leeds
Leeds, LS2 9JT

MaPS and Engineering joint Faculty Research Ethics Committee (MEEC FREC)
University of Leeds

23 May 2014

Dear Esther

Title of study **Improving sanitation in rural littoral communities of developing countries**
Ethics reference **MEEC 13-021**

I am pleased to inform you that the application listed above has been reviewed by the MaPS and Engineering joint Faculty Research Ethics Committee (MEEC FREC) and I can confirm a favourable ethical opinion as of the date of this letter. The following documentation was considered:

Document	*Version*	*Date*
MEEC 13-021 Ethical Review Form- Esther Sample.pdf	1	07/05/14
MEEC 13-021 Fieldwork Risk Assessment Form - Esther Sample.pdf	1	07/05/14
MEEC 13-021 Participant Information sheet.docx	1	07/05/14
MEEC 13-021 Collaboration letter.pdf	1	07/05/14

The Committee would like to emphasise the need to communicate the information about the study in a way that is accessible to the younger children.

Some Committee members felt that the language in the consent form was over-complicated and uses words which may not be understandable to the potential participants, not just the children i.e. the use of the phrase 'sanitation experiences', also the whole section under 'what will I benefit...'. It would be very easy to write this in simple language. You had already identified that there may be people uncomfortable with signing papers, and who may need interpreters.

Please notify the committee if you intend to make any amendments to the original research as submitted at date of this approval, including changes to recruitment methodology. All changes must receive ethical approval prior to implementation. The amendment form is available at http://ris.leeds.ac.uk/EthicsAmendment.

Please note: You are expected to keep a record of all your approved documentation, as well as documents such as sample consent forms, and other documents relating to the study. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two week notice period if your project is to be audited. There is a checklist listing examples of documents to be kept which is available at http://ris.leeds.ac.uk/EthicsAudits.

We welcome feedback on your experience of the ethical review process and suggestions for improvement. Please email any comments to ResearchEthics@leeds.ac.uk.

Yours sincerely

Jennifer Blaikie
Senior Research Ethics Administrator, Research & Innovation Service
On behalf of Professor Gary Williamson, Chair, MEEC FREC

CC: Student's supervisor(s)

Performance, Governance and Operations
Research & Innovation Service
Charles Thackrah Building
101 Clarendon Road
Leeds LS2 9LJ Tel: 0113 343 4873
Email: ResearchEthics@leeds.ac.uk

UNIVERSITY OF LEEDS

Esther Sample
School of Civil Engineering
University of Leeds
Leeds, LS2 9JT

MaPS and Engineering joint Faculty Research Ethics Committee (MEEC FREC)
University of Leeds

15 April 2015

Dear Esther

Title of study **Improving sanitation in rural littoral communities of developing countries**
Ethics reference **MEEC 14-023**

I am pleased to inform you that the application listed above has been reviewed by the MaPS and Engineering joint Faculty Research Ethics Committee (MEEC FREC) and following receipt of your response to the Committee's initial comments, I can confirm a favourable ethical opinion as of the date of this letter. The following documentation was considered:

Document	*Version*	*Date*
MEEC 14-023 Revised Ethical Review Application - Esther Sample.pdf	2	01/04/15
MEEC 14-023 Fieldwork Risk Assessment Form - Esther Sample.pdf	1	17/03/15
MEEC 14-023 Participant Information sheet for Children school group survey.docx	2	01/04/15
MEEC 14-023 Participant Information sheet.docx	2	01/04/15
MEEC 14-023 Household Survey Questionnaire.docx	1	17/03/15
MEEC 14-023 School Survey Questionnaire.docx	1	17/03/15
MEEC 14-023 Response to comments from Ethics Committee.docx	1	01/04/15

Please notify the committee if you intend to make any amendments to the original research as submitted at date of this approval, including changes to recruitment methodology. All changes must receive ethical approval prior to implementation. The amendment form is available at http://ris.leeds.ac.uk/EthicsAmendment.

Please note: You are expected to keep a record of all your approved documentation, as well as documents such as sample consent forms, and other documents relating to the study. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two week notice period if your project is to be audited. There is a checklist listing examples of documents to be kept which is available at http://ris.leeds.ac.uk/EthicsAudits.

We welcome feedback on your experience of the ethical review process and suggestions for improvement. Please email any comments to ResearchEthics@leeds.ac.uk.

Yours sincerely

Jennifer Blaikie
Senior Research Ethics Administrator, Research & Innovation Service
On behalf of Professor Gary Williamson, Chair, MEEC FREC

CC: Student's supervisor(s)

Appendix B : Household survey Questionnaire

Sanitation in Riverine Communities of Developing Countries.
Household Survey QuestionnaireSanitation in Riverine Communities of Developing Countries. Household Survey Questionnaire

House I.D No. Name of Community Click here to enter text.

