Current and Future Emissions of Urban Chemicals into the Aquatic Environment

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June 2023

Abstract

Urban environments are hot spots for chemical use and emissions and urban aquatic systems are under constant pressure from exposure to chemical mixtures. Chemical emissions and impacts are expected to change in the future due to socio-economic, climate and technological changes. However, the impact of these changes on chemical use and emissions is uncertain. This study therefore investigated how the emissions of chemicals of concern in European urban aquatic systems might evolve in the future due to global changes.

A systematic review demonstrated that more than 1100 chemicals, belonging to 19 class categories, have been detected in urban environments around the globe. Comparison of the measured concentrations with ecotoxicological data indicated that 168 of these chemicals pose an unacceptable risk for at least one location and should be regarded as priority chemicals.

To determine the current level of risk associated with selected priority chemicals in Europe, two antibiotics and ten metals were monitored in rivers in York (UK), Madrid (Spain) and Olso (Norway) for one year. Results showed that aluminium, zinc, iron, copper, mercury, chromium and the antibiotic clarithromycin all posed an unacceptable risk.

To investigate how chemicals emissions might change in the future, a framework was developed to extend the Shared Socio-economic Pathway approach, an approach used in climate change forecasting, to forecast changes in chemical emissions in the future. Following, pilot-testing with insecticidal products and antidepressants, the framework was used to forecast antibiotics emission in European freshwater systems in 2050. This resulted in a number of different future emission scenarios characterised by either an increase or decrease in antibiotic emissions depending on the pathway.

Overall, the thesis has demonstrated that chemical pollutants do pose an unacceptable risk to European urban aquatic environment. It illustrates how emissions of chemicals are likely to increase or decrease in the future depending on the pathways that society follows. The findings will be invaluable to decision makers involved in the risk assessment and management of chemical products and the natural environment.

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Abbreviations

AA-EQS	Annual Average Environmental Quality Standard
AF	Assessment Factor
AMAP	Arctic Monitoring and Assessment Programme
AMR	Antimicrobial Resistance
BBP	Benzyl butyl phthalate
DEET	N,N-Diethyl-meta-toluamide
DEHP	Di(2-ethylhexyl)phthalate
EC	European Commission
EC50	Half-Maximal Effective Concentration
ECHA	European Chemicals Agency
ECOSAR	Ecological Structure Activity Relationships
EPA	United States Environmental Protection Agency
EQS	Environmental Quality Standard
GMO	Genetically Modified Organisms
GNI	Gross National Income
HIV	Human Immunodeficiency Virus
HPLC-MS	High Performance Liquid Chromatography Mass Spectrometry
ICO	International Coffee Organisation
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
IPCC	Intergovernmental Panel on Climate Change
IVIVE	*in-vitro-to-in-vivo* Extrapolation
LC	Liquid chromatography
LC50	Concentration required to kill 50% of the population
LC-MS/MS	Liquid chromatography-tandem mass spectrometry
LOD	Limit of Detection
LOQ	Limit of Quantification
MAC-EQS	Maximum Average Concentration Environmental Quality Standard
MEC	Measured Environmental Concentration
MS	Mass Spectrometry
ND	Mot Detected
NOEC	No Observable Effect Concentration
OECD	Organization for Economic Cooperation and Development
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
PAHs	Polycyclic Aromatic Hydrocarbons
PBT	Persistent Bioaccumulative Toxic
PCBs	Polychlorinated Biphenyls
PEC	Predicted Environmental Concentration
PFBA	Perfluorobutanoic acid
PFCA	Perfluoroalkyl carboxylic acids
PFCs	Perfluorochemicals
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonic acid
PNEC	Predicted No Effect Concentrations

QC	Quality control
QSAR	Quantitative Structure–Activity Relationships
RCP	Representative Concentration Pathways
REACH	Registration, Evaluation and Authorization of Chemicals
RQ	Risk Quotient
SSP	Shared Socio-Economic Pathways
STP	Sewage Treatment Plant
TKTD	Toxicokinetic Toxicodynamic
UE	European Union
UN	United Nations
UNEP	United Nations Environment Programme
USGCRP	United States Global Climate Research Program
UV	Ultraviolet
WBD	World Bank Data
WFD	Water Framework Directive
WHO	World Health Organization
WWTP	Wastewater Treatment Plant

Acknowledgements

I would like to express my sincere gratitude to my supervisors, Alistair Boxall and Brett Sallach, who have granted me tremendous freedom to conduct this research while consistently providing support, encouragement, and guidance throughout my PhD journey. I am very grateful for everything I have learned.

I would also like to thank Kasper Kok and Simona Pedde who gave me the opportunity to do a secondment at Wageningen University. Your guidance and questioning on how to include the societal dynamics within research fields have influenced the way I aspire to conduct research in the future.

A special mention to Ed Bergstrom who skillfully transformed a HPLC-MS analysis nightmare into an enjoyable learning opportunity in the field of chemical analysis. I have learned so much and your time, support and guidance have deeply touched me.

A big thank you to past and current PhDs fellows from the Boxall, Sallach and Environmental research group. Ari, Karine, Luke, Ruru, Victoria and Alice, thank you for your constant help, support and for making such a nice working environment. You held my motivation during the difficult time.

I was so lucky to be part of the ECORISK2050 project with great ESRs fellows: Poornima, Rudi, Taylor, Andrei, Anju, John, Markus, Francesco, Sabrina, Sophia, Sam and Joanke. Thank you for the support, your friendship and all the great times! I am looking forward to continuing my career alongside all of you.

I would like to thank my friends Maria, Amalia, Ellen, Danaë, Constant, Baptiste, Lulu, Anne, Marlène, Milan, Arnaud, Alexandre and Meg. Your friendship during this endless journey and in my life is priceless. A special mention to Clarisse, Aurélie and Virginie for being there since primary school.

Last, I would like to thank my family for always helping me see things in perspective. Thanks to my parents, Jean and Fabienne, who supported my long studies. Your generosity and belief that I can do whatever I want allowed me to get and finish this PhD. I am extremely grateful for your endless love and support. Thanks to my siblings, Charlotte, Thomas, Julie, Camille,

Timothée and new family Grégoire and baby Ellie, for always being able to comfort and distract me. I do not have the words to express the way you make me laugh and make life so much easier. Last, to my grandmothers, Jacqueline and Suzanne, for being ageless force of nature.

Declaration

All the chapters of this thesis have been written as papers for international per-reviewed journals. All the papers have been reworked to fit style and format of thesis of the University of York. Current publications status of papers are presented in Table 1.

The papers from chapter 1 to chapter 6 were written by the PhD candidate as a lead author. PhD candidate works with co-authors who advised, edited and corrected papers, which significantly increase the quality of papers. Chapter 5, which is published in the journal *Futures,* is available in annexe 0.1.

For chapter 3, sampled in Madrid were collected and shipped by Francesco Polazzo and sampled in Norway by Samuel Welch and Anne Luise Ribeiro. ICP-MS for metals analysis were conducted by John Angus in the Biorenewables Development Centre in York, UK.

The work presented here was part of the Innovative Training Network ECORISK2050 and was supported by the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No [813124]. PhD was mostly conducted in the Environment and Geography Department at the University of York (June 2019 – June 2023). An secondment of 6 months was undertaken at Wageningen University (the Netherlands) under the supervision of Professor Kasper Kok for Chapter 4 and 5. PhD candidate also participated to the SETAC Pellston Workshop on Integrating Global Climate Change into Ecological Risk Assessment from the 20th to the 24th of June 2022 in Oslo, Norway. During the workshop, a framework was developed to integrate climate change into chemical risk assessments. The manuscript detailing this research is currently being prepared and is available in annexe 6.

Table 1 - Status of the papers presented in this thesis with respect to the publication process

Chapter	*Authors*	*Title*	*Status*	*Journal*
1	Desrousseaux, A.O.S, Sallach, J.B, Boxall, A.B.A	Review of Chemical Pollution in Urban Freshwater System of the World	In prep	*Environmental Toxicology and Chemistry*
2	Desrousseaux, A.O.S, Sallach, J.B, Boxall, A.B.A	Identifying priority chemical contaminants in urban riverine systems in world	In prep	*Environmental Toxicology and Chemistry*
3	Desrousseaux, A.O.S, Polazzo F, Ribeiro A.L, Welch S, Angus J, Bergstrom E, Sallach, J.B, Boxall, A.B.A	Temporal and spatial risks of 15 priority chemicals in urban river systems of York, Madrid and Oslo	In prep	*Water Research*
4	Desrousseaux, A.O.S; Nagesh, P; Gajraj, R; Dekker, S.C; Eitzinger, J; Sallach, J.B; Boxall, A.B.A; Kok, K.	A Shared Socio-Economic Pathway Based Framework for Characterising Future Emissions of Chemicals to the Natural Environment	Published	***Futures***
5	Desrousseaux, A.O.S, Sallach, J.B, Boxall, A.B.A	Antibiotics emissions scenarios under 3 European SSPs: Eur-SSP1, Eur-SSP4 and Eur-SSP5	In prep	***Futures***
6	Cains, M; Desrousseaux, A; Boxall, A.B.A; Molande, S; Molina-Navarro, E; Sussams, J; Critto, A; Stahl Jr, R.G; Rother H-A	Environmental Management Cycles for Chemicals and Climate Change, EMC4: A new conceptual framework contextualizing climate and chemical risk assessment and management	In prep	***Integrated Environmental Assessment and Management***

Chapter 1 - Introduction

1.1 Urban Freshwater Chemical Pollution

From pharmaceuticals used for health to metals for the development of sustainable decarbonised energy systems, natural and synthetics chemicals are used in all aspects of modern life. However, the high use of chemicals by society has led to freshwater bodies being constantly contaminated from chemical emissions (Carpenter *et al.*, 2011; Inostroza *et al.*, 2017; Mushtaq *et al.*, 2020)

Urban environments are hotspot of chemical pollution because of numerous human activities associated with our towns and cities. Construction, industry, hospitals, leisure activities and parks, public transport, traffic all emit chemicals that are then transported into urban natural environments. For example, hospitals and geriatric homes are locations with high consumption of pharmaceuticals colouring (Ortiz de García, García-Encina and Irusta-Mata, 2017). Textile industries utilise metals, dyeing, fixing agents, and whitening agents and surfactants for textile production (Khan and Malik, 2014; Malik, Akhtar and Grohmann, 2014; Pattnaik, Dangayach and Bhardwaj, 2018). Traffic generates dioxins and polycyclic aromatic carbons due to incomplete burning of oil (Chauhan *et al.*, 2010; Joshi, Navalgund and Shet, 2022; Wang *et al.*, 2023).

Chemicals are emitted in urban environment via two mains pathways: either via wastewater treatment plants (WWTPs) or by runoff. WWTPs treat collected wastewater to remove organics and then release the treated water to rivers, streams of lakes (Domercq, Praetorius and Boxall, 2018). The efficiency of WWTP depends on technology in place and chemicals are removed to different degrees depending on their physico-chemical properties and persistence (Kasprzyk-Hordern, Dinsdale and Guwy, 2009; Verlicchi, Al Aukidy and Zambello, 2012; Yaman *et al.*, 2017). WWTP effluent have been shown in multiples studies to be a major contributor of most to chemical emissions in urban environments (Roberts & Thomas, 2006; Waiser et al., 2011 Muir et al., 2017). Chemicals can also be emitted by runoff. Chemical runoff and leakage occur when rain falls onto urban hard surfaces which is then transferred to a drainage system(Masoner *et al.*, 2019). Runoff contaminated water is usually not captured and therefore does not go through any treatment plants.

A diversity of chemicals has been detected in urban freshwater bodies including pharmaceuticals, pesticides, cosmetics and personal care products, sterols, Polycyclic aromatic hydrocarbons (PAHs), Polychlorinated biphenyls (PCBs), metals, biocides, additives, flame retardants, perfluorinated compound (PFCs) are many others (Schreder and Guardia, 2014; Chau *et al.*, 2018; Gursoy-Haksevenler *et al.*, 2020; Wilkinson *et al.*, 2022). The pattern of chemical pollution reflects anthropogenic activities of a local environment or the socio-economic status of a city. For example: high concentrations of nitrogen, phosphorus and chromium were detected in Fez (Morocco) reflecting the important leather manufacturing activity of the city (Perrin *et al.*, 2014); high concentrations of sterols and faecal bacteria were seen in Hanoi or Ho Chi Ming (Vietnam) reflecting the absence of or ineffective wastewater management (Chau *et al.*, 2018); high concentrations of PAHs were seen in Thulamela municipaly (South Africa) reflecting local tyres burning activities (Edokpayi *et al.*, 2016); very high concentrations of PCFs detected in Zibo (China) reflecting the presence of the largest fluorine factory of the country (Li *et al.*, 2018)

The emissions of chemicals to urban environments can adversely affect ecological communities. A range of effects of chemicals in freshwater bodies on aquatic living organisms have been reported. For example: endocrine-disrupting chemicals (e.g. bisphenol A; 17B-estradiol) lead to feminisation of clams in the UK, carps in Spain and tilapedia fish in Zimbabwe (Solé *et al.*, 2000; Langston, Burt and Chesman, 2007; Teta *et al.*, 2018); PFOA and other perfluorinated compounds bioaccumulate in animals' tissue and biomagnify throughout the food chain (Stahl, Mattern and Brunn, 2011; Lau, 2015); metals can be lethal at low concentrations for fishes (e.g. mercury, lead) or can alter development, reproduction and survival of fishes, molluscs, daphnids and algae at relevant environmental concentrations (Géret *et al.*, 2002; Levesque *et al.*, 2002; De Schamphelaere, Lofts and Janssen, 2005; Öner, Atli and Canli, 2008; Donnachie *et al.*, 2014); antibiotics emissions lead to the development of antimicrobials resistance genes threatening global health and countries' stability with a pandemic (WHO, 2014; Zhang *et al.*, 2022). Freshwater pollution also affect human health. Recreational activities (e.g. bathing, swimming) can be restricted when pollution is too high. Bathing has been forbidden in different areas in France or the UK because of bacterial-contaminated overflowing wastewater from treatment plant (Penna *et al.*, 2021; BBC News, 2022; France 3, 2022). Polluted freshwater is also used for drinking water and for irrigations of agricultural field leading to potential serious public health issues (Chen *et al.*, 2013; Wang, Li and Li, 2017).

Urban freshwater chemical pollution is a worldwide threat: in a recent study, antibiotics and pharmaceuticals were monitored in rivers in 104 countries in all continents. Out of 258 rivers monitored, only two rivers that no antibiotics or pharmaceuticals detected (Wilkinson *et al.*, 2022).

1.2 A rapidly changing world

Chemical consumption worldwide is currently operating "outside the safe operating space of the planetary boundary" according to Persson et al., 2022. This means that humanity is currently producing and releasing chemicals that pose risks that are greater than societies can assess and monitor: current chemical consumption could threaten the integrity of Earth System processes (Persson *et al.*, 2022). This risk is expected to increasingly intensify by a variety of global megatrends (Retief *et al.*, 2016).

First megatrend to be considered is demographic change. The world population will level off between 9 and 11 billion in habitants in 2050. While population size is expected to decrease in Europe, the population in Africa is expected to double.

Second, 80% of the world population is expected to live in cities in 2050 (UN-Habitat, 2022). Forty millions of rural acres are expected to change to urban areas to welcome the increasing urban population (UNEP, 2019). Cities will also have to adapt to provide good services (e.g. wastewater treatments, roads infrastructures, hospitals) for urban population.

Despite the fact that water demand could increase up to 80% compared to 2010, climate change will intensify resource scarcity, including water scarcity (UN Water, 2018; Boretti and Rosa, 2019). While terrestrial water storage is diminishing, some regions of the world will suffer from intensive rainfalls and floods events while other regions will suffer from drought. (UN Water, 2023) Last, accelerating technology innovation could change society dynamics. Technology innovation will continue to accelerate, especially in energy technology. The main challenge of technology innovation will not only be the development but the accessibility of these technology to countries that would benefit the most of it (Retief *et al.*, 2016).

Global megatrends are intensifying environmental challenges like water safety and brings new risks and uncertainties (European Environment Agency, 2020). Despite the fact that chemicals are used in all aspects of our lives and are causing harmful effects on human and environmental health, the future outlook of chemicals in societies resulting from socio-economic change, climate change and technological development is unknown.

1.3 Megatrends and chemicals emissions

Urban environments are rapidly changing due to socio-economic, climate change and technological development. These changes will impact the risk of chemicals emissions.

Materials consumption for urban expansion will increase from 10 billion tonnes in 2010 to 90 billion tonnes in 2050 (UN-Habitat, 2022). Increasing materials consumption and water demand for urban expansion will be a challenge, especially in climate change. Climate change events impacts on chemical efficiency, chemical emissions and chemical demand. Increasing temperature decrease the efficiency of pesticides, leading to a higher usage of pesticides. Precipitations can compromise WWTP capacity and increase the amount of untreated wastewater release into the environment (Shrestha *et al.*, 2015; Zouboulis and Tolkou, 2015). Changing climate change diseases patterns and pharmaceuticals demands. For example allergies and other respiratory diseases are expected to increase with temperature change, leading to increasing demand for antihistamines, decongestants or cortisones (Redshaw *et al.*, 2013). While some climate events could lead to a decrease of chemicals emissions (e.g. a decrease in precipitations could decrease traffic-related chemicals runoff), majority of effects studies in the literature are expecting to increase chemicals emissions and worsen current urban chemical emissions.

Socio-economics changing like education, technology development, policies, and regulations can also impact chemicals emissions. Chemical emissions can be limited with strict regulations. The pesticide atrazine is detected at high concentrations in the US but not in Europe. Atrazine was banned in the EU since 2004 while it is still allowed in the US (Deb, 2006; Sass and Colangelo, 2014). Strict regulations can also change chemical demand. The EU bisphenol A banned in 2018 lead plastic industries to subsidised it by other bisphenols with similar toxicity (Rochester and Bolden, 2015; Qiu *et al.*, 2019). Education can also play a role in individuals and professional behaviours. Antibiotics usage and prescriptions was showed to decrease in hospitals were practitioners followed trainings on antibiotics misuses and antimicrobials resistance genes (Tan *et al.*, 2018; Muloi *et al.*, 2019). Advances in WWTP technology can decrease the load of chemicals emission from WWTP effluent. Ozone and activated carbon are advanced technology significantly increase toxic chemical removal compared to traditional WWTP technology (Pistocchi *et al.*, 2022). These technology is however not easy to expand throughout countries and usually rely on governance politics or financials benefits from private compagnies (Renwick, Brogan and Mossialos, 2015). Adaptation to climate change will also change chemicals demand and emissions. Shift towards electric cars or sustainable decarbonised energy systems requires chemicals like lithium, aluminium or hydrogen to cite a few (Addison, 2018; Hodgkinson and Smith, 2021). Advances in medicines and pharmaceuticals designed could also reduce toxicity and/or quantity of antibiotics needed for a treatment (Yang *et al.*, 2015; Genilloud, 2019).

How societal changes will affect chemicals demand, usage and emissions in freshwater has not been studied yet. The future risks of chemicals emissions in freshwater systems is currently unknown.

1.4 Scenarios to study future risks of chemicals emissions in urban environments

To be able to study the future chemical emissions in changing societies, scenarios provide a good tool to study multiples alternatives futures (Alcamo and Henrichs, 2008). The shared socio-economics pathways scenarios (SSPs) and representative concentration pathways (RCPs) were developed by the Intergovernmental Climate Change Panels (IPCC) to allow scientists to future different potentials futures under the same storylines (O'Neill *et al.*, 2017). They are used as baseline for climate change and sustainable development research. The SSPs describe five future societies based on their abilities to adapt and mitigate to climate change challenges (O'Neill *et al.*, 2017): SSP1 is a sustainable society based on global cooperation, high investment in human development and a desire for less resources-intensive life-style; SSP3 is a society with high competition between and among regions. Countries are closing on themselves because of high concerns for competitiveness and security. Technology development, human development and environmental concerns are low; SSP4 is a society with high inequalities. Power is hold by a small elite political and business elite. Human and technological investments are accessible to the upper class; SSP5 is a society with strong faith in rapid economic growth thanks to free-trade worldwide and fossil fuels exploitation. There are high investments in human and technology developments. Environmental concerns are low as technology is believed to be able to fix any issue. The last storyline, SSP2, lacks its own identify as all socio-economics developments change moderately. (Kok *et al.*, 2019) SSP2 depicts a future scenario in which development trends do not lean towards either extreme end of the spectrum but instead follow moderate and balanced paths within the range of possible outcomes for each element. (O'Neill *et al.*, 2017)It is crucial to research the risks of chemicals in the future. Mitigation and adaptation strategies to climate change and future freshwater chemicals pollution will not be adequate and relevant if these risks are not identified. Identified risks will not be relevant if all potentials socio-economics, technological and climate drivers are not considered all togethers in the complex and dynamics societies we are living in. SSPs scenarios have not been adaptive to chemicals emissions yet. This means that societal changes including socio-economic change and technological development alongside climate change have not been studied altogether as global change interacting together on chemicals. The development of SSPs scenarios for chemicals emissions is crucial

1.5 Thesis aims and objectives.

The primary aim of this thesis was to explore how the emissions of chemicals of concern in European urban aquatic systems might change in the future due to climate change and other global megatrends.

To identify harmful chemicals in urban environments, the research focused on addressing three objectives:

1. To review available information of concentrations of chemicals in urban environments worldwide;
2. To assess the risk of monitored chemicals to ecological health; and
3. For groups of compounds identified as posing a risk, perform a 12 month monitoring study of their occurrence in three European cities: Oslo (Norway), Madrid (Spain) and York

For those classes of compounds identified as posing a risk in European cities, work was done to assess how emissions of these chemicals could change in the future. This was achieved using the following objectives:

4. To develop a framework to adapt SSPs scenarios to chemicals emissions scenarios; and
5. To apply the developed framework to explore how emissions of priority chemicals in European urban freshwater systems in 2050 could change compared to today.

The aims and objectives described above were addressed in five Chapters which constitute the main body of this thesis:

Chapter 1 provides a systematic review of measured concentrations of chemicals in urban environments worldwide. The chemicals identified in the review were divided into 19 chemicals class categories and categorised by continent and country. Chemical concentrations were compared across different urban environment types and to socio-economic information to help identify the drivers associated with urban chemical pollution.