Date of interview Click here to enter a date. Start Time Click here to enter text.

Interviewer's Name: Esther Sample Esther Sample End Time Click here to enter text.

Northings: Click here to enter text. Eastings Click here to enter text.

Instructions: please tick the box or fill in the space as appropriate

A. Participant Characteristics

i. Age range (in years) ☐15-25 ☐26-35 ☐36-45 ☐46-55 ☐56 and over	ii. Gender ☐Male ☐Female
iii. Occupation ☐Farming ☐Trading ☐Civil servant ☐Fishing ☐Others	iv. Highest level of education ☐None ☐Primary School ☐Secondary School ☐Tertiary Education

B. Household Characteristics

v. How many people live in your household? ☐1 ☐2	vi. In household, Total No. of Male Click here to enter text.

☐3 ☐4 ☐5 and more	Total No. Female Click here to enter text. No. of Adults Click here to enter text. No. of Children Click here to enter text.
vii. How many children in your household are less than 5 years old? ☐0 ☐1 ☐2 ☐3 or more	viii. What type of property is your household living in? ☐Owner occupied ☐Rented ☐Rent free but not owned ☐Others Click here to enter text.

C. Water Source, storage and treatment

Question 1	Options	Code
What is your main source of drinking water?	☐Borehole within compound (free) ☐Borehole within compound (paid) ☐Public borehole (free) ☐Public borehole (paid) ☐Well with raised sides and cover ☐Well – no raised sides, no cover ☐River ☐Rainwater ☐Pure Water ☐Others Click here to enter text.	
Question 2	Options	Code
Do you use this source of drinking water all year round?	☐Yes ☐No. Please specify alternative source	
Question 3	Options	Code

How do you store your drinking water at home?	☐Do not store drinking water ☐In an open water pot ☐In a water pot with cover ☐In a plastic bucket with cover ☐In an open plastic bucket ☐In a jerry can with cover ☐In a jerry can without cover ☐Open basin ☐Open drum ☐Drum with cover ☐Others Click here to enter text.	
Question 4	Options	Code
How long do you store one cycle of collected drinking water for?	☐Do not store drinking water ☐Replace daily ☐2-4 days ☐5-10 days ☐Over 10 days ☐Others Click here to enter text.	
Question 5	Options	Code
How do you collect a portion of the stored water when you need a drink?	☐Using any container with a handle always ☐Using any container, with or without a handle ☐Others Click here to enter text.	
Question 6	Options	Code
At what age can children under 5 collect a portion of stored drinking	☐Under 5 years ☐5-10years ☐Over 10 years	

water to drink without help?	☐No children under 5 in household ☐No specific age ☐I don't know ☐Whenever they are ready	
Question 7	Options	Code
How do you treat your drinking water	☐No treatment ☐Boiling ☐Filtering through cloth ☐Adding chlorine ☐Use of Alum ☐Leaving to stand and pouring out the clear portion ☐Add Camphor ☐Add Dettol ☐Others Click here to enter text.	
Question 8	Options (more than one can be selected)	Code
What is your source of water for washing, bathing, cooking	☐Borehole within compound (free) ☐Borehole within compound (paid) ☐Public borehole (free) ☐Public borehole (paid) ☐Well with raised sides and cover ☐Well – no raised sides, no cover ☐River ☐Rainwater ☐Others Click here to enter text.	

D. Hand Hygiene Behaviour

Question 9	Responses	Code
At what activity times	Click here to enter text.	

in a day do you wash your hands		
Question 10	Responses	Code
At what activity times in a day do children under five in your household wash their hands	Click here to enter text.	
Question 11	Options (more than one can be selected)	Code
What do you use to wash your hands	☐Water only always ☐Water only, most of the time ☐Water and soap always ☐Water and soap most of the time ☐Sand ☐Ash ☐Others Click here to enter text.	
Question 12	Options (more than one can be selected)	Code
Describe how you wash your hands before a meal	Click here to enter text.	

E. Sanitation Infrastructure and Behaviour

Question 13	Options (more than one can be selected)	Code
Where do you urinate	☐Open pit latrine ☐Pit latrine with slab	

when at home	☐Pour flush to pit/septic tank ☐In nearby bushes ☐Behind your house ☐Overhang latrine at the river ☐Public/community shared toilet ☐Others	
Question 14	Options (more than one can be selected)	Code
Where do you urinate when you are away from home	☐Open pit latrine ☐Pit latrine with slab ☐Pour flush to pit/septic tank ☐In nearby bushes ☐Behind any building ☐ In the river ☐Public/community shared toilet ☐Go back home ☐Others Click here to enter text.	
Question 15	Options (more than one can be selected)	Code
Where do you poo when at home	☐Open pit latrine ☐Pit latrine with slab ☐Pour flush to pit/septic tank ☐Poo, wrap and dispose with household waste ☐Poo, wrap and dispose in nearby bushes ☐Poo, wrap and dispose in the river ☐Shallow hole in ground covered immediately with sand ☐Open defecation in nearby bushes ☐Open defecation direct into river ☐Public/community shared toilet ☐Others Click here to enter text.	

Question 16	Options (more than one can be selected)	Code
Where do children under 5yrs within your household poo when at home	☐Anywhere on the ground outside the compound then wrapped and disposed in nearby bush ☐In a potty or its equivalent, emptied into the toilet within the household ☐Anywhere on the ground then wrapped and disposed with household waste in the river or dump site ☐On paper or leaves placed on the floor, then wrapped and disposed in nearby bush ☐On plastic bag placed on the floor, then wrapped and disposed in waste pit ☐ No child under 5 within household	
Question 17	Options (more than one can be selected)	Code
Where do you poo when at church/ place of worship?	☐Go back home ☐Go to a friend or relative's house near my location to use their toilet ☐Poo and dispose in nearby bushes ☐Poo and dispose in the river ☐Open defecation in nearby bushes ☐Open defecation directly into the river ☐Use shared pour flush or pit toilet within the Church or place of worship premises/compound ☐Not applicable	
Question 18	Options (more than one can be selected)	Code
Where do you poo when at the market or other community space	☐Go back home ☐ Go to a friend or relative's house near my location to use their toilet ☐Poo, wrap and dispose in nearby bushes ☐Poo, wrap and dispose in the river ☐Open defecation in nearby bushes	

	☐Open defecation directly into river ☐Public/community shared toilet ☐Others Click here to enter text.	
Question 19	Options (more than one can be selected)	Code
Where do you poo when at work	☐Go back home ☐Open pit latrine ☐Pit latrine with slab ☐Pour flush to pit/septic tank ☐Poo, wrap and dispose with household waste ☐Poo, wrap and dispose in nearby bushes ☐Poo, wrap and dispose in the river ☐Shallow hole in ground covered immediately with sand ☐Open defecation in nearby bushes ☐Open defecation direct into river ☐Public/community shared toilet ☐Others Click here to enter text.	
Question 20	Options	Code
If you have a toilet at home, how many other households do you share it with	☐No toilet at home ☐Do not share ☐1 ☐2 ☐3 – 5 ☐More than 5 ☐I don't know	
Question 21	Options	Code
Are there any public	☐Yes ☐No	

toilets in your community	☐I don't know	
Question 22	Options	Code
Are the public toilets free	☐Yes ☐No, please specify charge per use Click here to enter text. ☐I don't know	

F. Knowledge of Diarrhoea

Question 23	Responses	Code
What is diarrhoea	Click here to enter text.	
Question 24	Responses	Code
What are the causes of diarrhoea	Click here to enter text.	
Question 25	Responses	Code
What are the main symptoms of diarrhoea	Click here to enter text.	
Question 26	Response	Code
Has anyone in your household experienced any of these symptoms in the past 2 weeks	☐No ☐Yes. Please give details Click here to enter text.	
Question 27	Responses	Code
What would you do first if someone had	Click here to enter text.	

diarrhoea in your household		

G. Flooding Experience

Question 28	Options	Code
How often does flooding occur in your community	☐Never ☐Every year ☐Every 2-5 years ☐More than 5 years intervals	
Question 29	Responses	Code
What part of your community suffers more from floods	Click here to enter text.	
Question 30	Responses	Code
During what months of the year do you experience flooding		
Question 31	Options	Code
During floods, how often do you come in contact with flood waters in a week	☐Never ☐Once a week ☐Two times a week ☐Three times a week ☐Everyday	
Question 32	Responses	Code
During floods, how often do children under 5 in your	☐Never ☐Once a week	

household play in flood waters in a week	☐Two times a week ☐Three times a week ☐Everyday ☐ No Children under 5 within household	
Question 33	Options	Code
Has your home ever been flooded	☐No ☐Yes	
Question 34	Responses	Code
How did you get the flood water out of your home		

Appendix C : Microbiological Sample Collection and Processing Form

Microbiological Sample Collection and Processing Form

Sample Collection

Sample ID — Sample Type :

Eastings…… — Northings……

Sample Collection Date……. — Sample Collection Time……..

Name of community …Kaiama…… — Name of Sample Collector ……

Sample Description

……
……
……
……
……
……
……

Sample Processing

Name of Sample Processor: ……

Sample processing Date — Sample Processing Time ……..

Date placed in incubator — Time placed in incubator ……..

Date removed from incubator — Time removed from incubator……..

Vol of sample was filtered:

Sample	Dilution							E.Coli Count (CFU/100ml)
	1:1	1:10	1:100	1:1000	1:10000	1:100000	1:1000000	
Sample								
Duplicate								

Results taken by …. ……