Chapter 2 prioritises the chemicals identified in Chapter 1 using risk quotient calculations. Predicted no effects concentrations for each chemical identified in the review were calculated based on acute and chronic toxicity data collected from databases (ECHA REACH database and ECOTOX) or predicted using in-silico toxicity prediction software (ECHA REACH ToolBox, VEGA Hub, EPA Test and ECOSAR). A list of priority chemicals for each continent was developed and most dangerous chemicals were identified.

Chapter 3 described a monitoring study for 12 priority metals and three priority pharmaceuticals identified in Chapter 2 as a priority in Europe. Surface water samples were collected in Madrid (Spain), Oslo (Norway) and York (UK) from 10, 6 and 11 samples locations respectively. Sample locations were chosen strategically to so that surface water was obtained from upstream and downstream of city centres and wastewater treatment plants. Samples were collected once every 3 months over one year to allow for a seasonal analysis of trends in chemical occurrence. Metals were measured by ICP-MS analysis and pharmaceuticals by HPLC-MS-MS analysis. Risk quotients were calculated in the same way as in Chapter 2 to assess and confirm the current risk posed by priority chemicals in Madrid, York and Oslo.

Chapter 4 describes a framework developed specifically to adapt existing global and European SSP scenarios to chemical emissions scenarios. The framework involves four steps and allows chemical emissions in the future to be forecast using the SSPs. The framework is then tested for antidepressants and insecticide emissions in European urban freshwater systems in 2050.

Chapter 5 then employs the framework developed in Chapter 4 to explore how antibiotic emissions to European urban freshwater systems could alter by 2050. Experts from academia, industries and medical practitioners were involved in the scenario development process. Storylines and overall trends for antibiotics emissions in 2050 were developed.

Finally, the conclusions of the work and recommendations for future research in provided in the last part of this thesis.

Chapter 2- Review of Chemical Pollution in Urban Freshwater System of the World

2.1 Introduction

Urban environments are hot spots for chemical consumption as a result of their high population densities and the presence of sites where chemical usage is high such as health care institutes (e.g. hospitals, retirement homes) and industrial facilities (Pincetl *et al.*, 2013) Urban freshwater bodies around the globe are polluted with heavy metals (Abedi Sarvestani and Aghasi, 2019), pharmaceuticals (Wilkinson *et al.*, 2022), pesticides (Weston, Holmes and Lydy, 2009; Lu *et al.*, 2020; Meftaul *et al.*, 2020), industrial chemicals (Chau *et al.*, 2018; Gursoy-Haksevenler *et al.*, 2020), plasticizers and many others (Kunacheva *et al.*, 2010; Maggioni *et al.*, 2013; Mahmood, Al-Haideri and Hassan, 2019). Aquatic species diversity and abundance is likely impacted by chemicals exposure and poor water quality (e.g. salinisation, hypoxia, declining calcium) (Kidd *et al.*, 2007; Durrant *et al.*, 2011; Herbert *et al.*, 2015; Reid *et al.*, 2019). The extend of the impacts of long-term chemical pollution remain unknown (Van den Brink *et al.*, 2018).

Advances in analytical technology and methods for chemical analysis make data on chemical pollution now make it possible to study the occurrence of a wide range of chemical classes in aquatic environments at concentrations in the ng/l range and over the past two decades a wide range of monitoring studies have been done to characterise chemical pollution in urban aquatic environments. However, these studies usually focus on one class of chemical and or one geographical region meaning we do not currently have a full picture of the global scale of the problem of urban river pollution. By combining these existing studies in a systematic review it should be possible to understand the dynamics of chemicals emissions in urban environments and to visualize the burden of water pollution worldwide.

The aim of this chapter, therefore, was to perform a systematic review of monitoring studies that have assessed chemical pollution in urban aquatic environments around the globe. The specific objectives of the review were to: 1) identify chemicals detected in urban environments; 2) compare concentrations of chemicals between urban environments worldwide and 3) identify socio-economics drivers associated with chemical pollution of urban riverine systems.

2.2 Materials and methods

The systematic review was conducted using the Scopus and Web of Science databases using the following key words: ("surface water" or "freshwater") AND ("urban" or "city") AND ("chemical*" OR "contaminant*" OR "pollutant*") AND ("occurrence" or "quantif*" or "analys*"). The year of publication was limited to 2000 to 2020. An initial screening of the identified articles was performed and articles were removed when 1) they did not include surface water sampling data; and/or 2) where they did not include monitoring locations in urban environments. When articles had sampling locations in urban and non-urban areas, only data in urban areas were kept. If no distinction of data was given between both areas, the article was discarded. Articles looking at chemical concentrations after a climatic event (e.g. as storm water event) were also removed. This is because the chronic chemical pollution of urban freshwater bodies is studied here, not the acute impacts of specific events on urban chemical pollution. Extra articles, cited in the identified articles, were added to the list when considered relevant (Annexe 1.1). The final selection of papers were used to develop an excel spreadsheet of monitoring data.

Data published in core and/or supplemented materials of article were collected. When reported, all raw environmental concentrations (for each monitoring events and each locations) were collected. When raw data were not reported, ranges of data (e.g. minimum, maximum, median) and/or “transformed” data (e.g. average, 95th percentile) were collected and included in the excel spreadsheet.

Where a result was reported as “not detected” (ND) or “lower than detection limit” (<LOD) these were included into the excel file and labelled as “not detected”.

Along with monitoring data, chemical name, location and year of sampling, and the number and the frequency of sampling events were extracted. Chemicals were associated with their Chemical Abstracts Service (CAS) registry number to permit comparison. The CAS number was either extracted from article or attributed to each chemical using the EPA Comptox Chemicals Dashboard (https://comptox.epa.gov/dashboard/) and PubChem database (https://pubchem.ncbi.nlm.nih.gov). When no CAS number was found, chemicals and associated data were not considered. A list of all chemicals without CAS number is available in Annexe 2.1.

Chemicals were sorted into 19 class categories: anti- biotics/microbials, biocides, cosmetics and personal care products (PCPs), flame retardants, food and food additives, industrials chemicals, inorganic anions/cations, metals, metabolites, perfluorinated compounds (PFCs), pesticides, petrochemicals, pharmaceuticals, plastic and plastic additives, polybrominated diphenyl ethers (PBDEs), polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) and sterols. Another category was added for chemicals with no class category defined. Use/product category of chemicals were defined using the EPA CPCat Chemicals inventory (https://www.epa.gov/chemical-research/chemical-and-products-database-cpdat). The idea of this approach was that it allowed us to obtain concentration distributions for each chemical, category, urban environment, country and continent and to be able to compare them.

2.3 Results and Discussion

One hundred and thirty-seven articles were identified that met the acceptance criteria for the systematic review. One hundred and eight articles covered urban environments in the Northern hemisphere and 29 in the Southern hemisphere.

Which urban environments in the world have chemical monitoring data?

One hundred and ten urban environments had been studied in the different articles, including 13 cities in Africa, 34 in Asia, 28 in Europe, 24 in North America, 10 in South America and one in Oceania (Figure 1). The USA, China and Brazil had the highest number of cities monitored with 15, 13 and 7 cities respectively. The urban environments monitored differed in size and economic status and included capital cities such as London (UK), Seoul (Korea), Nairobi (Kenya), Rome (Italy), Beijing (China), Madrid (Spain), Hanoi (Vietnam), Jakarta (Indonesia) or Mexico City (Mexico); touristic cities such as Venice (Italy), York (UK) or Rocha (Uruguay); and industrial cities like Zibo, Jinan (China) or Fez (Morocco). Data were available for 10 megacities of which 9 were located in China (Beijing, Changzhou, Haikou, Hangzhou, Harbin, Shanghai, Shenyang, Suzhou, Wenzhou, Wuhan) and one in Indonesia (Jakarta). The least populated city, for which data was available, was La Bouille, a village in France with only 750 inhabitants.

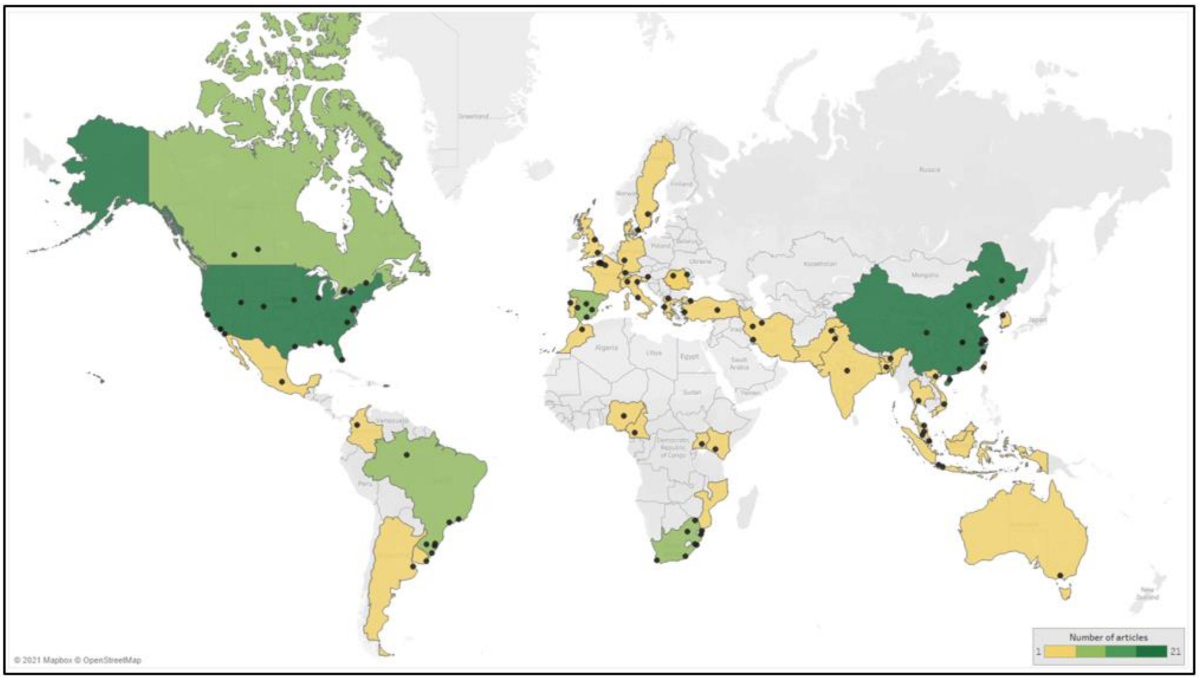


Figure 1 - Number of articles by country containing data on the occurrence of chemicals in surface waters. Black dots represent geographical locations of 110 cities for which monitoring data were available.

<u>What chemicals have been monitored?</u>

Monitoring data were available for 1119 distinct chemicals. These included, biologically active molecules, such as pesticides, pharmaceuticals and antibiotics/antimicrobials , which comprised 51% of chemicals researched with 265, 260 and 52 chemicals respectively. A larger focus on biologically active compounds is likely due to multiples reasons: they are active ingredients and therefore potentially highly toxic to living organisms; active ingredients have been "under the radar" since the 90s, which means that analytical methodologies to study have only recently become available in the scientific literature compared to other chemicals; sources and consumption/sales data can be accessible, meaning that researchers have opportunities to relate environmental concentrations to socio-economics dynamics.

Other major classes of chemicals that had been monitored were the cosmetics and PCPs (99 substances), industrial chemicals (90 substances), biocides (58 substances), flame retardants (36 substances), PCBs (34 substances), PAHs (29 substances), petrochemicals (26 substances), metals (20 substances), PFCs (21 substances), metabolites (20 substances) and plastics and plastic addictive (20 materials/substances). The PBDEs, inorganics anions, food and food additives and sterols all had fewer than 10 substances in the dataset. Forty-three chemicals had no class category defined.

The diversity of chemicals monitored varied by region. The diversity and number of chemicals researched in countries in the Northern hemisphere were higher than the Southern hemisphere. In Europe, data were available for 632 chemicals from 16 categories, in Asia data were available for 460 chemicals from 15 categories, in North America 363 chemicals had been studied from 14 chemical classes. In the southern hemisphere, 136 chemicals from 10 categories were researched in Africa, 124 chemicals from 7 categories from South Africa and only 2 pesticides in Oceania (Figure 2).

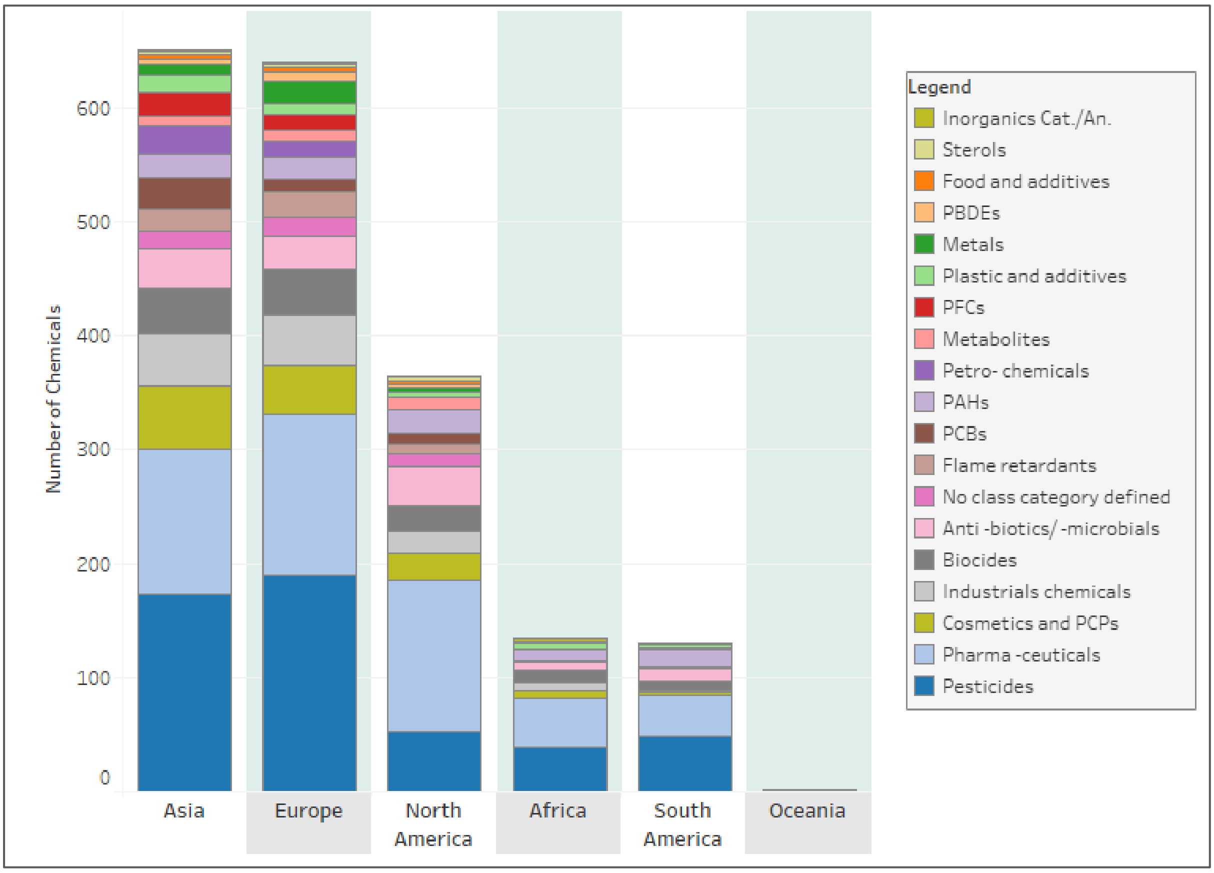


Figure 2 - Number and class category of chemicals identified in the systematic review for each continent (n=1 107)

Which class categories were detected at the highest concentrations and what could be the sources?

Four categories of chemical had concentrations above 1 µg/L namely the PFCs, inorganics cations/anions, metals and PAHs. Data by continent are presented in Figure 3 and by country in annexe 1.2. PFCs was the category with the highest concentration (276 mg/L). PFCs data were collected in urban environments in Asia (China, India, Malaysia) and in Europe (Italy, Spain, Romania and Switzerland). PFCs from 40 ng/L up to 276 mg/L were specific to Asia. In Europe countries, highest concentration was 34 ng/L. PFCs have been used since the 1950s in diverse products and industrial applications worldwide because of their unique physical and chemicals characteristics, including high thermal tolerance and high chemical and biochemical stability. They are regularly cited as components of fire foams, food-packaging, non-stick pans or specific-textiles. PFCs are very persistent and very bioaccumulate (vPvB), they have therefore been detected in all environmental matrices (groundwater, freshwater, seawater, rainwater etc) but also in animals and human's tissues, blood and hair (Suja, Pramanik and Zain, 2009; Houde *et al.*, 2011; Jian *et al.*, 2017). High concentrations of PFCs were therefore expected. Differences between Europe and Asia could be because of regulations. In Europe, PFCs are regulated under the EU's Persistent Organic Pollutants Regulation since 2006 (ECHA, no date). In China, PFOS being largely prohibited since March 2019 (Li *et al.*, 2021). Since May 2019, PFOA and its salts were listed into the into the Stockholm Convention on Persistent Organic Pollutants (POPs) (Stockholm Convention, no date). PFCs been very persistent, PCFs could be detected in the environment for many years.

Inorganic cations/anions and metals were the next categories with the highest concentrations. Four inorganics cations/anions were researched: ammonium, bromide, nitrate and cyanide in Europe (n=13) and Africa (n=48). Concentrations distributions were smaller in Africa (100 µg/L - 44.7 mg/L) compared to Europe (<LOQ - 23.7 mg/L). Data for 20 metals were collected in Europe (n=467), Asia (n=93), North America (n=20) and Africa (n=24). Metals distributions was the largest in Europe (<LOQ – 11 mg/L) and smallest in North America (13.5 µg/L – 85 µg/L). The larger distribution in Europe is probably due to a higher number of data collected there. Inorganic cations/anions and metals are expected to be high in urban environments as they occur naturally in the environment (from rocks weathering) and are ubiquitous in terms of their use by modern societies; metals are also wildely used in

architecture, transports infrastructures, plumbing to cite a few (Comber et al., 2014; Eurometaux, 2021).

For PAHs and plastics and plastics additives, concentrations ranged from <LOQ to 1.7mg/L. Concentrations above 100 µg/L only occurred in Africa. Distributions of PAHs in Africa ranged from 126 µg/L to 8 mg/L while concentrations were below 12 µg/L in other continents. PAHs maximum concentrations were 12 µg/L in Asia, 7.1 µg/L in Europe, 3.9 µg/L in North America and 711 ng/L in South America. PAHs are chemical composed of two or more benzene rings. They are emitted into the environment by incomplete combustion of organic materials and via dry and wet atmospheric pollution. PAHs can be emitted by natural sources (e.g. natural forest fires) and anthropogenic activities (e.g burning of fossils fuels; cooking of foods) (Zhang and Tao, 2009; Kim *et al.*, 2013).

For plastics and plastics additives, concentrations ranged from <LOD to 8 mg/L in Africa (n=254). For other continents, maximum concentrations were below 13 µg/L in Asia and 2 µg/L. Plastics and plastics additives are emitted in freshwater because of mismanagement of plastic items but also, especially in urban environments, because of tyres degradations from anthropogenic transport activities and from plastic polymers used in textiles (Dris, 2016).

Which class categories had the most data collected?

Pharmaceuticals (n=3102), pesticides (n=1434), antibiotics/antimicrobials (n=1036) and biocides (n=956) were the class categories with the highest number of data collected. The number of data collected in Europe, North America and Asia were systematically higher compared to Africa, South America and Oceania.

Concentrations distributions of pharmaceuticals across continents were quite similar despite differences in data collection (less than 1000 data in Africa and South America). Maximum concentrations were 116 µg/L in Asia, 67 µg/L in Europe, 45 µg/L in South America, 33 µg/L in Africa and 11 µg/L in North America. For biocides, concentrations distributions were similar in Europe, Asia and North America with maximum concentrations of 22 µg/L, 35 µg/L and 203 µg/L respectively. In South America and Africa, concentrations were lower: 450 ng/L and 100 ng/L respectively. Differences between continents probably result from the low data availabilities in Africa (n=30) and South America (n=37).

For pesticides, data collections were low in Oceania (n=4) and South America (n=67). Maximum concentrations were 323 µg/L in Africa, 30 µg/L in Europe, 23 µg/L in South America, 12 µg/L in North America, 5.2 µg/L in Asia and 4.8 µg/L in Oceania. Despite lower number of data, medium concentrations in Oceania and South America (2950 ng/L and 460 ng/L respectively) were higher compared other continents (86 ng/L for Africa, 38 ng/L in Asia, 15 ng/L in Europe and North America). Lastly for antibiotics, concentrations distributions were the same for Asia, Europe, North and South America with maximum concentrations below 13 µg/L in Africa and Europe and below 5 µg/L in other continents. Fewer data were collected in Africa but median concentration was the highest: 562 ng/L.

Which class categories were detected at the lowest concentrations?

PCBs and PBDEs were the two categories with the lowest concentrations. These categories were only found to be monitored in Asia, Europe and North America. Maximum concentrations of PCBs were 84 ng/L in Asia, 13 ng/L in North America and 2.1 ng/L in Europe. PCBs are synthetics molecules that were used in many industrials and commercials applications such as electrical equipment, paints, plastics or sealants. Because of their toxicity, PCBs are banned in many countries by the Stockholm convention since 2011. They are still detected as they are very persistent (UNEP - Stockholm Convention, 2022). For PBDEs, highest concentrations were 2.9 ng/L in Europe, 2 ng/L in North America and 0.7 ng/L in Asia. Similarly as PCBs, most PBDEs are banned by the Stockholm Convention because of their toxicity (Public Health England, 2009). PCBs and PBDEs had low number of data collected: 163 data for PCBs and 61 for PBDEs.

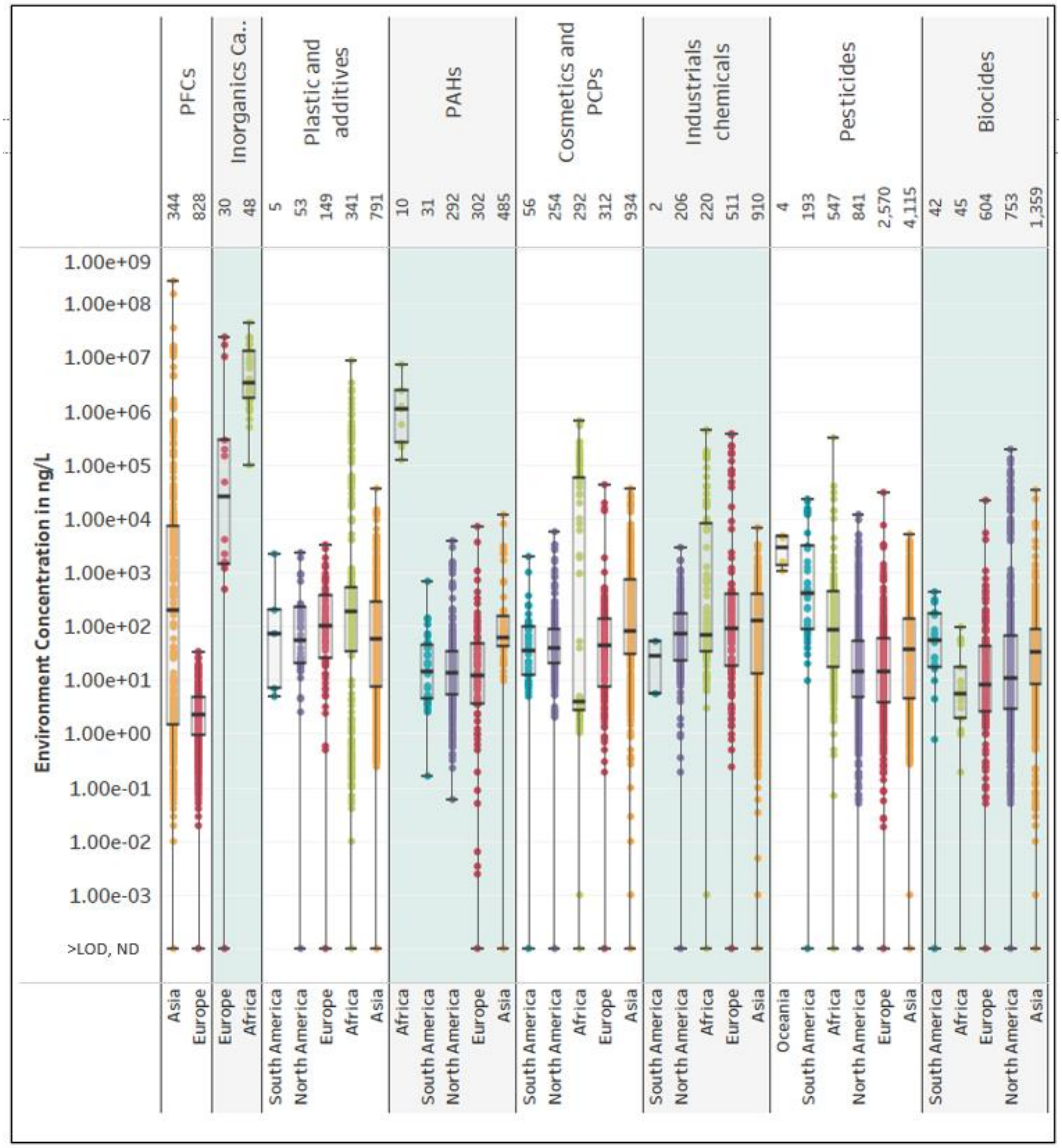


Figure 3 - Environmental concentrations of chemicals in ng/L extracted across all studies. Chemicals are presented by class categories and by continents. Every dot represents a concentration detected at 1 site in 1 of the monitoring studies. The lowest data on the panel represent “<LOQ”, “<LOQ” or ND. Data from the different continents are marked with different colours. Boxplots indicated lower line represents minimum concentration and upper line maximum concentration. Median concentration is the line within the boxes. n= 17 186

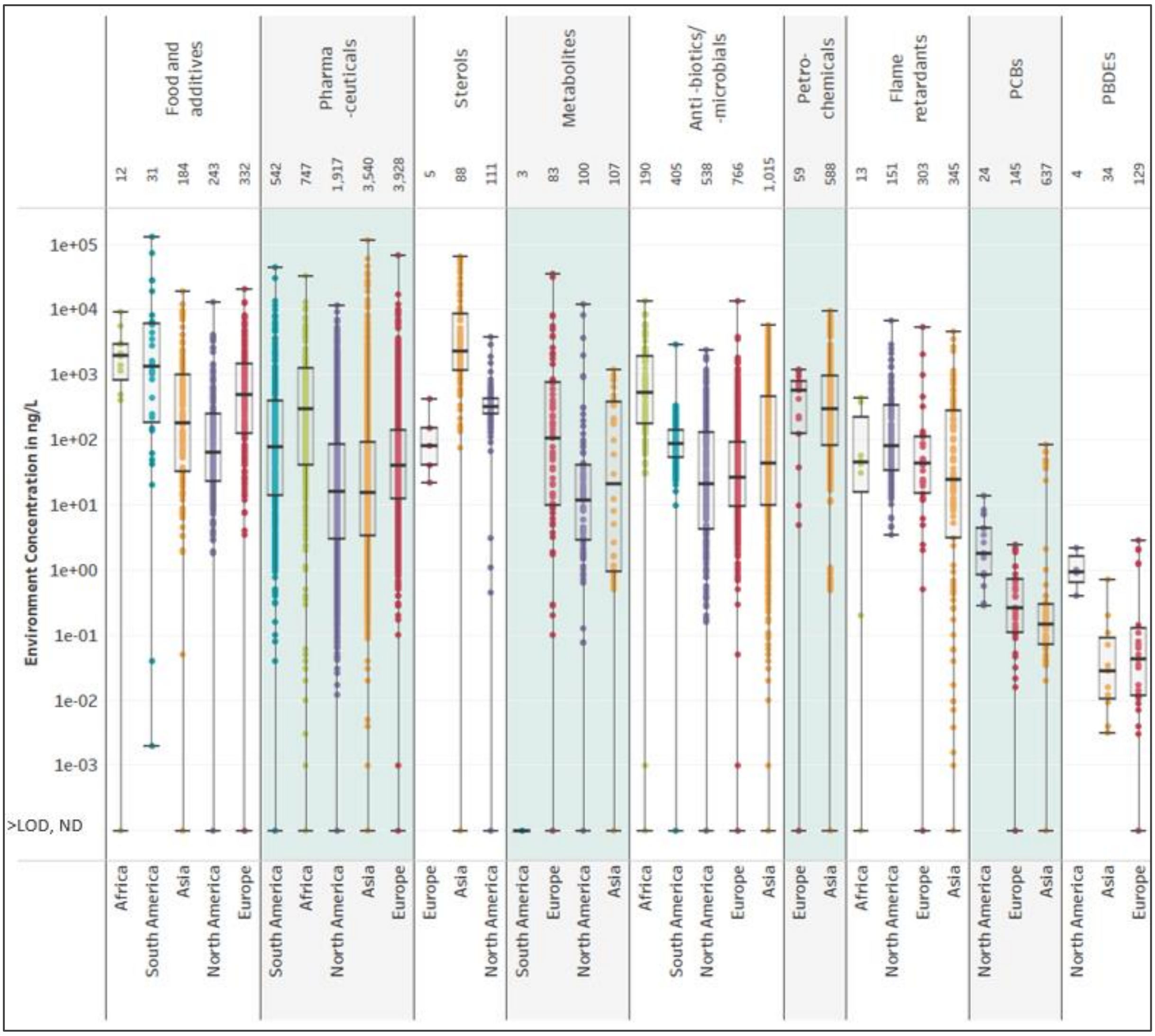


Figure 3 - (continued) Environmental concentrations of chemicals in ng/L extracted across all studies. Chemicals are presented by class categories and by continents. Every dot represents a concentration detected at 1 site in 1 of the monitoring studies. The lowest data on the panel represent "<LOQ", "<LOQ" or ND. Data from the different continents are marked with different colours. Boxplots indicated lower line represents minimum concentration and upper line maximum concentration. Median concentration is the line within the boxes. n= 17 186

Are chemicals/class categories detected at similar concentrations in urban environments?

Figure 4 presents the concentrations distributions of the top 5 chemicals per category. For each chemical, the city where the maximum concentration was detected is indicated.

PFOA, PFhxA, PFCA, PFCA and PFBA were the PFCs with highest concentrations. Maximum concentrations were 276 mg/L for PFOA, 16 mg/L for PFhxA, 15 mg/L for PFCA, 12 mg/L PFCA and 4mg/L. These high concentrations were detected in the city of Zibo (China). Zibo is located in the very industrialised Shandong province. These PFCs were measured downstream of the largest fluorine production park of China, which likely explains the very high concentrations (Li *et al.*, 2018). In Europe, concentrations did not go over 33 ng/L. As the production of PFCs is restricted in Europe (production of PFOA and PFOS are banned), emissions in the environments are possibly related to atmospheric depositions and degradation of PFCs-containing products like clothes, fire foams, non-stick pans etc (Müller *et al.*, 2011).

As mentioned previously, only four inorganics cations/anions were found in our systematic review: ammonium, nitrate, cyanide and bromide. The cities of Fez (Morocco) and Kemalpasa (Turkey) had the highest concentrations. The high concentrations of ammonium (up to 44 mg/L) and nitrate (up to 6 mg/L) in Fez were associated with textiles, leather and dyeing factories. For bromide and cyanide in Kemalpasa, concentrations reached 23 ng/L and 4 µg/L respectively. Sources were likely from the manufacture of chemicals and chemicals products (Perrin *et al.*, 2014; Gursoy-Haksevenler *et al.*, 2020).

Nickel, silicon, iron, chromium and aluminium were metals with the highest concentrations. Concentrations above 1 mg/L only occurred in cities in Turkey (Kemalpasa, Yunusemre and Alasehir). Metals concentrations were below 548 µg/L in other urban environments. The high concentrations in Turkey were explained by geochemical composition of sediments, industrials and agricultural local activities (Gursoy-Haksevenler *et al.*, 2020).

The top five PAHs (benzo(b)fluoranthene, fluoranthene, fluorene, benzo(a)pyrene and pyrene) were systematically detected above 1 mg/L and up to 7 mg/L in Thulamela Municipality in South Africa. These concentrations are higher than the solubility levels of PAHs and are attributed to the pre-treatment of the samples with liquid-liquid extraction. Sources of PAHs were burning of lands for agriculture and burning of vehicles tyres by people with low or no-income to generate heat in the winter or to recover steel straps (Mahlangu, 2009;

Edokpayi *et al.*, 2016). In other cities, the maximum concentration of PAHs was 3 µg/L for fluoranthene in Detroit (USA).

Dibutyl phthalate, diethyl phthalate, bisphenol A, benzyl butyl phthalate (BBP) and bis(2-ethylhexyl) phthalate (DEHP) were the plasticizers detected at the highest concentrations. Phthalates are plasticizers that degraded easily as they are not covalently bounded to plastic (Perez, 2021). They are largely studied for their endocrine disruptor toxicity. Bisphenol A is also a well-known plasticizers associated with multiples perinatal, childhood and adult adverse health effects for humans and living organisms (Rochester, 2013). For dibutyl phthalate, diethyl phthalate and BBP, concentrations above 10 µg/L and up to 633 µg/L were found in Cape Town (South Africa). Higher concentrations of phthalates and bisphenol A in Cape Town could result from plastic mismanagement or a higher consumption of plastic in this city. Perez et al mentioned that, unlike other countries in Africa, South Africa had not banned low-value plastic packaging, which could lead to a higher plastic pollution specific to South Africa (Perez, 2021).

Phenol, 2-nitrophenol, p-chlorocresol, 2,4 dimethylphenol and 2,4,6-Trinitro-1,3-dimethyl-5-tert-butylbenzene were the cosmetics chemicals detected at the highest concentrations. Sources of these chemicals are difficult to determine as they are used for multiple purposes. Phenols and all phenols-based chemicals can be used as a solvents or detergents in cosmetics, but they are also used in pesticides, fertilizers and in the phenolic resins used in construction, automobiles and appliance industries. This is similar for the top 5 industrial compounds (chlorophenol, n-benzyladenine, DEHPs, 4-nitrophenol and 2,4,6 trichlorophenol)) which are used for multiple purposes. Information on sources been very limited, only speculations could be proposed here for sources. Four cosmetics (phenol, 2-nitrophenol, p-chlorocresol, and 2,4 dimethylphenol) and 4 industrials chemicals (2 chlorophenol, n-benzyladenine, DEHPs, 4-nitrophenol and 2,4,6 trichlorophenol) were detected the highest in Cape Town (South Africa). This indicates that there is a general issue with chemical pollution in Cape Town – this could result from ineffective wastewater collection, sewage connectiveness to WWTP and WWTP technology (Olujimi *et al.*, 2012; Inam *et al.*, 2019).

The pesticides detected at the highest concentrations were pentachlorophenol, 2,4-dichlorophenoxyacetic acid (2,4-D), clomazone, metolachlor and diuron. Pentachlorophenol is used to control termites to protect wood from fungal-rot and wood-boring insects. It is also used as a molluscicide for snail-borne schistosomiasis (Jin *et al.*, 2012; Zheng *et al.*, 2012). Concentrations above 308 ng/L and up to 323 µg/L occurred in Cape Town (South Africa). 2,4-D is a herbicide used to control broadleaf weeds in crops, lawns, forest and rights-of-way (Burns and Swaen, 2012). The highest concentration of 2,4-D was detected in Kemalpasa, Turkey (30 µg/L). Concentrations in other cities were below 5 µg/L. Clomazone was only monitored in Rio Grande (Brazil) where it was detected up to 23 µg/L. Clomazone is a herbicide used primarily in rice culture (Zhang et al., 2004). Metalochlor, another hercide, was monitored in 14 cities with concentrations ranging from <LOQ to 14.6 µg/L. Concentrations above 1 µg/L were only measured in Laguna de Castillos (Uruguay). Lastly, diuron was measured in 17 cities. Concentrations above 1.6 µg/L and up to 13.8 µg/L occurred in Yaoundé (Cameroon).

The pharmaceuticals detected at the highest concentrations were diclofenac, carbamazepine, 17β-estradiol, acetaminophen and ibuprofen. These chemicals are well known medicines used worldwide. 17β-estradiol is an oral contraceptive that has been extensively studied for its adverse effects on endocrine systems in aquatic species. 17β-estradiol was added in 2016 to the European Watch list. Concentrations of this molecule ranged from <LOQ to 450 ng/L except for two data points collected in Laguna de Castillos (Uruguay) where 17β-estradiol was there detected up to 45.5 µg/L. This concentration was detected once downstream of Castillo city and in the winter season when there was low rainfall (Griffero *et al.*, 2019). In other cities, 17β-estradiol was detected below 450 ng/L. Acetaminophen is one of the world most sold analgesics and is the active ingredient in paracetamol (Igwegbe *et al.*, 2021). Highest concentration for acetaminophen was 17 µg/L seen in Granada (Spain).

The top five antibiotics were sulfamethoxazole, ciprofloxacin, amoxicillin, trimethoprim and erythromycin. These five antibiotics are used worldwide for human and animal consumptions. For ciprofloxacin concentrations from 509 ng/L to 990 ng/L were seen in Hanoi (Vietnam) and in Istanbul concentrations up to 13 µg/L were reported. Similarly for amoxicillin, concentrations from 80 ng/L – 5.2 µg/L occurred in Hanoi. Maximum concentrations of trimethoprim and erythromycin were 4.6 µg/L which were seen in Kemalpsan (Uruguay) and 3.6 µg/L which were seen in Madrid (Spain). Because they are in the top 5 chemicals most researched in this database diclofenac, carbamazepine, ibuprofen and sulfamethoxazole are further researched in the next section of the chapter.

The sterols detected at the highest concentrations were cholesterol, coprosterol, beta-sitosterol, stigmasterol and stimastanol. Concentrations of cholesterol, coprosterol, beta-sitosterol and stigmasterol above 1 µg/L and up to 68 µg/L were systematically detected in Hanoi and Da Nang (Vietnam). Sterols emissions are associated with faecal pollution and ineffective WWTP. In cities in Vietnam, high faecal pollution was demonstrated in multiple studies because of rapid urbanisation without development of adequate and effective wastewater management (Pham and Kasuga, 2020; Nguyen *et al.*, 2021).

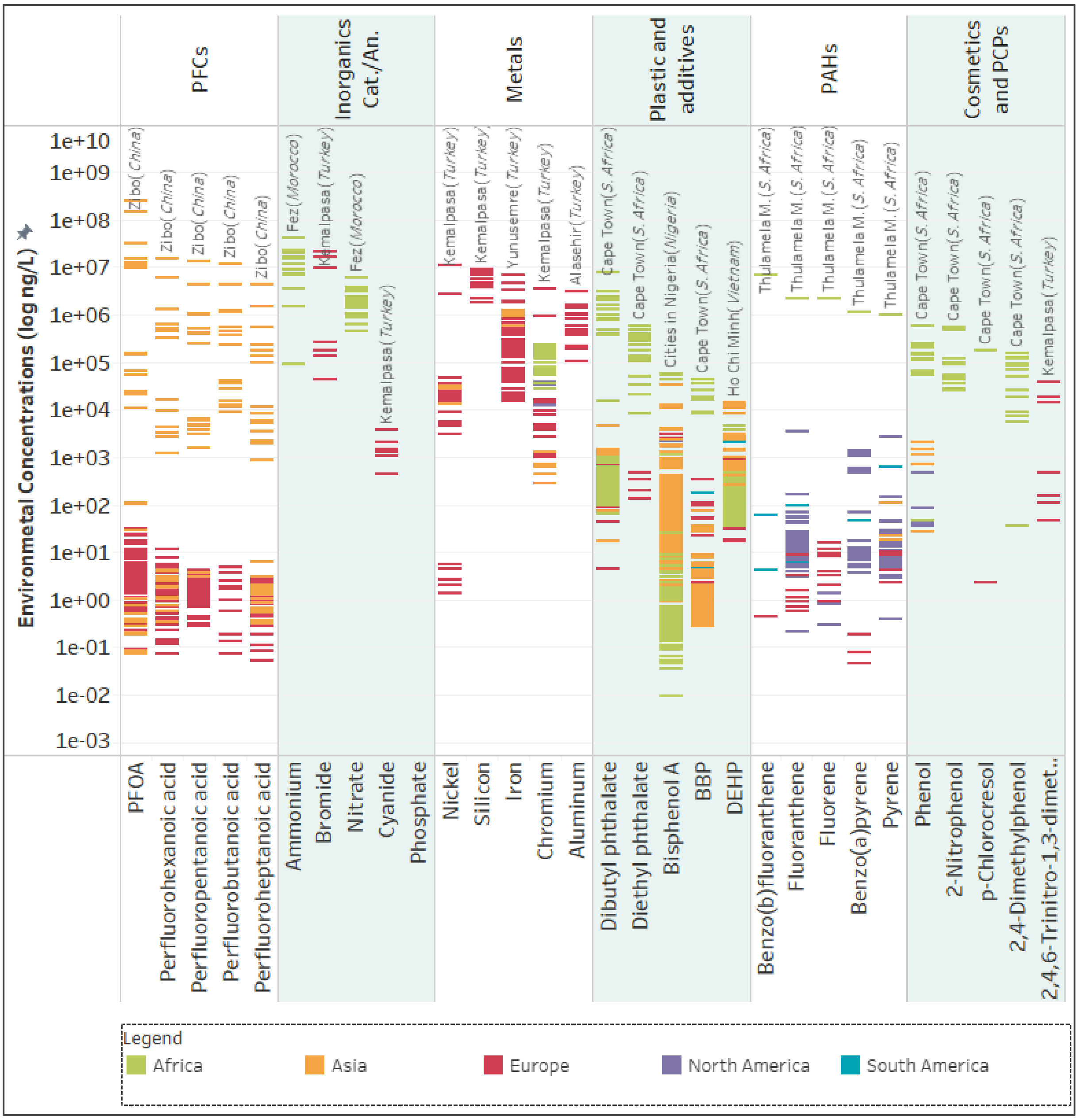


Figure 4 - Environmental concentrations of the top 5 chemicals in ng/L for each category across all studies of the systematic review. Every line represents a concentration detected at 1 site in 1 of the monitoring studies. The lowest data on the panel represent "<LOQ", "<LOQ" or ND. Data from the different continents are marked with different colours. For each chemical, the urban environment and country where the highest locations were extracted is labelled.

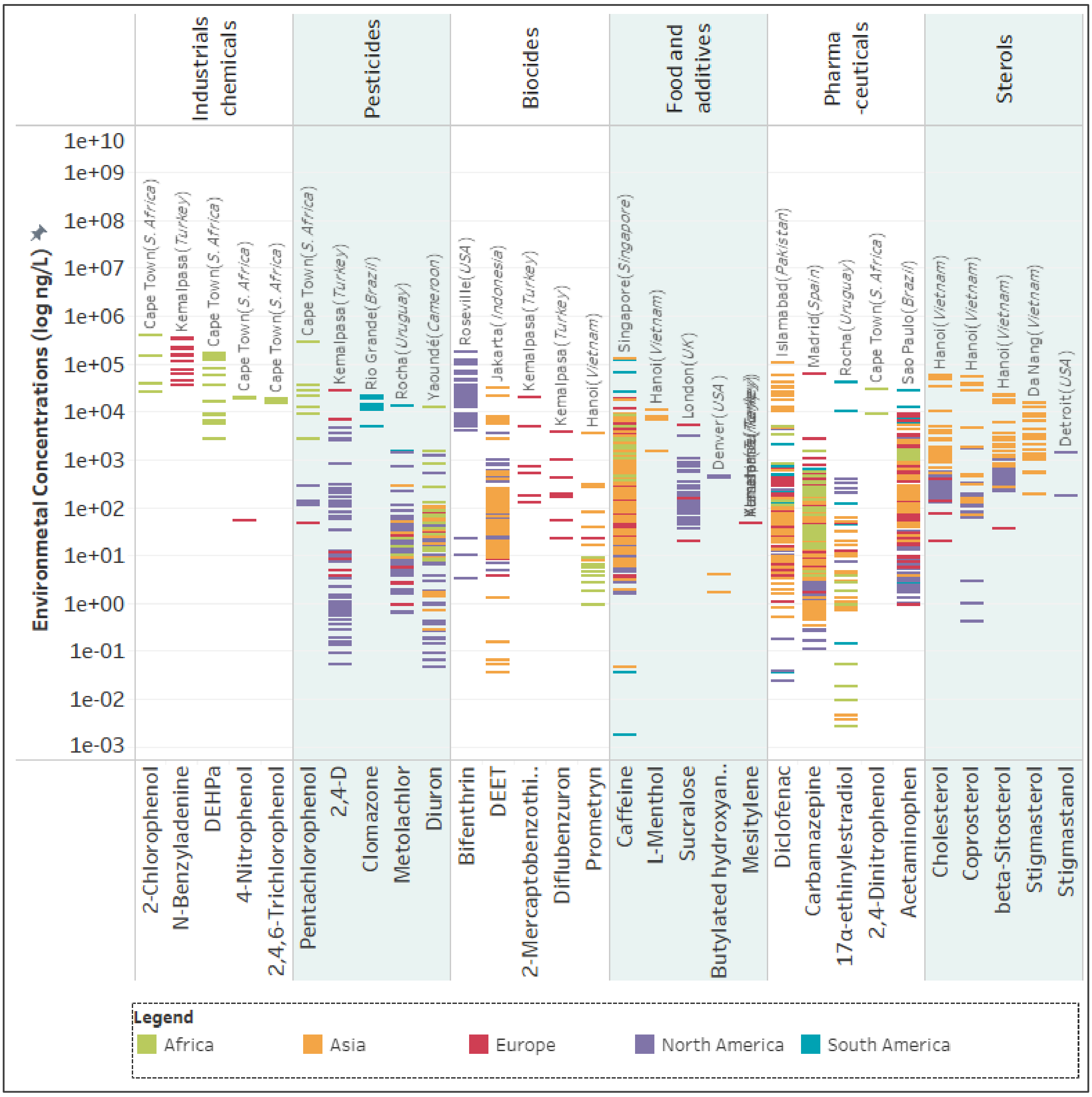


Figure 4 - (continued) Environmental concentrations of the top 5 chemicals in ng/L for each category across all studies of the systematic review. Every line represents a concentration detected at 1 site in 1 of the monitoring studies. The lowest data on the panel represent "<LOQ", "<LOQ" or ND. Data from the different continents are marked with different colours. For each chemical, the urban environment and country where the highest locations were extracted is labelled.

Figure 4 - (continued) Environmental concentrations of the top 5 chemicals in ng/L for each category across all studies of the systematic review. Every line represents a concentration detected at 1 site in 1 of the monitoring studies. The lowest data on the panel represent "<LOQ", "<LOQ" or ND. Data from the different continents are marked with different colours. For each chemical, the urban environment and country where the highest locations were extracted is labelled.

Which chemicals are the most researched in the world? (Table 2)

1. Caffeine n=478

Caffeine was the most researched chemical with 478 data points collected across 44 cities. Caffeine can be found in beverages like coffee, tea or sodas but is also used as a pharmaceutical or a stimulant. Caffeine is the most consumed stimulant in the world with an estimated consumption of 186 mg/L per day per capita in the US (Giovanini de Oliveira Sartori and Vieira da Silva, 2016; Korekar, Kumar and Ugale, 2019). Caffeine was monitored in three cities in South America, one in Africa, 16 in Asia, ten in Europe and 14 in North America. The maximum concentration was 129 µg/L in Sao Paulo (Brazil). Average concentrations were 10 698 ng/L in South America, 2 750 ng/L in Africa, 1 475 ng/L in Europe, 1 104ng/L in Asia and 319 ng/L in North America. The removal efficiency of caffeine by WWTP varies with technology: it can reach 100% with reverse osmosis (Egea-Corbacho Lopera, Gutiérrez Ruiz and Quiroga Alonso, 2019). In a few studies, caffeine concentrations were higher in rivers than in WWTP effluent, possibly indicating illegally untreated wastewater discharge as an important source of caffeine emissions. In Sao Paulo (Brazil), the specific high concentrations of caffeine could result from multiples factors: high population density, high culture of consumption of caffeine (4% of the adult Brazilian population consumed 400 mg/L per day per capita), samplings during a dry season, and a low efficiency water system to cite a few (López-Doval *et al.*, 2017).

2. Carbamazepine n=373

The pharmaceutical carbamazepine was the second most studied molecule researched in 41 urban environments. Carbamazepine is an anticonvulsant and mood stabilizing drug primary used for treatment of epilepsy, bipolar disorder, and trigeminal neuralgia (Ayano, 2016). In this systematic review, average concentrations of carbamazepine were 170 ng/L in Africa, 26 ng/L Asia, 41ng/L in North America, 164 ng/L in South America and 516 ng/L in Europe. The maximum concentration was 67 715 ng/L seen in Madrid (Spain). This high concentration was measured in a wastewater-dominated stream with pharmaceutical plants and a geriatric hospital located near to the sampling point. High concentrations were measured repeatedly at this location, indicating a potential malfunction of the WWTP in question to remove carbamazepine (González Alonso *et al.*, 2010; Valcárcel *et al.*, 2011). Carbamazepine is a chemical that is not easily removed by WWTPs (usually less than 10%). Removal efficiency can be negligible and can reach 68% with near-anoxic treatment in lab-scale conditions (Zhang, Geißen and Gal, 2008; Hai *et al.*, 2011, 2018).

3. Sulfamethoxazole n= 295

Sulfamethoxazole is a well-known antibiotic that has been used worldwide in combination with trimethoprim since the 1960s (Ho and Juurlink, 2011). The average concentrations of this molecule by continent were 3 044 ng/L in Africa, 194 ng/L in North America, 463 ng/L in Asia, 94 ng/L in Europe and 62 ng/L in South America. The highest concentration (13 800 ng/L) was observed in Nairobi, the capital of Kenya. One important socio-economic factor influencing sulfamethoxazole in Kenya is the HIV and malaria epidemy. Sulfamethoxazole is the recommended treatment for children with HIV-infected mothers with treatments recommended to occur daily up to the age of 4 based on WHO guidelines (WHO, 2015; Kasule *et al.*, 2018). Sulfamethoxazole is also used against malaria in Sub-Saharan Africa and Asia (Homsy *et al.*, 2014). Nairobi River is also contaminated with untreated domestic wastewater, which contributes to sulfamethoxazole emissions. Concentrations of 6 010 ng/L and 5 730 ng/L were also detected in Durban city (South Africa) and Hanoi (Vietnam) respectively. Removal rates for sulfamethoxazole by WWTPs in the literature varies greatly with technologies. It can reach 97.6% in Fenton/photo-Fenton process in lab-scale conditions (Prasannamedha and Kumar, 2020).

4. DEET n= 198

N,N-diethyl-m-toluamide (DEET) is an insect repellent primarily used in domestic products in spray or in skin lotion (Degennaro, 2015). Average concentrations of DEET were close 100 ng/L in Europe, South America and North America and 1297 ng/L in Asia. The maximum concentration 35 000 ng/L was detected in Jakarta, Indonesia. In Europe and North America, detected concentration were lower than in Asia. The impacts of a “local diseases profile” have an impact on DEET emissions. DEET is massively used to prevent malaria and therefore detected in high concentrations in sub-tropical cities (Hanoi and Jakarta). DEET regulations could also have an impact. Regulations in the US allow products with a concentration of 100% DEET while in Europe, maximum concentration allowed is 50%.

5. Ibuprofen n=173

Ibuprofen is a non-steroidal anti-inflammatory drug sold over-the-counter (Bushra and Aslam, 2010). The average concentration of ibuprofen was 1 076 ng/L in Europe, 573 ng/L in North America, 367 ng/L in south America and 249 ng/L in Asia. The highest concentration of 20.7 µg/L was observed in a river channel of Granada, Spain. However, the same location was sampled again the next day and the concentration of ibuprofen had dropped to 5.3 µg/L. The authors explained high concentration by sampling in the dry season in a wastewater dominated stream with low water transport (Luque-Espinar *et al.*, 2015).

6. Diclofenac n=173

Diclofenac, a human and veterinary anti-inflammatory that is used worldwide, was the 7th most researched chemical across all studies. Diclofenac was detected at average concentration of 7 419 ng/L in Asia, 2 021 ng/L in Africa, 315 ng/L in North America, 160 ng/L in South America, and 106 ng/L in Europe. The highest concentration was 116 000 ng/L in Islamabad, Pakistan. In other cities, diclofenac concentrations were below 5 µg/L. High concentrations of diclofenac in India and Pakistan could be explained by the use of diclofenac for veterinary usage in Asia, while it is restricted and only permitted in 5 countries in Europe: Spain, Italy, Estonia, Czech Republic and Latvia (Margalida & Oliva-Vidal, 2017).

Table 2- Average and maximum concentrations in ng/L of caffeine, DEET, sulfamethoxazole, diclofenac, carbamazepine, Ibuprofen across 40 urban environments worldwide. Red colour cells are chemicals maximum concentration across our database.

				Caffeine		Carbamazepine		DEET		Diclofenac		Ibuprofen		Sulfamethoxazole	
				Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Asia	China	Beijing	21.3 M	2,746	9,785	68	189	188	546	77	170			30	43
		Ghangzhou	15.3 M	561	6,980	1	11	0	0	195	645	180	542	1	4
		Wuhan	11 M	44	220	3	7							1	3
		Haikou	1.93 M	643	3,100			58	140			408	1,400		
		Yangtze River	150 M			44	146	184	575					13	26
	Vietnam	Hanoi	4.87 M	5,368	8,662									1,953	5,730
		Da Nang	1.19 M	330	645	28	28								
		Ho Chi Minh	9.08 M	3,189	9,652									238	664
		Hue	417 000												
	Pakistan	Lahore	11.1 M	76	132					2	3	9	18	1	1
		Islamabad	1 M							32,643	116,000				
	Bangladesh	Dahka	22.3 M	49	126			28	103						
	Indonesia	Jakarta	10.6 M	5,179	19,100			9,538	35,000	49	100	737	2,900		
	Malaysia	Kuala Lumpur	1.9 M	12	19					4	6			0	0
	Singapore	Singapore	5.7 M	6,493	144,179	21	54	410	6,232	21	21	41	111		
	South Korea	Seoul	9.78 M	130	250	78	160	105	190	39	98	80	270	64	190
	Thailand	Bangkok	9 M	737	1,610					75	121	226	419	11	29
Europe	Italy	Rome	2.87 M			69	75			120	120	153	210		
		Milan	1.35 M	2,394	4,339	122	246			260	695	98	174	7	14
	Romania	Cluj-Napoca	303047	298	333	46	56					46	63		
		Iasi	318 870	33	46	19	40	7	9	9	9			6	11
	Spain	Madrid	3.22 M	2,334	13,167	2,115	67,715			226	440	677	2,761	286	952
		Granada	232 200	2,467	8,100							8,480	17,250		
	France	Caudebec	4 141	69	160	25	83			49	173	86	611	73	121
	Greece	Ioannina	112 480	1,015	3,506	131	406			180	457	656	1,351	81	190
	Turkey	Istanbul	15.4 M	2,387	20,427					17	52	157	263	53	332
	UK	London	8.98 M	498	6,310	151	826	342	590	95	380	240	450	28	146
North America	USA	Los Angeles	3.96 M			324	330	620	860	101	124	41	41	861	932
		San Francisco	874 900	3	3	4	8					1,193	1,507	19	29
		Denver	705 570	1,332	3,760	174	390	1,181	3,970	1,338	4,830			427	772
		Raleigh	464 480	8	17	2	3	29	67			0	1	1	3
		Rochester	206 840	55	250	53	150	36	110					493	2,400
		Dickinson Bayou	20 900	38	120	7	68			28	45				
	Canada	Hamilton	579 200	484	3,280	83	299	117	470	0	0	832	3,990	103	441
		Cowansville	12 480	16	35	47	106					8	20	216	578
		Regina	190 400	1,470	1,470	350	350	490	490	260	260	1,590	1,590	510	510
Africa	Kenya	Nairobi	4.4 M											3,154	13,800
	South Africa	Durban city	595 000	2,750	9,250	428	1,650			3,277	5,300	7,233	11,000	2,260	6,010
	Uganda	Kampala	1.507 M			131	155			138	153			2,480	2,500
S.	Brazil	Sao Paulo	12.3 M	15,979	129,585	70	215			83	386	165	744		

Summary of socio-economics drivers of chemical pollution

Sources of chemical pollution in urban environments are usually related to socio-economics factors. The list below presents socio-economics drivers that were regularly cited by authors of articles identified in this systematic review as important drivers of chemical emissions:

- WWTP technology and connectivity: According to the 2021 UN report, 44% of household wastewater is not safely managed globally . The absence, low-technology and low-conductivity of wastewater to WWTP is major driver of urban chemical pollution(Ernstson *et al.*, 2010; Inam *et al.*, 2019). This is particularly true is developing-cities (Awad, Gar Alalm and El-Etriby, 2019). In this study, high sterols concentrations in Nairobi and Hanoi were related to lack of WWTP and water management (Ngumba, Gachanja and Tuhkanen, 2016; Chau *et al.*, 2018). Similarly in Cape Town, the diversity of chemicals detected in very high concentrations (plastics, cosmetics, industrials and others) showed part of wastewater is directly released in the surrounding freshwater body (Olujimi *et al.*, 2012).
- Climatic events (floods, drought): Climate change and reduction of pervious surfaces in urban environment led to increasing number of floods and droughts. Floods can provoke the release of untreated wastewater from WWTP because of overcapacity issue or leakage of waterpipes (Garofalo *et al.*, 2017). In the city of York (UK), paracetamol concentrations spiked at 9 822 ng/L in March because of a septic effluent due to sewer overflow. Paracetamol concentrations was below 200 ng/L in other monitoring events (Burns *et al.*, 2018). For droughts, river flows decrease and chemicals concentrations increase because of low dilution. This is particularly true for river Manzaneres in Madrid (Spain). Manzaneres river is a WWTP effluent-dominated river with a very low dilution factor because of rare rainfalls events (Rico *et al.*, 2019).
- Local industries/ agricultural activities: The profile of chemical pollution of a city reflects surrounding human activities: The pesticide clomazone was detected up to 23 000 ng/L in Rio Grande (Brazil) because of high rice culture (Primel *et al.*, 2010). Metolachlor was detected at 14 640 ng/L in streams next to the city of Castillos (Uruguay) because of agricultural activities (Griffero et al., 2019). PFCs were the

highest in a very industrialised city (Zibo, China) with fluorine production site (Li *et al.*, 2018).

- Local diseases pattern: profile of chemical pollution in city can also reflect local diseases patterns. In this systematic review DEET was detected at high concentrations in the tropical cities like Jakarta (Indonesia) or Singapore where mosquitoes-bites prevailed (Dsikowitzky *et al.*, 2014; Tran *et al.*, 2014) The same was seen with high concentrations of sulfamethoxazole used as a preventive treatment for HIV in Nairobi (Kenya) (Ngumba, Gachanja and Tuhkanen, 2016).
- Regulations: Regulations has a strong impact on chemical emissions. The most explicit example in this review is for atrazine. Atrazine is a herbicide that is banned in the UE since 2003 but is still in used in the US (Sass and Colangelo, 2013). Atrazine was detected up to 9 µg/L in Detroit (USA) while maximum concentration in Europe was 15ng/L in Iasi (Romania) (Moldovan *et al.*, 2018).

2.4 Limitations and recommendations

Three main limitations were encountered in this study to understand the problem of urban chemicals freshwater pollution better:

First, monitoring of chemicals in regions of the world with no or low data: Africa, South America, Middle-East, Eastern Europe, Siberia. These regions have no sufficient data. The influence of socio-economics drivers on chemicals emissions in these regions cannot be studied and mitigations strategies cannot be developed. The “baseline” situation of chemical pollution in these regions is for the moment only speculative.

Second, monitoring should have multiples samplings events. With a single monitoring event, chemicals concentrations cannot be compared or put into perspective. This limits the richness of data collected. In this review, 48 articles conducted freshwater analysis on a single event and 40 articles had a duration over one year. The longest monitoring lasted 5 and 6 years and sampled fresh water every 2.5 months for perfluoroalkyl acids in Madrid (Spain) and for fipronil in California’s cities (USA). Despite knowledge that spatial and temporal variations have an impact on chemical emissions, deeper analyses were not possible here because of limitations of data (Burns et al., 2018).

Third, out of 350 000 chemicals registered for production and use worldwide, we have identified data for only 1 119 of these representing only 0.32% of chemicals in use (Wang et al., 2020). High cost of analytical equipment and analytical knowledges are keys barriers to a larger studies on chemical pollution (Wilkinson et al., 2019). Accurate and precise analytical instruments can measure concentrations up to 0.001 ng/L, but methodologies must be developed for each chemical at a time and adapted to each analytical instrument.

Occurrence of chemicals in urban environments does not necessarily mean that chemicals posed a risk to human and environmental health. In the next chapter, the monitoring data collected in this chapter will be explored from a risk perspective for each urban environment identified.

Chapter 3: Identifying priority chemical contaminants in urban riverine systems in world

3.1 Introduction

In the last chapter, more than 1100 chemicals were identified that have been monitored in urban aquatic environments worldwide. In this chapter, the risks posed by these chemicals to aquatic organisms are described and a list of priority chemicals for each continent was developed.

Multiple prioritisation methods exist to identify toxic chemicals in the environment. These include exposure-based, hazard-based and risk based- methods. Expose-based methods usually rely on the use of predicted environmental concentrations (PECs). PECs are calculated on sales, prescription data, per capita consumption, the proportion of the chemical excreted unchanged (for ingested chemicals like pharmaceuticals and diets supplements), and wastewater treatment plant removal rates (Guo *et al.*, 2016; Bu *et al.*, 2020). The advantage of exposure-based methods that employ PEC predictions is that chemicals can be considered that have not previously been measured in the environment. The disadvantage is that the collection of data cited above can be difficult and, for many substances these data do not exist. Exposure-based prioritisation is therefore more applicable to substances like pharmaceuticals because prescription data, sales and metabolism data are more accessible.

Hazard based- methods prioritise chemicals based on factors such as the persistence, bioaccumulation and toxicity (PBT) of a chemical (Howard and Muir, 2010; Berninger *et al.*, 2016; EPA, 2018). As laboratory-PBT based data are very limited, hazard based methods often rely on use of in-silico models, such as EU QSAR Toolbox, EPIsuite, ECOSAR or Vega Hub software, which estimate the PBT properties of a chemical based on its chemical structure. While data on the PBT properties of chemicals can be easily obtained (e.g octanol/water partitioning, half-lives in water), the difficulty with hazard-based method is that the criteria for the identification of PBT chemicals varies greatly between methodologies and a consensus on defined PBT criteria has yet to be reached (Arnot *et al.*, 2012). PBT criteria are for example very different between EU REACH, UNEP or OSPAR frameworks (Moermond *et al.*, 2012).

Lastly, risk-based methods, typically prioritise chemicals based on risk quotient (RQs) which are calculated from PECs and predicted no effects concentrations (PNECs) derived from ecotoxicity date (Donnachie, Johnson and Sumpter, 2016; Johnson *et al.*, 2017; Milovanovic *et al.*, 2019; Rico *et al.*, 2019). The advantage of risk-based method is that they provide an indication on the likelihood of a chemical posing real harm to the environment.

Here, we described a prioritisation exercise aimed at identifying chemicals from multiples class categories in urban aquatic freshwater environments worldwide that have the greatest potential to cause harm, and which therefore require further scrutiny. The prioritisation exercise was conducted individually for each continent to identify potential geographical differences in pollution priorities. For each continent, the aim was to: 1) develop a list of priority compounds and identify the riskiest chemicals; 2) compare risks posed by the different class categories; and 3) identify cities with greatest risk for their natural systems. Finally, the results were compared between continents.

3.2 Methodology

Experimental occurrence data collected in the systematic review presented in the previous chapter (Chapter 2) was used in this chapter to conduct a risk-based prioritisation.

Derivation of predicted no effect concentration (PNEC)

Acute and chronic toxicity data for the apical effects of each chemical on fish, daphnia and algae were obtained. These included: 96h LC50 values and early life stage chronic NOEC values for fish; 48 h EC50 and 21 d reproduction NOEC values for *Daphnia*; and 72 h EC50 and NOEC values for algal growth. Measured toxicity data were collected from the ECOTOX (https://cfpub.epa.gov/ecotox/) and ECHA REACH databases (https://echa.europa.eu/). For instances where experimental data were not available for an endpoint, these were predicted using *in-silico* tools including ECOSAR (https://www.epa.gov/tsca-screening-tools/ecological-structure-activity-relationships-ecosar-predictive-model), QSAR Toolbox (https://qsartoolbox.org), EPA Toxicity Estimation Software Tool (TEST) (https://www.epa.gov/chemical-research/toxicity-estimation-software-tool-test) and VEGA Hub (https://www.vegahub.eu).

The measured and predicted ecotoxicity data were then used to derive PNECs using Equation 1 and the assessment factors (AF) recommended for derivation of quality standards in the EU Water Framework Directive (Environment Agency, 2007).

Derived PNEC = $$\frac{Minimum\ NOEC\ or\ LC/EC50}{AF}$$ **Equation 1**

An AF of 10 was applied if NOEC data were available for all three taxonomic groups (fish, daphnia, algae), 50 if NOEC data were available for only two species and 100 if a NOEC was available for only one species. If no NOEC was available for a chemical, then the lowest EC50/LC50 from acute studies with fish, daphnids and algae was used, and an AF of 1000 was applied.

PNEC-equivalent values, such as voluntary safe values or environmental quality values (EQS), from the industry and publics institutions were also incorporated into the analysis. PNEC-equivalent values were collected for: antibiotics from the AMR Industry Alliance website (www.amrindustryalliance.org/); and for the 15 watch list chemicals from the Water Framework directive and for the 45 priority chemicals from the European Commission website (https://eur-lex.europa.eu/). If a chemical had PNEC-equivalent and a derived-PNEC calculated, then the smallest of these was used for the subsequent risk quotient calculation.

If a chemical had no chronic, acute or any equivalent toxicity value collected or predicted, then no PNEC was calculated and the chemical was not considered for the rest of the study. A list of a chemicals with no PNEC value is presented in Appendix 2.2.

Risk quotient for chemicals

Risk quotients (RQ) were calculated for each chemical and each urban environment identified in Chapter 2 (110 urban environments in total) using Equation 2. A location with a name specified by authors (usually the name of a city, a town or a village) was considered an urban environment. When multiple data were available for one chemical in one urban environment, then 90th percentile measured environment concentration was used in the calculation in preference to maximum concentrations to avoid the use of extremely high measurements that could provide a misleading indication of the level of risk. If a chemical had only one concentration data point, this concentration was used to calculate the risk quotient.

$RQ = MEC_{90} / PNEC$ Equation 2

Where: MEC_{90}= 90^{th} percentile measured environmental concentration of a chemical in one urban environment and PNEC= derived PNEC or equivalent-PNEC for each chemical. A chemical was considered a "priority chemical" when its RQ was above 1.

Cumulative risk quotient per city

To study the overall risks for natural environments in each of the urban environments studied, the cumulative risk quotient per city was calculated by summing up all risk quotient of all chemicals detected at that location:

$$\textbf{Cumulated RQ} = \sum_{i=0}^{n+1} \frac{90th\ MEC}{Derived-PNEC} \quad \textbf{Equation 3}$$

Where: MEC90= 90th percentile measured environmental concentration in our database; and PNEC= derived PNEC or equivalent-PNEC for each chemical.

Ranking of chemicals and ranking of cities

Chemicals were first ranked by continent. Some chemicals were measured in multiple urban environments, meaning that some chemicals had multiple RQ calculated in the same continent. To be able to rank chemicals by continent, the average of all RQ calculated for the same chemical was used. Chemicals were then ranked from highest to lower. The higher the RQ, the higher the concern.

Cities were then ranked based on their cumulated RQ. All RQs of chemicals were summed-up for each urban environment. Similarly as for the chemicals ranking, the higher the cumulated RQ of an urban environment, the higher the risks posed by chemical pollution in the city.

3.3 Result

Part 1: Ecotoxicity and PNEC calculation

Using measured ecotoxicity value, it was possible to derive-PNEC values for 181 of the chemicals. With the addition of predicted ecotoxicity data, it was possible to expand the number of chemicals with PNECs to 949 chemicals (Annexe 2.3). For 191 chemicals that had environmental occurrence data, it was not possible to derive a PNEC. A list of chemicals with no PNEC-derived is available in Annexe 2.2. These chemicals were mostly industrials chemicals that were outside the applicability domain of prediction in-silica models. Model predicting toxicity of chemicals based on Quantitative structure-activity relationship (QSAR) approach can only predict toxicity if within the model the chemicals have structural similarity. If a chemical has with limited or no structural similarity with other chemicals (e.g. ECHA QSAR Toolbox), then no prediction toxicity can be determined. Other models can be limited to chemicals with specific physicochemical properties like molecular weight, logP (partition coefficient), and other relevant descriptors. Chemicals that different features will not be able to have predicted toxicity.

For 87 chemicals, PNEC-equivalent values were available that had been developed by industry and/or public institutions. PNEC-equivalent values were lower than the derived-PNEC for 65 chemicals so for these chemicals, the PNEC equivalent was used for the risk quotient calculations.

Part 2: Risk characterization and spatial analysis

2.1 Risk characterization and continental analysis

In total, 168 chemicals belonging to 16 class categories had an RQ above 1 in at least one urban environment and therefore considered priority chemicals. The categories with the highest number of chemicals with an RQ>1 were pesticides, petrochemicals, earth elements, industrial chemicals, cosmetics and personal care products and biocides. None of the PCBs and PBDEs had a risk quotient above 1.

Asia was the continent with the largest number of chemicals with an RQ>1 (75 chemicals from 14 classes) followed by Europe (67 from 14 class categories), Africa (46 from 11 classes), North America (43 from 12 classes) and South America (18 from 7 classes) (Figure 5). Petrochemicals were the largest class of top priority compounds for Asia, while for Africa, North America and South America, pesticides were the largest class. For Europe, the largest class were the earth elements.

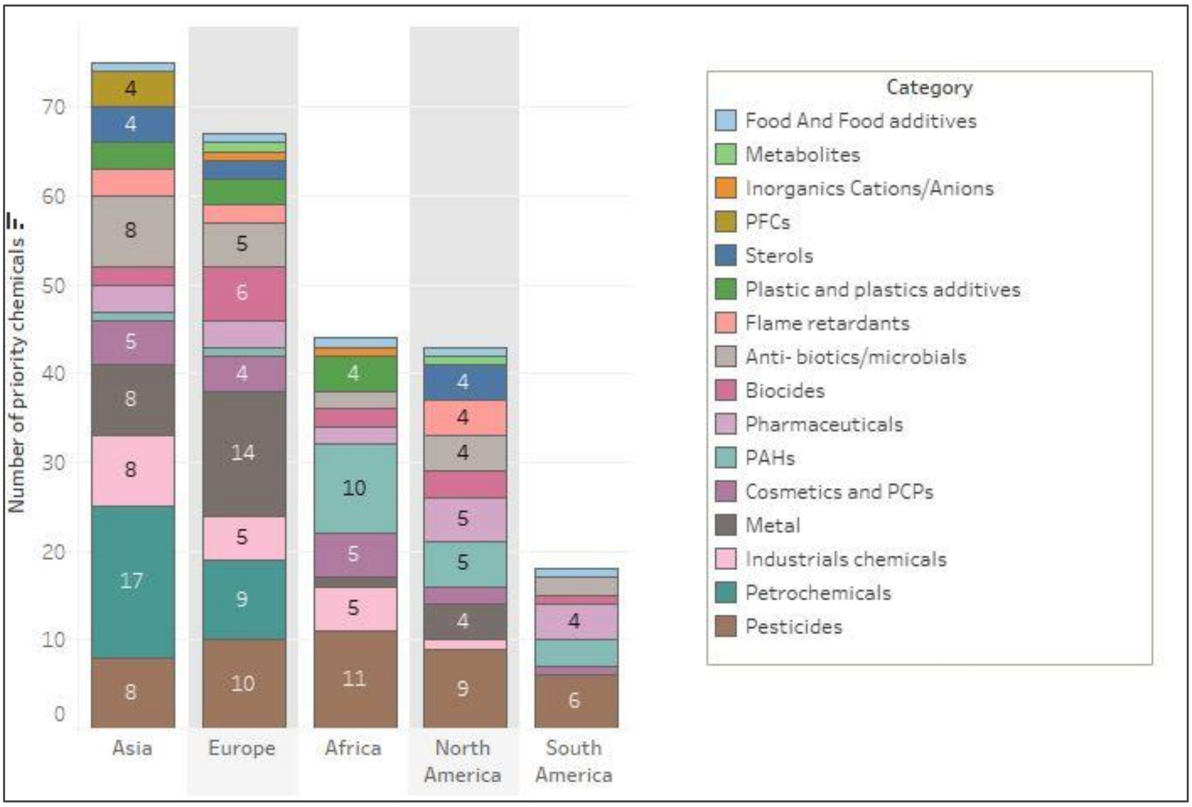


Figure 5 Number and class category of chemicals which had at least one RQ above 1 in one urban environment in the systematic review for each continent

All 168 priority chemicals are presented and ranked by class category and by continent in Table 3. There were 130 chemicals with an RQ below 100, 16 between 100 and 1 000 and 15 between 1 000 and 10 000. Eight substances were identified with an RQ exceeding 10 000, namely hexacosane and tricosane (both petrochemicals) in Asia and Europe; aluminium (metal) in Europe; benzo(b)fluoranthene, fluoranthene and benzo(a)pyrene (PAHs) in Africa; bifenthrin (biocides) in Europe and North America and pentachlorophenol (pesticide) in Africa (pesticides). The riskiest chemical in Africa was benzo(b)fluoranthene (RQ=250333), Hexacosane was the highest risk chemical in Asia (RQ=1 581 016) and in Europe (RQ= 752 162), bifenthrin was the highest risk chemical in North America (RQ=1 666 067) and 17β-estradiol was the highest risk chemical in South America (RQ=418).

In Asia, 648 chemicals were initially identified in the systematic review of which 406 were detected at least once above LOQ. RQ could be calculated for 365 chemicals. In total, 75 chemicals from 14 class categories had an RQ>1. Risk was mostly posed by eight chemicals with RQ above 1 000: four petrochemicals (hexacosane, tricosane, eicosane, nonadecane), three sterols/stanols (beta-sitosterol, cholesterol, coprostanol) and one PFC (PFOA).

Hexacosane and tricosane with continental RQ of 1581016 and 190890 respectively posed the greatest risks. These two petrochemicals had the lowest PNEC value (0.001ng/L for hexacosane; 0.016ng/L for tricosane) and higher environmental concentrations compared to other petrochemicals in Asia. Tricosane was detected up to 9 607 ng/L and hexacosane up 4 606 ng/L in Ho Chi Ming (Vietnam). Petrochemical risk was higher in megacities of our database (Hanoi, Ho chi Minh) compared to smaller cities. Four perfluorinated posed great risks including PFOA with a continental RQ of 1 349. The city of Zibo (China) had the highest RQ for PFOA: 4047. In other Asian cities, PFOA did not pose a risk to the natural environment in this study.

In Europe, 648 chemicals were initially identified of which 424 were detected at least once above the LOQ. RQs were calculated for 371 chemicals. In total, 66 chemicals from 14 class categories had an RQ>1. Seven chemicals had an RQ> 1000: hexacosane and nonadecane (petrochemicals) and aluminum, copper, nickel and zinc (metals) and bromide (inorganic anion).The chemical that posed the greatest risk was hexacosane. The highest concentration for hexacosane in Europe was 781.56 ng/L in Nova Sid. All metals measured in Europe were prioritised. Aluminium had a significantly higher continental RQ (RQ= 449 962) compared to other metals. Aluminium was detected at similar concentrations than other metals but its PNEC value was smaller (4 ng/L).

In North America, 362 chemicals were initially identified of which 299 were detected at least once above the LOQ. RQs were calculated for 280 chemicals. In total, 40 chemicals from 11 class categories had an RQ>1. The top three priority chemicals were bifenthrin, beta-sitosterol and stigmastanol with average continental RQs of 1303 856, 1991 and 963 respectively. Bifenthrin was systematically detected above the PNEC with concentrations ranging from 4-230000ng/L. RQs of sterols were smaller compared to Asia but ranged from 67 to 3600 in Detroit.

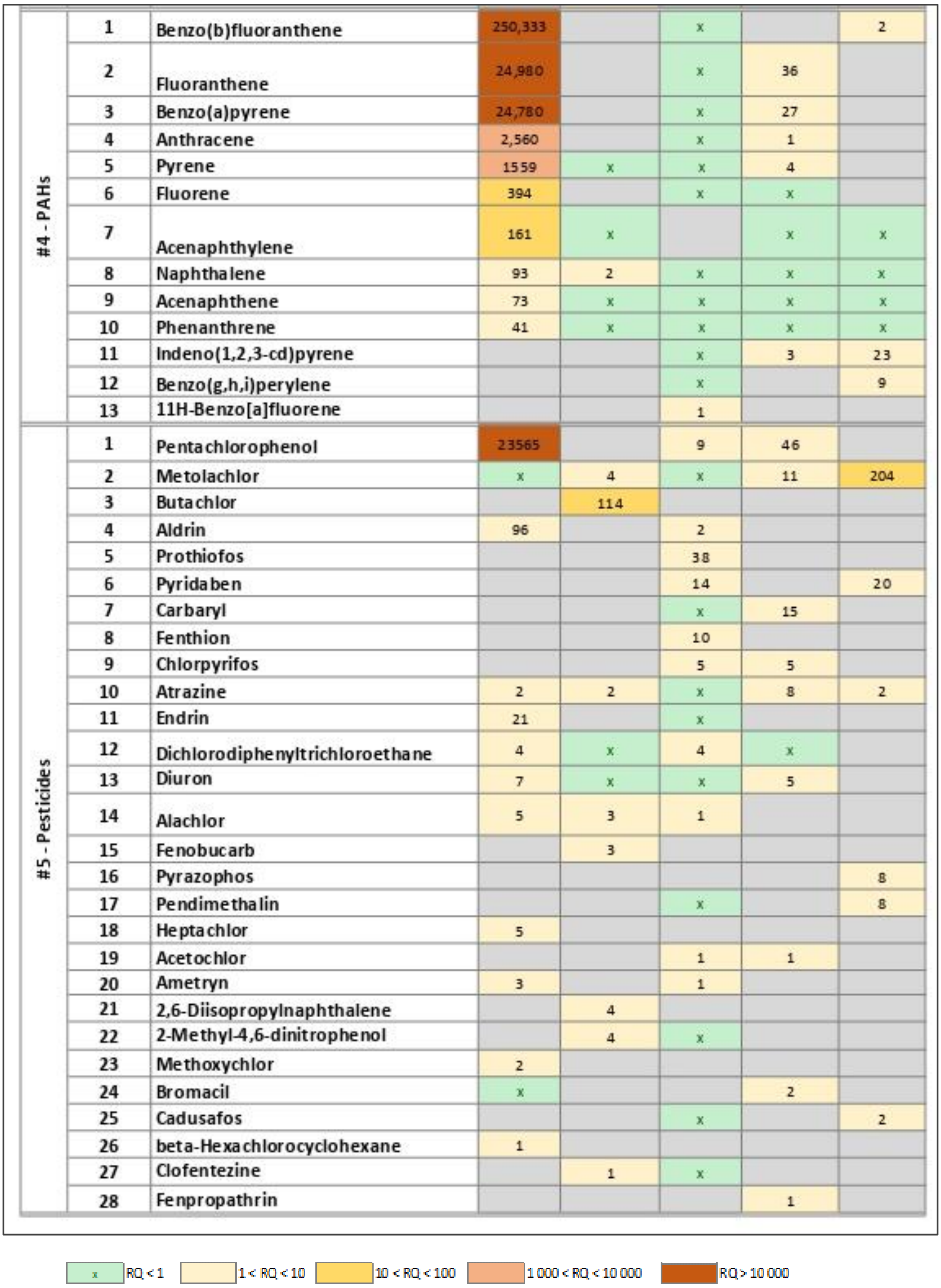
In Africa, 136 chemicals were initially identified of which 116 were detected at least once above the LOQ. RQs were calculated for 113 chemicals. In total, 46 chemicals from 11 class categories had an RQ>1. The largest class categories of priority chemicals were pesticides and PAHs with 11 and 10 priority chemicals respectively. The top priority chemicals were benzo(b)fluoranthene followed by fluoranthene and benzo(a)pyrene with continental RQs of 250333, 24980 and 24780 respectively. Benzo(b)fluoranthenes high continental RQ was driven by a high concentration of 7.150 mg/L, detected in Thulamela municipality (South Africa). The pesticides pentachlorophenol also posed a great risk (RQ=23565), especially in Cape Town (South Africa) where it was detected at 9.210 µg/L.

In South America 124 chemicals were initially identified of which 84 were detected at least once above the LOQ. RQs were calculated for 81 chemicals. In total, 18 chemicals from 7 class categories had an RQ>1. Pesticides and pharmaceuticals were the largest categories with 6 and 4 priority chemicals respectively. Highest continental RQ was 418 for 17β-estradiol (pharmaceuticals) and 204 for metolachlor (pesticides). The chemicals metolachlor, caffeine, atrazine, miconazole and 17β-estradiol had the highest continental RQs in South America compared to the other continents. The number of data collected for South America was less compared to the other continents.

Table 3 - Priority chemicals for each continent by class category. Average RQ of chemical for all urban environment within the continent is indicated in the cells. Category #11 corresponds to food, #13 to Inorganic anions/cations, #14 to food and additives and #15 to metabolites.

	Rank	Chemical name	Africa	Asia	Europe	North America	South America
#1 - Biocides	1	Bifenthrin				1,666,067	
	2	Cypermethrin			147		
	3	Diazinone			91		
	4	Permethrin			23	2	
	5	Pyriproxyfen			20		
	6	Diazinon		x	x	21	
	7	Pirimiphos-methyl	40				
	8	2-Mercaptobenzothiazole			10		
	9	Fenoxycarb			10		
	10	Miconazole		x		x	7
	11	Isoproturon	x	2	x		
	12	2-Phenylphenol		2	x		
	13	λ-Cyhalothrin	1				
#2 - Petrochemicals	1	Hexacosane		1,581,016	752,167		
	2	Tricosane		190,890			
	3	Eicosane		7,824			
	4	Nonadecane		4,846	1,145		
	5	Octadecane		885	773		
	6	Heptadecane		343	185		
	7	Hexadecane		202	120		
	8	Dotriacontane		92			
	9	Octacosane		69			
	10	Pentacosane		69	22		
	11	Docosane		32	8		
	12	Heneicosane		31	3		
	13	Tetradecane		10	19		
	14	Decane		9			
	15	Tridecane		3	x		
	16	Nonane		3	x		
	17	Pentadecane		1			
#3 - Metals	1	Aluminum			449,962		
	2	Copper		85	3252	269	
	3	Nickel		43	2352	40	
	4	Zinc		365	1384		
	5	Nitrogen	5300				
	6	Phosphorus	1317				
	7	Lead		47	314		
	8	Iron		80	201		
	9	Chromium	34	5	220	6	
	10	Silver			158		
	11	Titanium			82		
	12	Cadmium			13	185	
	13	Cobalt		25	24		
	14	Tin			21		
	15	Mercury			8		
	16	Vanadium			3		
	17	Barium		1			

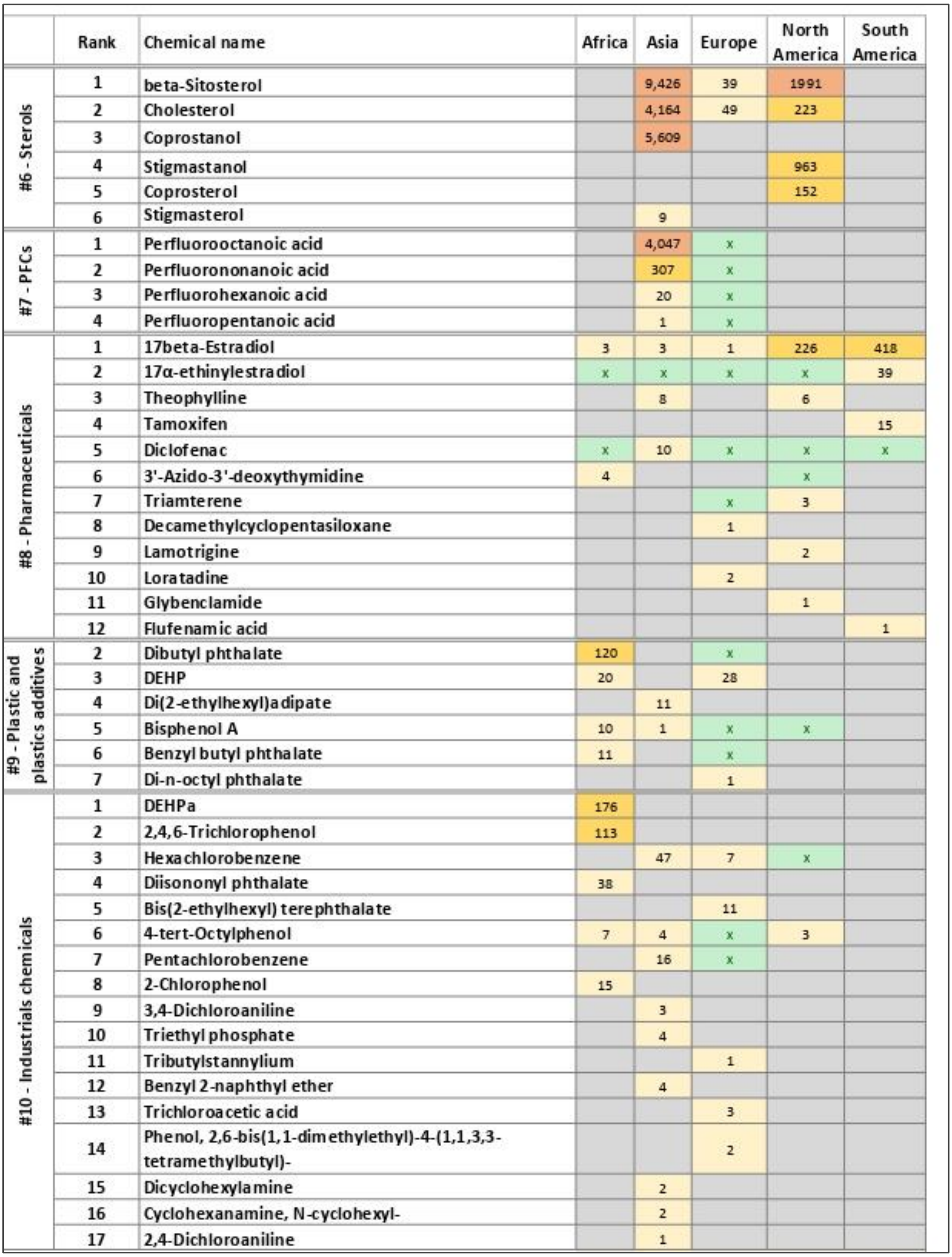
Table 3 – (continued) Priority chemicals for each continent by class category. Average RQ of chemical for all urban environment within the continent is indicated in the cells. Category #11 corresponds to food, #13 to Inorganic anions/cations, #14 to food and additives and #15 to metabolites.



#4 - PAHs	1	Benzo(b)fluoranthene	250,333		x		2
	2	Fluoranthene	24,980		x	36	
	3	Benzo(a)pyrene	24,780		x	27	
	4	Anthracene	2,560		x	1	
	5	Pyrene	1559	x	x	4	
	6	Fluorene	394		x	x	
	7	Acenaphthylene	161	x		x	x
	8	Naphthalene	93	2	x	x	x
	9	Acenaphthene	73	x	x	x	x
	10	Phenanthrene	41	x	x	x	x
	11	Indeno(1,2,3-cd)pyrene			x	3	23
	12	Benzo(g,h,i)perylene			x		9
	13	11H-Benzo[a]fluorene			1		
#5 - Pesticides	1	Pentachlorophenol	23565		9	46	
	2	Metolachlor	x	4	x	11	204
	3	Butachlor		114			
	4	Aldrin	96		2		
	5	Prothiofos			38		
	6	Pyridaben			14		20
	7	Carbaryl			x	15	
	8	Fenthion			10		
	9	Chlorpyrifos			5	5	
	10	Atrazine	2	2	x	8	2
	11	Endrin	21		x		
	12	Dichlorodiphenyltrichloroethane	4	x	4	x	
	13	Diuron	7	x	x	5	
	14	Alachlor	5	3	1		
	15	Fenobucarb		3			
	16	Pyrazophos					8
	17	Pendimethalin			x		8
	18	Heptachlor	5				
	19	Acetochlor			1	1	
	20	Ametryn	3		1		
	21	2,6-Diisopropylnaphthalene		4			
	22	2-Methyl-4,6-dinitrophenol		4	x		
	23	Methoxychlor	2				
	24	Bromacil	x			2	
	25	Cadusafos			x		2
	26	beta-Hexachlorocyclohexane	1				
	27	Clofentezine		1	x		
	28	Fenpropathrin				1	

🟩 x RQ < 1
🟨 1 < RQ < 10
🟨 10 < RQ < 100
🟧 1 000 < RQ < 10 000
🟫 RQ > 10 000

Table 3 – (continued) Priority chemicals for each continent by class category. Average RQ of chemical for all urban environment within the continent is indicated in the cells. Category #11 corresponds to food, #13 to Inorganic anions/cations, #14 to food and additives and #15 to metabolites.



	Rank	Chemical name	Africa	Asia	Europe	North America	South America
#6 - Sterols	1	beta-Sitosterol		9,426	39	1991	
	2	Cholesterol		4,164	49	223	
	3	Coprostanol		5,609			
	4	Stigmastanol				963	
	5	Coprosterol				152	
	6	Stigmasterol		9			
#7 - PFCs	1	Perfluorooctanoic acid		4,047	x		
	2	Perfluorononanoic acid		307	x		
	3	Perfluorohexanoic acid		20	x		
	4	Perfluoropentanoic acid		1	x		
#8 - Pharmaceuticals	1	17beta-Estradiol	3	3	1	226	418
	2	17α-ethinylestradiol	x	x	x	x	39
	3	Theophylline		8		6	
	4	Tamoxifen					15
	5	Diclofenac	x	10	x	x	x
	6	3'-Azido-3'-deoxythymidine	4			x	
	7	Triamterene			x	3	
	8	Decamethylcyclopentasiloxane			1		
	9	Lamotrigine				2	
	10	Loratadine			2		
	11	Glybenclamide				1	
	12	Flufenamic acid					1
#9 - Plastic and plastics additives	2	Dibutyl phthalate	120		x		
	3	DEHP	20		28		
	4	Di(2-ethylhexyl)adipate		11			
	5	Bisphenol A	10	1	x	x	
	6	Benzyl butyl phthalate	11		x		
	7	Di-n-octyl phthalate			1		
#10 - Industrials chemicals	1	DEHPa	176				
	2	2,4,6-Trichlorophenol	113				
	3	Hexachlorobenzene		47	7	x	
	4	Diisononyl phthalate	38				
	5	Bis(2-ethylhexyl) terephthalate			11		
	6	4-tert-Octylphenol	7	4	x	3	
	7	Pentachlorobenzene		16	x		
	8	2-Chlorophenol	15				
	9	3,4-Dichloroaniline		3			
	10	Triethyl phosphate		4			
	11	Tributylstannylium			1		
	12	Benzyl 2-naphthyl ether		4			
	13	Trichloroacetic acid			3		
	14	Phenol, 2,6-bis(1,1-dimethylethyl)-4-(1,1,3,3-tetramethylbutyl)-			2		
	15	Dicyclohexylamine		2			
	16	Cyclohexanamine, N-cyclohexyl-		2			
	17	2,4-Dichloroaniline		1			

x RQ < 1
1 < RQ < 10
10 < RQ < 100
1 000 < RQ < 10 000
RQ > 10 000

Table 3 – (continued) Priority chemicals for each continent by class category. Average RQ of chemical for all urban environment within the continent is indicated in the cells. Category #11 corresponds to food, #13 to Inorganic anions/cations, #14 to food and additives and #15 to metabolites

#11	1	Caffeine	14	12	10	7	43
#12 - Cosmetics and PCPs	1	4-Nonylphenol	7	27	x	7	
	2	Nonylphenol		50	1		
	3	4-n-Nonylphenol		50			
	4	Cyclopenta[g]-2-benzopyran, 1,3,4,6,7,8-hexahydro-4,6,6,7,8,8-hexamethyl-		9		6	
	5	p-Chlorocresol	15				
	6	2,4,6-Trinitro-1,3-dimethyl-5-tert-butylbenzene			7		
	7	2,4-Dimethylphenol	3				
	8	2-Nitrophenol	3				
	9	7-acetyl-6-ethyl-1,1,4,4-tetramethyl tetralin			3	x	
	10	Phenol	3	x		x	
	11	n-Nonylphenol					2
	12	Ethylene glycol nonylphenyl ether		2			
	13	7-Acetyl-1,1,3,4,4,6-hexamethyltetraline		2			
	14	Alkylbenzenesulfonate, linear			1		
	15	2-Ethylhexyl-2-cyano-3,3-diphenylacrylate		1			
#13	1	Nitrate	58				
	2	Bromide			7,631		
#14 - Anti- biotics/microbials	1	Azithromycin		41	13	36	2
	2	Sulfamethoxazole	9	6	1	2	x
	3	Clarithromycin		x	2	5	
	4	Ciprofloxacin		2	6	x	
	5	Amoxicillin		8	x	x	
	6	Erythromycin		x	1	2	
	7	Lincomycin		2	x	x	
	8	Trimethoprim	3	x	x	x	x
	9	Tylosin		2	x		
	10	Enrofloxacin		x	x		2
	11	Cephalexin		1			
	12	Ampicillin		1			
#15	1	Paraxantine		x	29	6	
#16 - Flame retardants	1	Pentabromodiphenyl ether			4		
	2	Tris(2-butoxyethyl) phosphate				3	
	3	Tris(2-chloroethyl) phosphate		2		x	
	4	Tris(1,3-dichloro-2-propyl) phosphate		2		1	
	5	Tris(2-chloroisopropyl)phosphate		x	x	2	
	6	C10-13 chloro alkanes			2		
	7	Tributyl phosphate			x	2	
	8	1,2-Bis(2,4,6-tribromophenoxy)ethane		1			

x	RQ < 1
🟨	1 < RQ < 10
🟨	10 < RQ < 100
🟧	1 000 < RQ < 10 000
🟫	RQ > 10 000

2.2 Urban system analysis

Out of 118 urban systems identified in the systematic review, 87 of these had at least one chemical with an RQ>1: 32 in Asia, 22 in North America, 15 in Europe, 12 in Africa and 6 in South America (Figure 6). Hanoi in Vietnam had the highest number of priority chemicals with 41 priority chemicals identified. Twelve other urban systems had more than 10 priority chemicals namely Kemalpasa, Yunusemre and Ataşehir in Turkey (38, 35 and 12 priority chemicals respectively); Da Nang in Vietnam (20), Cape town and Thulamela municipality in South Africa (12 and 10 priority chemicals); Novi Sad in Serbia (13), Rocha in Uruguay (13), Detroit and Denver in USA (15 and 13), Ho Chi Minh and Danang in Vietnam (28 and 20) and Madrid in Spain (11) (Figure 6).

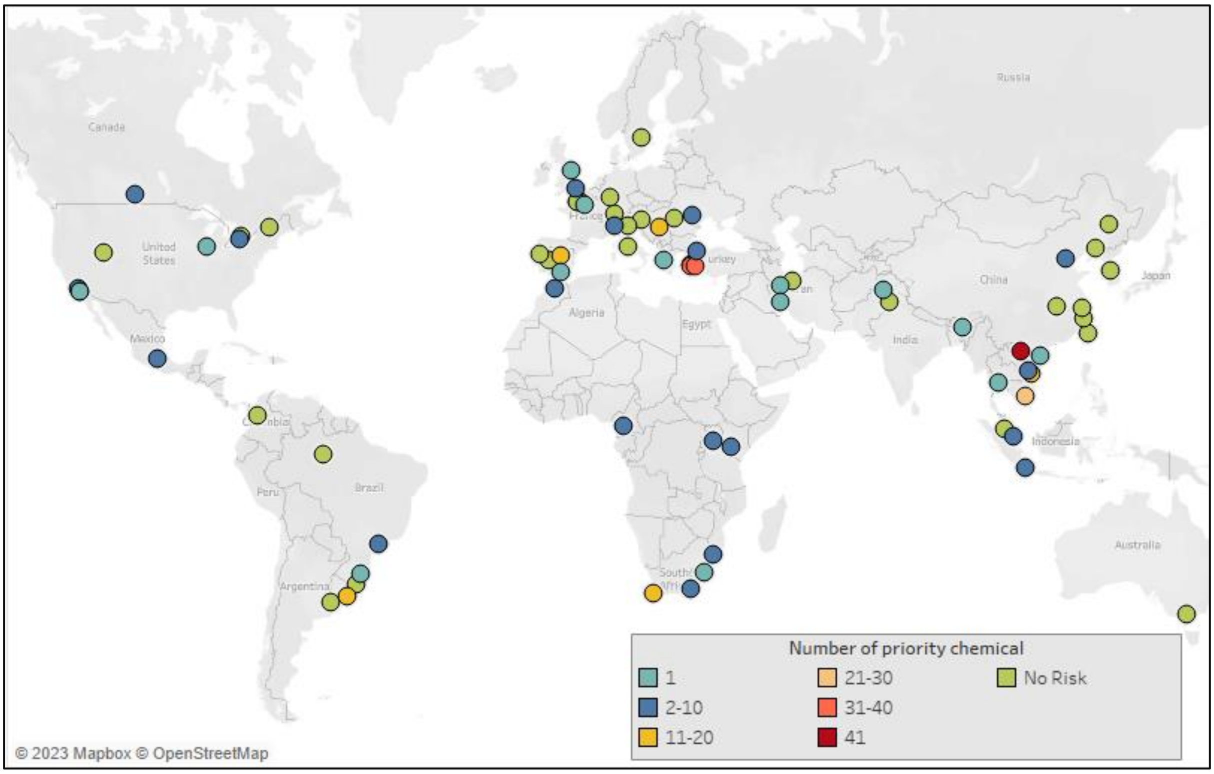


Figure 6 - Number of priority chemicals by urban environments. Sizes of circles indicated number of priority chemicals. Urban environments were no chemical had RQ above 1 are greens.

The sum and class category of chemicals RQ for each city is presented in Figure 7. The highest cumulative risk quotient of 4580684 was observed for Ho Chi Minh (Vietnam). Seven other cities had cumulative risk quotients above 10^6, namely Aliso Viejo, Laguna Niguel, Folsom, Dublin and Pleasant Hill in the US, Kemalpasa in Turkey and Hanoi in Vietnam. Petrochemicals drove the risk for Ho Chi Minh and Hanoi and the biocide bifenthrin drove the risks in cities in the US and Kemalpasa. The chemical classes driving the cumulative risk varied depending on the urban systems and could be either driven by one class category only, or by multiple classes.

For cities in China and other Asian countries, cumulative RQ chemical profiles varied greatly between cities: the risk was driven by PFOA in Zibo, by industrial chemicals in Beijing, by caffeine in Haikou (China) and Bangkok (Thailand), by pharmaceuticals in Islamabad (Pakistan), by plastics and plastics addictive in Malaysia or by multiples categories in Jakarta (Indonesia) or Yangtze (China).

In Europe, four cities had cumulative RQs between 10^3 and 10^6 namely Ataşehir, Kemalpasa and Yunusemre due to aluminium (Turkey), and Novi Sad (Serbia) due to petrochemicals. Risk chemical profile varied between cities in Europe: risks were mainly driven by caffeine in Granada (Spain), Milan (Italy) and Istanbul (Turkey) or by multiples class categories in Madrid (Spain) and Epinay-Sur-Seine (France).

In North America, five cities had cumulative RQs above 10^6 namely Aliso Viejo, Laguna Niguel, Folsom, Dublin and Pleasant Hill (all in the US) with the risk at these locations driven by bifenthrin. Different class categories drove the risk in other cities in North America: sterols in Miami and Detroit, metals in Pensacola, pharmaceuticals in Denver, caffeine in San Diego (USA) and PAHs in Alberta (Canada).

In Africa, Thulamela Municipality in South Africa had the highest cumulative RQ (304 974) followed by Cape Town in South Africa (24 082) and Fez in Morocco (6 709). Risk was driven by PAHs in Thulamela Municipality, by pentachlorophenol in Cape town and by metals in Fez. Other class categories driving the risk in other cities included plastics additives in Nigeria, antibiotics in Kampala (Uganda) and Nairobi (Kenya), caffeine in Durban city (South Africa) or biocides in Maputo (Mozambique).

In South Africa, six cities were identified with a cumulative RQ above 1 namely Rocha in Uruguay and Sao Paulo, Sinos River Valley, Vacacai, Porto Alegre and Paracombi in Brazil. The highest cumulative RQ was 1 126 in Rocha in Uruguay and was driven by pharmaceuticals, pesticides and biocides. In other cities in South America the risk was either driven by caffeine

(Sao Paulo and Sinos River Valley), pharmaceuticals (Vacacai), antibiotics (Porto Alegre) or cosmetics and personal care products (Paracombi), all in Brazil.

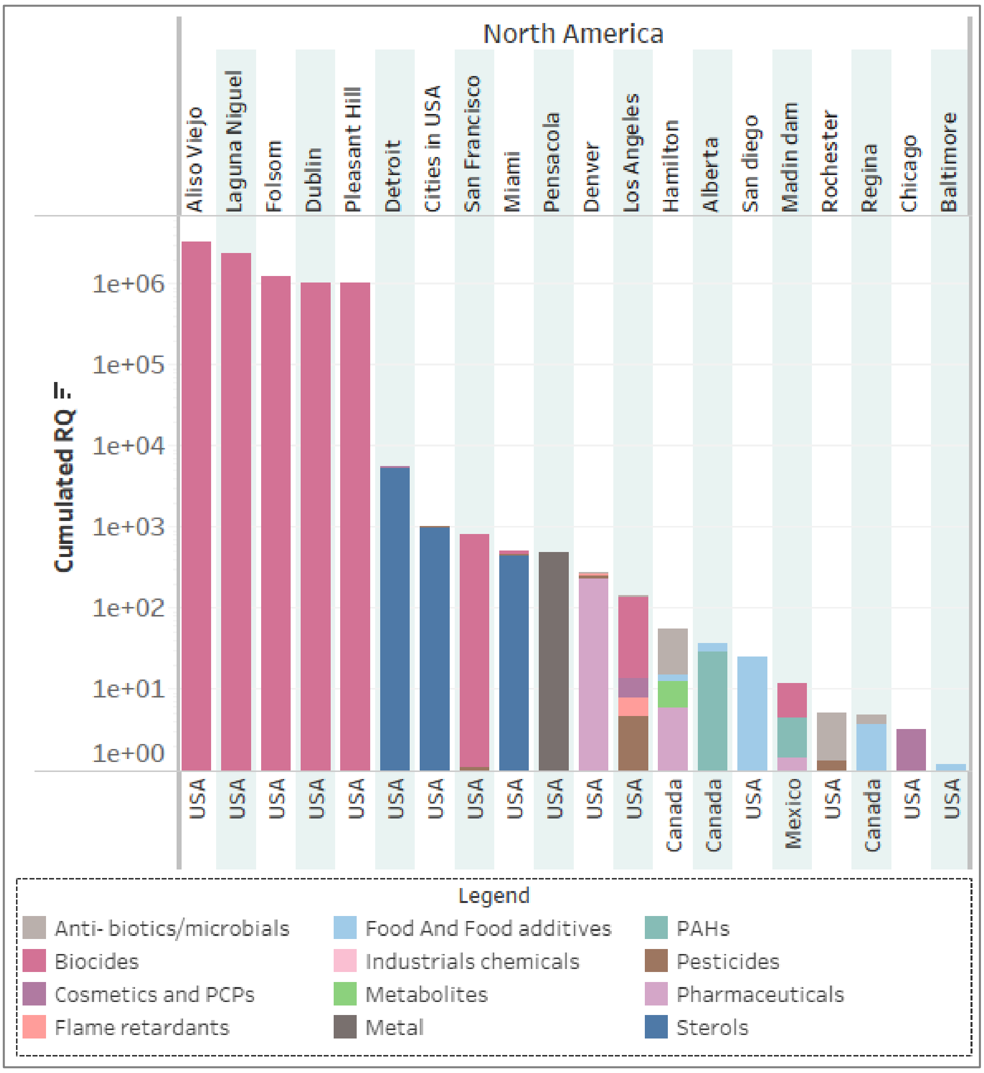


Figure 7 Cumulated RQ for each urban environment with at least one priority chemicals. Colours indicate class category of chemicals RQ

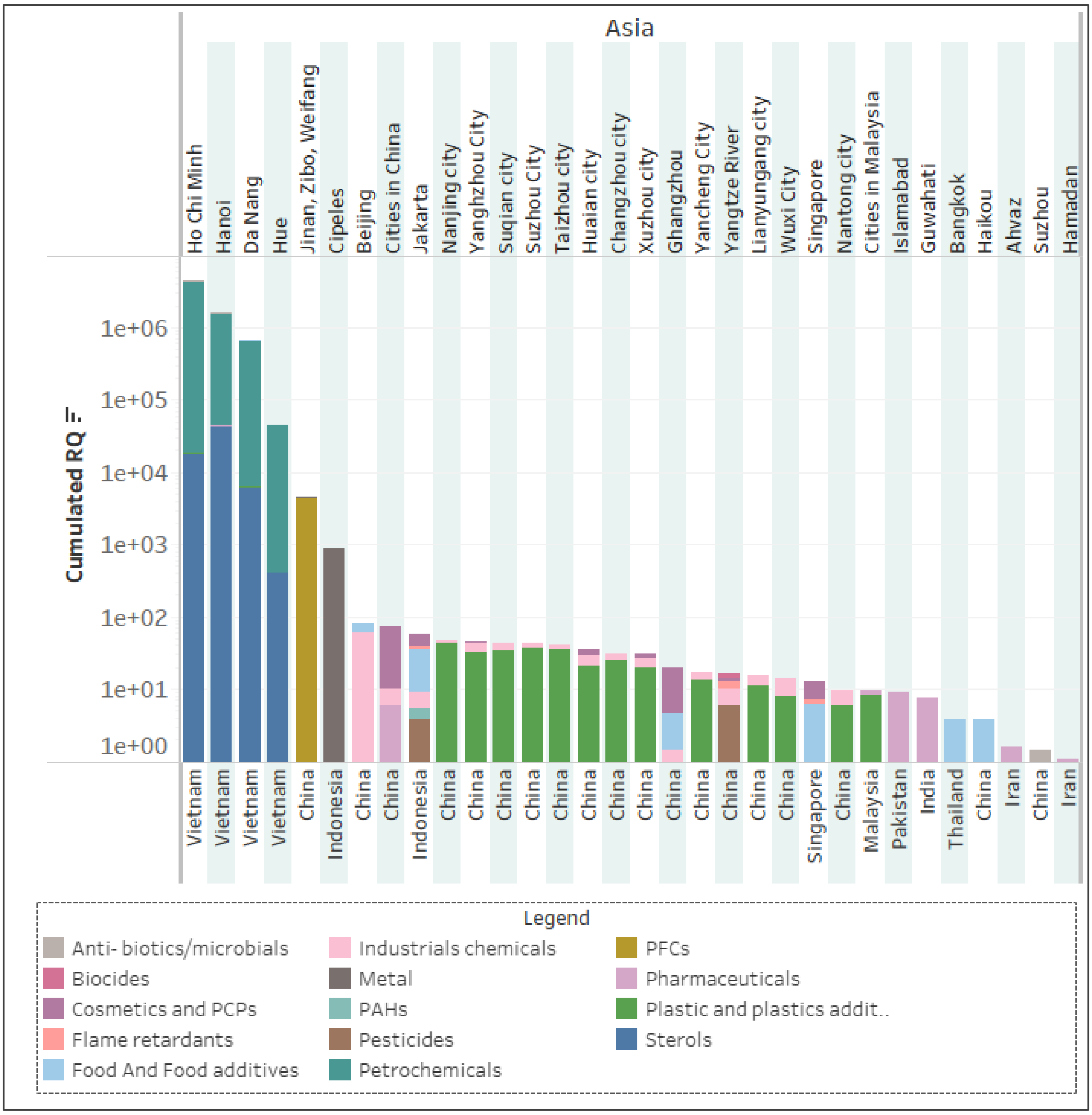


Figure 7 – (continued) Cumulated RQ for each urban environment with at least one priority chemicals. Colours indicate class category of chemicals RQ

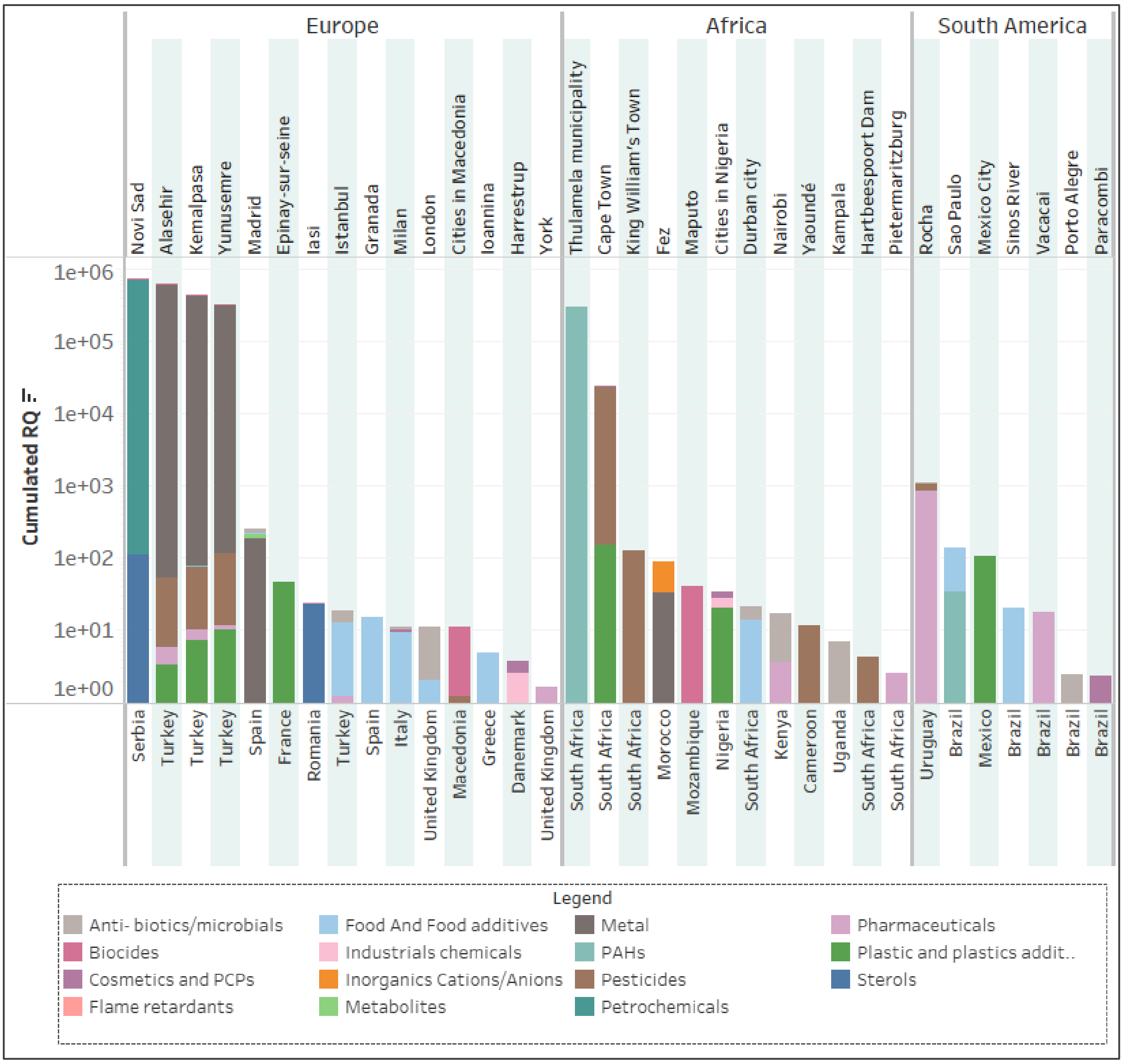


Figure 7 – (continued) Cumulated RQ for each urban environment with at least one priority chemicals. Colours indicate class category of chemicals RQ

3.4 Discussion

Concerns over the potential impacts of chemical emissions on the quality of urban freshwater systems has led to an increasing number of studies to characterise concentrations of a wide range of contaminants in receiving waters. While a substantial literature-base of monitoring is available, few studies have explored these data from an environmental risk perspective. In this study, we present a worldwide systematic review to identify high risk pollutants in urban freshwater systems in Asia, Europe, Africa, North and South America.

What explains the high RQs of the top priority compounds ?

The top priority chemicals in this study, with RQ above 10^4, were hexacosane and tricosane (both petrochemicals), aluminium (metal), benzo(b)fluoranthene, fluoranthene and benzo(a)pyrene (all PAHs); bifenthrin (biocide) and pentachlorophenol (pesticide). These chemicals were either detected at very high concentrations and/or had very low PNEC values. Hexacosane, tricosane and bifenthrin were the chemicals with the lowest PNEC in this study: 0.027 ng/L for bifenthrin, 0.00103 ng/L for hexacosane and 0.016 ng/L for tricosane. In other studies and in regulations framework, bifenthrin had a PNEC 0.13 ng/L and hexacosane a PNEC of 0.00022ng/L (Milovanovic *et al.*, 2019). No other PNEC was found for tricosane. These chemicals were also detected at very high concentrations: 203 µg/L for bifenthrin in Aliso Viejo in the US, 5295ng/L for hexacosane and 466 µg/L for tricosane in Novi Sad in Serbia.

For aluminium, benzo(b)fluoranthene, fluoranthene and benzo(a)pyrene, the very high RQ was driven by high concentrations up to 3531 µg/L, 7510 µg/L, 2498 µg/L and 1239 µg/L respectively. The PNECs of these chemicals were 4 ng/L for aluminum, 30 ng/L for benzo(b)fluoranthene, 2498 µg/L for fluoranthene and 1239 µg/L for benzo(a)pyrene. The aluminium PNEC value in this study is more conservative compared to other studies (Johnson et al., 2017; Razak et al., 2021). In the US, freshwater organisms are considered protected if average total aluminium concentrations do not exceed 4800 µg/L for more than one hour and 3200 µg/L for more than four days. PNECs of metals calculated in this study were generally more conservative compared to other studies (Johnson et al., 2017; Razak et al., 2021). That is because PNEC was derived in this study using minimum ecotoxicity data found in experimental database (e.g. ECOSAR; ECOTOX) while other studies used median or average ecotoxicity data. For benzo(b)fluoranthene, fluoranthene and benzo(a)pyrene, PNEC was less conservative compared to other studies. Benzo(b)fluoranthene had a lower PNEC of 17ng/L defined by the INERIS institute. Fluoranthene and benzo(a)pyrene had PNEC of 120ng/L and 270ng/L defined by the European commission. These PNECs were smaller because further refined for bioaccumulation, persistence or phototoxicity potential, which are not included in PNEC calculation in this study (Eqs *et al.*, 2011; WFD, 2011; OSPAR, 2014; INERIS, 2020).

Why are certain chemicals a risk only in certain areas?

Selected chemicals posed a risk only in some urban environments. This is usually related to local socio-economics drivers. For example, pentachlorophenol had an RQ of 23565 in Africa and an RQ below 50 in Europe and North America. This could be due to a less strict regulations of pentachlorophenol in Africa compared to the other continents before pentachlorophenol was added to the Stockholm convention list in 2015 (UNEP, 2013). Because of pentachlorophenols transboundary transport and persistence, the risk of pentachlorophenol is probably still important in South Africa despite strict usage limitations by the convention.

Similarly all PAH RQs were high in Africa, and especially in Thulamela Municipality (South Africa). PAHs RQ in Europe, Asia and North America were much lower (RQ<1 to 39). PAHs are usually emitted from oil combustion of cars, concrete and tyres degradation or even from cooking, very common activities in urban environments. However what the PAHs RQ of Thulamela municipality in South Africa showed was that PAHs represent extremely higher risks when local activities include pyrogenic activities. Thulamela municipality is surrounded by multiples industries including recycled and burning of vehicle tyre which likely explain the high PAHs concentrations and risks (Edokpayi *et al.*, 2016).

Lastly, sterols had multiples chemicals with continental RQ above 1000. Sterols can occur naturally but are usually emitted from leakage or due to the absence or wastewater treatments plants. This was demonstrated in Hanoi, Ho Chi Minh and Da Nang (Vietnam). High sterol RQs in these cities indicate inadequate domestic wastewater management in urban environment in Vietnam (Pham and Kasuga, 2020; Nguyen *et al.*, 2021). In 2019, only 12.5% domestic wastewater was treated in Vietnam (World Bank Group, 2017) Similarly as for PAHs, sterols/stanols should be considered priority chemicals especially in urban environments with ineffective wastewater management.

How do our findings compare to other prioritisation exercises - which chemicals have been picked up before. Which are new?

The class categories of plastics additives, inorganics anions, pharmaceuticals, industrials chemicals, metabolites, food, cosmetics and PPCPs, antibiotics and flame retardants posed a lower risk in this study with chemicals with continental RQ below 100. These results are consistent with others studies which compared multiples class categories. In a study conducted on UK rivers, Johnson *et al.* (2017) found that the relative risk posed by metals was significantly greater than pharmaceuticals with zinc being the chemicals with the highest RQ in their study - Zn had a relative risk a millions times greater than the beta-blocker metoprolol (Johnson *et al.*, 2017). In this study, aluminium was the most toxic metal and posed a risk 140 times greater compared to copper second most toxic metal. Similarly, in a study conducted in Serbia, risk assessments of 369 chemicals found that most hazardous group of compounds were linear and branched alkanes (petrochemicals) and sterols across all seasons, pesticides in summer and PAHs in autumn (Milovanovic *et al.*, 2019). Most chemicals identified in this study were prioritised in other studies all around the world. Pesticides pentachlorophenol, aldrin, endrin, carbaryl, pyrazophos, pendimethalin, heptachlor, chlorpyrifos, alachlor, ametryn, metolachlor, methoxychlor, cadusafor, dichlorodiphenyltrichloroethane and beta-Hexachlorocyclohexane were all at least prioritised at least once in previous studies conducted in Spain, Indonesia, Costa Rica, Uruguay, Greece, Sweden and the UK (von der Ohe *et al.*, 2011; Tsaboula *et al.*, 2016; Gros *et al.*, 2017; Johnson *et al.*, 2017; Carazo-Rojas *et al.*, 2018; Llorens *et al.*, 2020; Utami *et al.*, 2020). Most pharmaceuticals (tamoxifen, 17β-estradiol, lamotrigine, glybenclamide and loratadine), biocides (bifenthrin, pirimiphos-methyl, diazinon, miconazole, permethrin, λ-cyhalothrin, isoproturon) and antibiotics (azithromycin, amoxicillin, sulfamethoxazole, clarithromycin, lincomycin and enrofloxacin) were previously prioritised in Kenya, China, Kazakhstan, France, Spain, Antarctica and Iraq (Besse, Kausch-Barreto and Garric, 2008; Al-Khazrajy and Boxall, 2016; Aubakirova, Beisenova and Boxall, 2017; Kandie *et al.*, 2020; Llorens *et al.*, 2020; Olalla, Moreno and Valcárcel, 2020; Guo *et al.*, 2021). All petrochemicals, heavy metals, PAHs, PFCs, PCBs and PBDEs negative effects on human health and the environments have been extensively studied in Iran, Korea or France (Gasperi *et al.*, 2006; Dong and Lee, 2008; von der Ohe *et al.*, 2011; Abdollahi *et al.*, 2013; Peng *et al.*, 2017).

Is the evidence of impacts of some of the high priority chemicals in the real world.

Looking at toxicity of these chemicals, impacts on freshwater systems are worrying. At concentration lower than the ones gathered in this study, PFOS was lethal to mature fathead minnow (21 days exposure at 1mg/L) and affected zebrafish embryos development at 1-8mg/L after 6-120h after fertilization (Huang *et al.*, 2010). Similarly for pharmaceuticals, 17β-estradiol can cause feminisation of fishes above 2 ng/L (Caldwell *et al.*, 2012); loratadine can alter the development of 10% of the population of green algae at 0.29 µg/L (Iesce *et al.*, 2019); tamoxifen affects hatchability of fishes and increase the proportional of males at concentrations greater than 5 µg/L (Sun *et al.*, 2007). For pesticides, diuron was found to affect swimming and group behaviours of goldfish at 0.5 µg/L after 24 hours exposure (Saglio and Trijasse, 1998); aldrin and heptachlor alter growth and gills morphology in juvenile zebrafishes (Campagna *et al.*, 2007). Petrochemicals can also bioaccumulate in animal' and were recently found at 2585.62 ± 23.01 mg/Kg in tissue of white shrimp *Nematopalaemon hastatus* in Nigeria (Akinola, Olawusi-Peters and Akpambang, 2019). Risks associated with antibiotics emissions are well-known: they affect non-target species (algae, bacteria, fishes) and provoke antibiotics resistance genes associated with human high morbidity and mortality (Frieri, Kumar and Boutin, 2017; Grenni, Ancona and Barra Caracciolo, 2018; Kumar *et al.*, 2019). These are only a few examples of the toxic potentials of priority compounds identified in this study.

<u>**Limitations in the study and potential future work.**</u>

The aim of the work described in this Chapter was to obtain a broad understanding of priority chemicals in urban aquatic environments. The complexity of the topics was highlighted by the diversity of priority chemicals, they arise from multiples sources and the concentrations and risks are influenced by socio-economics factors. The study does have, however, a number of limitations:

- Only 1100 chemicals were assessed in this study while 350 000 chemicals are currently registered for production and usage in the world (Wang *et al.*, 2020). There is a need for broader monitoring a risk studies that consider a much wider range of chemicals in use. The availability of cheaper analytical methods that permit monitoring of broad suites of chemicals larger spatial scale (e.g. Wilkinson et al. 2019; Wilkinson *et al.*, 2022) might provide a solution.
- The urban environments that were assessed were clustered in the same regions (Europe, China, USA and South Africa). Many regions, especially in the southern hemisphere, had no urban chemical emissions data. The risk pose by chemicals in these regions, characterized by lower socio-economics development, is likely to be

higher compared to developed regions. However detailed analysis of the risk there could not be studied here due to a lack of data.

- There was big variation in the numbers of environmental concentrations and toxicity values collected for a particular chemical. For environmental concentrations, some chemicals were only measured in one location. For these chemicals, it is difficult to determine if they pose a risk in one specific environment or if they should be considered as common urban priority chemicals.
- For toxicity data, the quality of data differed between chemicals: only 8 chemicals had derived-PNEC calculated with measured chronic toxicity and 173 with measured acute toxicity data. For all other chemicals (766), derived-PNECs were calculated was based on predicted chronic or acute toxicity data. There is a need for high quality chronic data for a wider range of chemicals, particularly those detected frequently in aquatic systems.
- The RQ values do not provide an indication of actual impacts. It is difficult to comprehend the effect of chemicals with RQ of 10^5 or more on living organisms. Moreover, target-specific toxicity was not considered here, which probably underestimates the toxicity of active ingredients.
- Lastly, risks of chemical mixtures were calculated in this study by the sum of all chemicals RQ in a city. The potential synergism risk of chemicals mixtures was not considered here. Yet some of the cities monitored had multiple chemicals occurring in their aquatic environments. It is likely that these chemicals will be working in combination to elevate risks to the ecosystems.

What would be your recommendations going forward.

Despite the limitations, this study shows interesting findings. Firstly, risks posed by chemicals pollution in urban environments cannot be limited to active ingredients such as pharmaceuticals, antibiotics, or biocides. Research on petrochemicals, earth elements or sterols should be emphasized. Sources, emissions, and effects on natural environments of these class categories' chemicals should be studied and included into chemical pollution mitigations and adaptations strategies. Secondly, urban environments around the world have chemical pollution that poses a great risk for living organisms. Very high cumulative RQs in cities were found to be related to multiples socio-economics factors: population size, population density, road density, traffic, wastewater management facilities, regulations and surrounding industries. These correlations between chemicals emissions and socio-economics factors should be further studied. Results could allow cities that cannot performed water chemical analysis to determine a full profile of their chemical pollution based on socio-economics information only.

In the future, the risks posed by priority chemicals should be further analysis within cities with temporal and spatial analysis of risks. Understanding if risks is posed in certain areas within a city (e.g. downstream WWTP) or in specific season or specific event will be keys to develop relevant mitigation and adaptations strategies for chemicals emissions today and in the future.

In the next chapter, priority chemicals identified here are monitored in three Europeans cities: York (UK), Oslo (Norway) and Madrid (Spain) throughout one year. The aim was to further analyse risks of these priority chemicals across cities (upstream, downstream WWTP and city centre) and across seasons with seasonal samplings.

Chapter 4 – Temporal and spatial risks of fifteen priority chemicals in urban river systems of York, Madrid and Oslo

4.1 Introduction

In chapter 2, we identified 66 urban priority chemicals in Europe aquatic systems based on measured environmental concentrations from the literature. To be able to further characterize the temporal and spatial risk of these chemicals in urban environments, a one-year long monitoring campaign with seasonal sampling was conducted in the cities of Madrid (Spain) and Oslo (Norway) and in York (UK). Out of the 50 urban priority chemicals in Europe, 15 chemicals were chosen to be monitored: 12 metals, two antibiotics and caffeine.

Metals are essential for the development of humans and any livings organisms (Comber *et al.*, 2014). They are naturally occurring in freshwater systems by weathering of trace metals-bearing rocks (Caillaud *et al.*, 2009). Metals are also ubiquitously used in urban environments in plumbing, in architecture, in construction, in transportation, in paints, as coagulants in wastewater treatments plants, and in household appliances (Eurometaux, 2021). This widespread consumption means that tonnes of metals are emitted to European freshwater systems each year. Yearly estimates of emissions, include 33.9 tonnes of mercury, 8 8 kilotons of copper, 5 083 tonnes of zinc (AMAP & UNEP, 2019; Comber et al., 2022; Van den Roovart, J. et al., 2017). Metals can be highly problematic because, unlike most organic pollutants, they do not biodegrade. Metals can therefore bioaccumulate in human tissues and biomagnify through the food chain (Wang and Rainbow, 2008; Ali and Khan, 2018). Mercury and lead are famously known to have bioaccumulated throughout the food chain and to have impacted humans, especially the neurological behaviours in children following pre- and post-natal exposure (Lidsky and Schneider, 2003; Davidson, Myers and Weiss, 2004). Other studies show that long term exposure to metals can cause alterations in development, reproduction and survival of fishes, molluscs, daphnids and algae at relevant environmental concentrations (Géret *et al.*, 2002; Levesque *et al.*, 2002; De Schamphelaere, Lofts and Janssen, 2005; Öner, Atli and Canli, 2008; Donnachie *et al.*, 2014).

In comparison to metals, 4 264 tonnes of antibiotics were prescribed in Europe in 2018 (OECD, 2022). Despite being used in lower quantities than metals, emissions of antibiotics into freshwater systems is thought to result in the selection of antimicrobial resistance (AMR) in microbes in the environment (WHO, 2014). The threat of AMR represents a major world-scale social and economic burden. The potential of human to fight future microbial diseases is threatened (World Health Organization, 2021; OECD, 2022). Moreover the risks posed by antibiotics is expected to increase in the future under global change with increasing population and changes in diseases patterns (Redshaw *et al.*, 2013).

The presence and risks posed by antibiotics and metals in Europeans freshwaters systems were highlighted in chapter 2 and in previous studies (Devarajan *et al.*, 2015; Guo *et al.*, 2016; Eurometaux, 2021; Wilkinson *et al.*, 2022).

By using data collecting from the literature to develop priority chemical list, there are limitations. Chemicals are measured using different analytical techniques including variations in sampling protocols, analytical techniques, and quality control measures. This means that reported concentrations can lead to inconsistencies and challenges in comparing data across different sources. Moreover some chemicals are over-studied with spatial and temporal concentrations reported and others, less-studied, might have only one concentration reported for one sampling event. This impact the picture of priority chemicals in urban environment and limit comparisons.

In this chapter, three urban environments (Madrid, Oslo and York) were chosen to compare risks of chemicals across European cities with different social, economic and geographic characteristics. Madrid is a highly urbanised capital city with a population of 3.22 million habitants. Madrid is located in a semi-arid region with a temperate continental Mediterranean climate and estimated rainfall of 415 mm per year (Almorox *et al.*, 2011; Climate Data, 2015). Environmental pressures of the Manzanares river, the river going though Madrid, are effluents from industries, medical houses and wastewater treatment plants serving the Madrid population. WWTP effluents represent 90% of the river Manzanares.

Oslo is the capital of Norway and has 635 000 inhabitants. Oslo has a humid continental climate with an estimated annual rainfall of 769 mm. The particularity of Oslo is that WWTP effluents are released into the fjord, therefore rivers do not receive WWTP effluent. Environmental pressures of this river come from runoff and landfills landfill effluent of the surrounding urbanised and industrials zones. Companies near-by the river are recycling industries, logistics terminal and several vehicle reparations and sales companies (Allan and Ranneklev, 2011; Aro *et al.*, 2021).

Lastly, York is a touristic city in the UK with 210 000 inhabitants. The Rivers Foss and Ouse flow through the city centre of York. The River Ouse is a larger river with a high flow while the river Foss is a small river with a low dilution. Both rivers come together in the city centre of York. York had a temperate climate with an estimated rainfall of 755 mm per year. Note that York has a long history of flooding. Severe floodings events occur every year when rivers banks burst. Since few years now, floodings are causing more damage as both rivers are overflowing. In the past, only the river Ouse caused flooding (Coles *et al.*, 2017). Environmental pressures of the river Foss and the river Ouse are therefore flooding events but also recreational activities (boat renting compagnies, fishing, bathing), wastewater, landfill, medical houses and industrials effluent (Burns *et al.*, 2018).

In the systematic review conducted in Chapter 1, Madrid and York were identified in the systematic review of Chapter 1. Environmental concentrations data were collected for 104 chemicals (metals, pharmaceuticals, metabolites, antibiotics, biocides, flame retardants, industrails chemicals and food additives) and 33 chemicals (only pharmaceuticals) in Madrid and York respectively. No data were collected for Oslo. The risk posed by these chemicals were analysed in Chapter 2. For York, only the antihistaminic loratadine were prioritised. For Madrid, 11 chemicals were prioritised: 4 antibiotics (sulfamethoxazole, erythromycin, clarithromycin, and azithromycin), 5 metals (copper, iron, lead, mercury and zinc), caffeine and paraxanthine, a caffeine metabolite and dietary supplements.The aim of this chapter was to monitor and analyse the risks of all chemicals prioritised in Europe in Chapter 2 in the cities of York, Madrid and Oslo. However developing analytical methodologies was out of the scope of this thesis. Therefore only priority chemicals with available analytical methodologies developed at the University of York were analysed. In total, 15 European priority chemicals identified in chapter 2 were monitored in this chapter: 12 metals (aluminium, iron, cadmium, copper, cobalt, chromium, iron, lead, mercury, silver, tin and zinc), 2 antibiotics (sulfamethoxazole, clarithromycin) and caffeine.

The aim of this chapter was to 1) monitored these 15 priority chemicals upstream , downstream and within city centres of York, Madrid and Oslo throughout one year with seasonal samplings, 2) analyse risks posed by priority chemicals at each location and sampling event following by calculating risk quotients in the same way as in Chapter 2 and 3) compare risk quotient between and within cities spatially and temporally.

4.2 Method

Test substance for HPLC-MS and sampling materials

All chemicals (caffeine, sulfamethoxazole and clarithromycin) were purchased from Sigma Aldrich (UK) and were of ≥95% purity. Deuterated internal standard atrazine D5 were used all pharmaceuticals and for caffeine and were purchased from Sigma Aldrich (UK). HPLC-MS grade water, methanol and acid nitric were obtained from VWR (UK). Column used for HPLC-MS analysis was the A ZORBAX Eclipse Plus C18 chromatography column (3.0 × 100 mm, 1.8 µm, 600 bar) obtained from Agilent Technologies (UK).

Amber glass sample vials (5 mL), 15 mL luer lock syringes were obtained from Fisher Scientific (UK). 0.45-µm glass microfiber syringe filters were obtained from Whatman.

River’s descriptions

Samples were collected across four rivers: river Manzanares in Madrid (Spain), river Foss and river Ouse in York (UK) and river Alna in Oslo (Madrid). Sampling locations were chosen based on ease to access and position in relation in WWTP: samples were collected upstream and downstream of WWTP to analyse the impacts of WWTP effluent. A description of samples locations in each city is given below.

River Manzanares in Madrid

River Manzanares was sampled at 10 locations (SP1-SP10) upstream and downstream of the city centre of Madrid (Figure 8). Sites were located upstream and downstream of the city and of three WWTP: “La China”, “Butarque” and “Sur” (Table 4). “La China” was built in 1934 and is the oldest WWTP of Madrid. It serves a population of 1 335 000 inhabitants and treats 285,000 m^3/day of water per day (SICE website). The WWTP is equipped with primary, secondary and tertiary treatment. Only water reclaimed for irrigation and street cleaning goes though tertiary treatment. Effluent entering the river Manzanares goes through primary and secondary treatment (Futurenviro, no date). WWTP “Butarque” was built in 1982 and serves a population 1 500 000 inhabitant and has the capacity for 432,000 m^3/day (Paredes, Andreu and Solera, 2010). “Sur” was built in 1983. It serves a population of 3 million inhabitants and treats 80 million m^3/year of water. “Butarque” and “Sur” are both equipped with primary and secondary treatment. These three WWTP produce a flow of 7.35 m^3/s. Effluent of “La China”, “Sur”, “La Butarque” and the 6 other WWTP of Madrid contribute to 90% of the river flow downstream of Madrid (Paredes, Andreu and Solera, 2010). A description of the sampling sites in Madrid is given in Table 3.

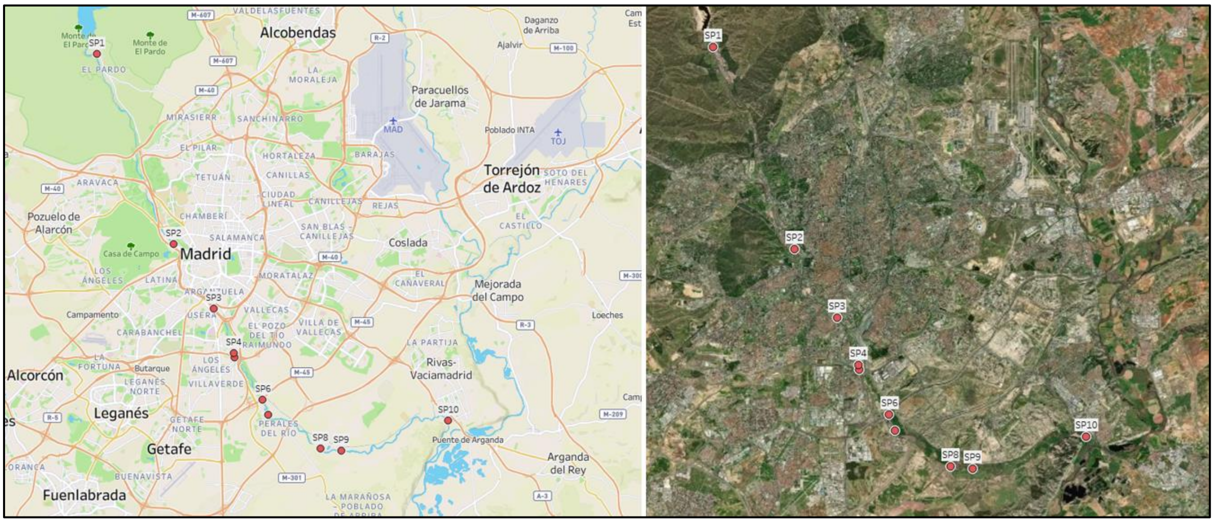


Figure 8 - Locations of the 10 samplings sites on river Manzanares around the city of Madrid. Panel A shows locations on a streets map and panel B on a satellite map.

Table 4 - Descriptions of samplings sites in Madrid

Site Name	Site description
SP1	Upstream city perimeter
SP2	Inside city perimeter
SP3	City centre
SP4	Outside city perimeter Upstream STP ´La China´
SP5	Outside city perimeter Downstram STP ´La China´
SP6	Outside city perimeter Upstream STP ´Butarque´
SP7	Outside city perimeter Downstream STP ´Butarque´
SP8	Outside city perimeterUpstream STP ´Sur´
SP9	Outside city perimeterDownstream STP ´Sur´
SP10	Outside city perimeter Before confluence with the river Jarama

River Foss and river Ouse in York (UK):

Five locations were chosen on the river Foss (F1-F5) and 6 on the river Ouse (O1-O6), upstream and downstream of York city centre and three WWTPs (Figure 9). WWTP-1 serves 18 600 inhabitants and is equipped with a trickling filter with biological aerated filtration. Effluent of this WWTP goes to river Foss. WWTP-2 serves 27 900 inhabitant and treats water with conventional activated sludge with nitrifying filters. Lastly, WWTP-3 serves 180 500 inhabitant and treats water with surplus activated sludge (Burns *et al.*, 2018). River Foss and river Ouse flow in the city centre of York. River Ouse is a larger river than river Foss, with a higher flow. Both rivers come together in the city centre of York. A description of the sampling sites in York is given in Table 5.

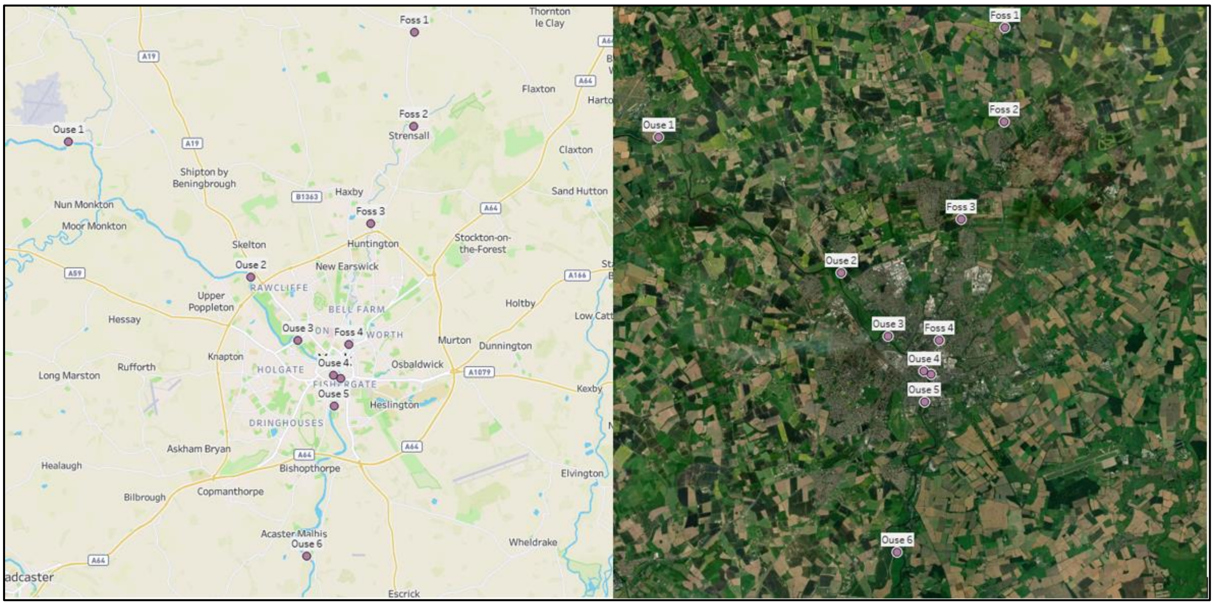


Figure 9 - Locations of the 11 samplings sites on river Ouse and river Foss around the city of York. Panel A shows locations on a streets map and panel B on a satellite map.

Table 5 - Descriptions of samplings sites in York

Site Name	Site description	River
F1	Upstream city perimeter Upstream of WWTP 2	River Foss
F2	Inside city perimeter Downstream of WWTP 2	River Foss
F3	Inside city perimeter Further downstream of WWTP 2	River Foss
F4	Inside city center	River Foss
F5	Inside city center Upstream of the River Foss and the River Ouse confluence	River Foss
O1	Upstream city perimeter	River Ouse
O2	Inside city perimeter Upstream of WWTP 1	River Ouse
O3	Inside city perimeter Downstream of WWTP 1	River Ouse
O4	Inside city center	River Ouse
O5	Outside city center	River Ouse
O6	Downstream city perimeter	River Ouse

River Alna in Oslo (Norway):

The Alna in Oslo is 17 km long, it starts at the Alna Lake (upstream Oslo city centre), goes through the city centre of Oslo and flows in the Oslo fjord. Areas surrounding the river are forest, parks and recreational areal, commercials, industries and urban areas. Alna was sampled at 6 locations (1-6) (Figure 10). A description of the sampling sites in Oslo is given in Table 6.

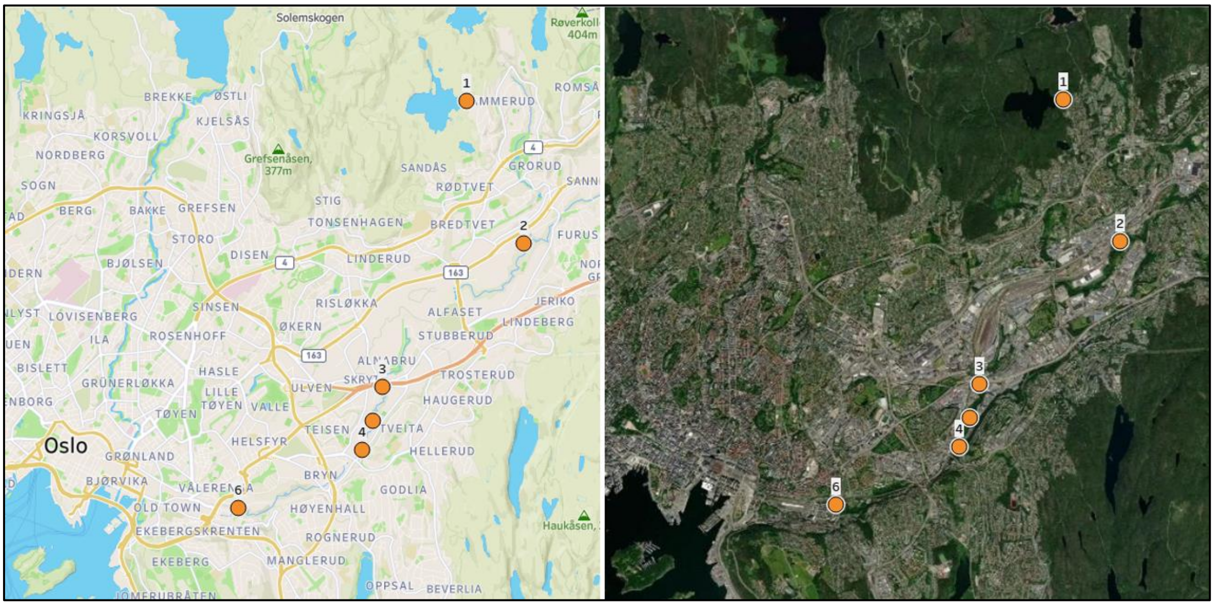


Figure 10 - Locations of the 11 samplings sites on river Alna around the city of Oslo. Panel A shows locations on a streets map and panel B on a satellite map.

Table 6 - Description of sampling sites in Oslo

Site Name	Site description
1	Inside city perimeter Upstream of city Center
2	Inside city center Next to logistic transportation centre
3	Inside city center Next to logistic transportation centre
4	Inside city center
5	Inside city center
6	Inside city center Location closest to Oslo fjord

Samples collection methodology

Samples were collected every season in 2021/2022. Seasonal samples were sampled withing three days of each other in York, Madrid and Oslo. Samples were collected on 20.05.21 (Spring), 20.08.21 (Summer), 18.11.21 (Autumn) and 18.02.22 (winter). All samples were collected following the same protocol. Samples were collected in the same order and at the same time. At each site, four 4 ml samples were obtained (two for pharmaceutical analysis and two for for metals analysis). Samples were collected from the middle of bridge when possible or alternatively from the riverside. The water was collected using Nalgene-plastic bottle attached to a nylon rope. Collected water was then drawn up into a 12 mL disposable syringe and filtered with 0.45 um glass fiber filter into 5mL amber glass vials. The Nalgene bottle, the syringes and amber-glass vial were all primed three times with river water before the actual samples were collected. Samples for pharmaceutical analysis were frozen at -20°C degree at arrival at institute. Samples for metals analysis were treated with 60 µL of ultra-trace element nitric acid to before also being frozen.

To ensure that filtration and sampling procedure did not results in cross-contamination, HPLC-grade water were sampled in the field following the same procedure as river samples. These fields banks were then frozen and analysed like river samples.

Shipping of samples

Samples collected in Madrid and Oslo were kept frozen until being sent to York for analysis. Samples were shipped using DHL fast international delivery services. Sampled were carefully placed in a polystyrene box with a minimum of three ice packs. Shipments took between 1 to 2 days to arrive at the Environment Department in the University of York where sampled were kept at -20°C until analysis.

HPLC-MS for quantifications of sulfamethoxazole, clarithromycin, and caffeine

Analysis for sulfamethoxazole, clarithromycin, and caffeine was by high-pressure liquid chromatography-tandem mass spectrometry (HPLC-MS), conducted at the Centre of Excellence in Mass Spectrometry of the University of York (UK). A Thermo Scientific Endura TSQ triple quadrupole mass spectrometer coupled with a Thermo Scientific Dionex UltiMate 3000 HPLC was used. Samples were analysed following the methodology developed by

Wilkinson et al., (2019). Briefly, samples were placed in a 4D temperature-controlled autosampler. An aliquot of 100 µL was injected into a ZORBAX Eclipse Plus C18 chromatography column (3.0 × 100 mm, 1.8 µm, 600 bar) at a constant flow of 450 µL/min. Each target compound and internal standards had two transitions monitored by positive electrospray ionization: one transition for quantification and one transition for confirmation. Mass to charge (m/z) ratio, collision energy and retention time of transition 1 and transition 2 of target compounds and internal standards are available in Wilkinson et al., 2019. Mobile phase A consisted of HPLC-grade water with 0.01 M formic acid and 0.01M ammonium formate. Mobile phase B was methanol. Analysis started at 10% mobile phase B. Mobile phase B reached 40% after 5 min, 60% after 10 min and 100 % after 15min where it remains until the end of the analysis. After the analysis of each sample, re-equilibrium to 10% mobile phase B lasted 10 min.

Quantification was obtained with a 15-point calibration curve ranging from 1 to 8 000 ng/L using Thermo Fisher Xcalibur™ Software. The standard method developed by Furlong et al., (2014) was used for all calibrants to obtain same proportion of methanol in final calibrants solutions.

For method quality control, all internal standards were spiked at 80 ng/L in samples, calibrations solutions and blanks. For environmental samples, samples were prepared by spiking 995 µL of sample with 5 µL of internal standards solutions at 80 ng/L. Similarly, calibrations solutions were prepared by spiking 975 µL HPLC-grade water with 5 µL of internal standards solutions at 80 ng/L and 20 µL of relevant calibration solution.

For instrumental quality control, blanks and an instrumental QCs were run every 10 injections during samples analysis. Blanks were HPLC water with internal standards spiked at 80 ng/L. Instrumental QCs were solutions with target compounds at 400 ng/L and internal standards at 80ng/L. Moreover the column and entire system was flushed prior to all analysis and at least 10 blanks were run before and after processing of all analytical batches. Detection limit (LOQ) and quantification limit (LOQ) were determined following Wilkinson et al., 2019. LOD and LOQ are presented in Table 7.

Table 7 - Detection limit (LOD) and quantification limit (LOQ) in ng/L for caffeine, clarithromycin and sulfamethoxazole

	LOD	LOQ
Caffeine	21.03	40.39
Clarithromycin	13	26
Sulfamethoxazole	1.76	3.52

ICP-MS for metals quantification

Quantification of metals was performed by the Biorenewables Development Centre at Dunnington (UK) using an Agilent 7700 series ICP-MS. Briefly, samples were thawed and spiked with 0.1 mL of hydrochloric acid to stabilize silver priori to analysis.

Quantification was obtained with a 5-point calibration curve ranging from 50 to 100 000 µg/L. All acid used was trace metal grade. Blanks and calibrations solutions were run first. Results for each element were fitted onto the calibration curve. The result recorded was then multiplied by the dilution factor, to produce the concentration for each element in the sample. Detection and quantification limit are presented in Table 8.

Table 8 - Detection and quantification limit in µg/L for metals for each analytical run performed

	Spring	Summer	Autumn	Winter
Aluminium	3.5	3.5	2.807	4.905
Phosphorus	172.1	172.1	22.349	52.934
Chromium	0.1	0.1	0.073	0.035
Manganese	0.1	0.1	0.039	0.036
Iron	1.2	1.2	0.937	1.857
Cobalt	0.01	0.01	0.013	0.01
Nickel	0.01	0.01	0.203	0.107
Copper	0.2	0.2	0.173	0.355
Zinc	0.9	0.9	0.767	2.166
Silver	1.6	1.6	1.574	0.056
Tin	0.1	0.1	0.127	0.091
Cadmium	Not measured	Not measured	0.13	0.09
Mercury	Not measured	Not measured	0.35	0.01
Lead	Not measured	Not measured	0.02	0.03

Prioritisation of chemicals

Risk quotient (RQ) of chemicals was measured similarly as in chapter 2. Risk quotients (RQ) were calculated for each chemical, each season and each location using the equation:

RQ = AVG / PNECmin   Equation

Where: AVR= Average measured environmental concentration of a chemical and PNECmin= lowest PNEC or EQS or equivalent-PNEC for each chemical. Because the number of chemicals was more manageable than in chapter 2, PNEC and environmental quality standard (EQS) from government agencies and industries were collected. Database of INERIS (https://substances.ineris.fr/fr/), EU WFD (https://eur-lex.europa.eu/), US EPA (https://comptox.epa.gov/), Canada WQS (https://ccme.ca/en/current-activities/canadian-environmental-quality-guideline) and China WGC (Wang *et al.*, 2021) for metals and the AMR industry alliance (AMR Industry Alliance, no date) for antibiotics were examined for PNEC and EQS reference. Lowest PNEC or EQS collected was used as PNECmin.

4.3 Results

Measured environmental concentrations

Twelve metals were quantified in the collected samples: aluminium, cadmium, chromium, cobalt copper, iron, lead, mercury, nickel, silver, tin and zinc. Mercury, cadmium and lead were only measured in samples collected in autumn and winter. Measured environmental concentrations are presented in figure 11-13.

Aluminium and iron were the metals detected at the highest concentrations in York, Madrid and Oslo. Aluminium concentrations ranged from 602-1752 µg/L in Madrid (Figure 11), 416-1166 µg/L in Oslo (Figure 13) and 633-1794 µg/L in York (Figure 12). Iron was detected at 294-1098 µg/L in Madrid, 12-2291 µg/L in Oslo and 320-1501 µg/L in York. Concentrations of aluminium and iron were constant across seasons and locations in the three cities.

Zinc was the metal with the third highest concentrations. Zinc concentrations varied greatly between cities, locations and seasons. In Madrid, concentrations of zinc were below 30 µg/L in summer and autumn with the exception of 288 µg/L detected in SP3 in summer. In Spring and winter, zinc concentrations varied between locations with concentrations ranging from 11 to 821 µg/L in spring and from 6 to 6 959 µg/L in Summer. Peak concentrations occurred in SP4, SP7 and SP10 in Spring and in SP2, SP5 and SP8 in Winter. In Oslo, zinc concentrations were lower in autumn (5-622 µg /L) and winter (5-186 µg /L) compared to spring (126-2317 µg/L) and summer (34-1404 µg/L). Peak concentrations occurred in location 4 in spring, summer and autumn, but not in Winter. Similarly in York, zinc concentrations were lower in autumn (5-302 µg/L) and winter (5-74 µg/L) compared to spring (4-2560 µg/L) and summer (6-2178 µg/L). Concentrations varied between locations and seasons. For the river Foss, maximum concentrations were measured at location F5 in spring (1172 µg/L) and in winter (41 µg/L) and at location F3 in summer (334 µg/L) and autumn (161 µg/L). For the river Ouse, highest zinc concentrations were measured at location O1 (1631 µg/L) and O4 (2108 µg/L) in Spring. Maximum concentration was 997 µg/L in O5, 108 µg/L in O5 and 18 µg/L in O3.

Copper was systematically above 1 µg in autumn and winter in the three cities but not spring and summer. In Madrid, copper was only measured at SP4 in spring; SP3 and SP5 in summer at concentration lower than 2 µg/L. In autumn and winter, copper was measured at all locations and at a range from 1 to 38 µg/L. In York, copper was between <LOQ-6 µg/L in all seasons with one peak of 112 µg/L detected in F5 in winter. In Oslo, copper was not detected in spring. In summer, copper was measured in location 3 to 5 with concentrations ranging from 6 to 26 µg/L. In autumn and winter, concentrations ranged from 1 to 4 µg/L with a single peak of 347 µg/L detected at location 6 in winter.

Except for a few locations nickel concentrations were constant and stable across locations and seasons in the three cities. In Madrid, concentrations ranged from 0.6-8 µg/L except for 12 µg/L detected in F4 in summer and 14 µg/L in O5 in winter. In Oslo, concentrations ranged <LOQ-5 in all seasons. In York, concentrations were systematically below 4 µg/L except for F4 in summer (12 µg/L) and O5 in winter (14 µg/L).

Tin was systematically detected in Madrid only. Concentrations ranged from 1 to 4 µg/L. In Oslo, tin was only measured in winter (0.3-1 µg/L). In York, tin was only measured at 1 µg/L in O5 in spring, at 16 µg/L in summer and from 0.1 to 1 µg/L in winter.

Chromium concentrations were constant across locations and cities. The highest concentrations were 7.8 µg/L in Madrid, 9.7 µg/L in Oslo and 11 µg/L in York. Cobalt was the metal detected at the lowest concentrations. The maximum concentration was 0.6 µg/L in

Madrid, 1 µg/L in Oslo and 1.3 µg/L in York. Mercury, cadmium and lead were only analysed in autumn and winter. Mercury concentrations ranged from 0.2 to 3.3 µg/L in York, 0.1 to 6.7 µg/L in Oslo and 0.3 to 1.3 µg/L in Madrid. Cadmium and lead were measured in winter and at concentrations below 6 µg/L. Silver was not detected in this study.

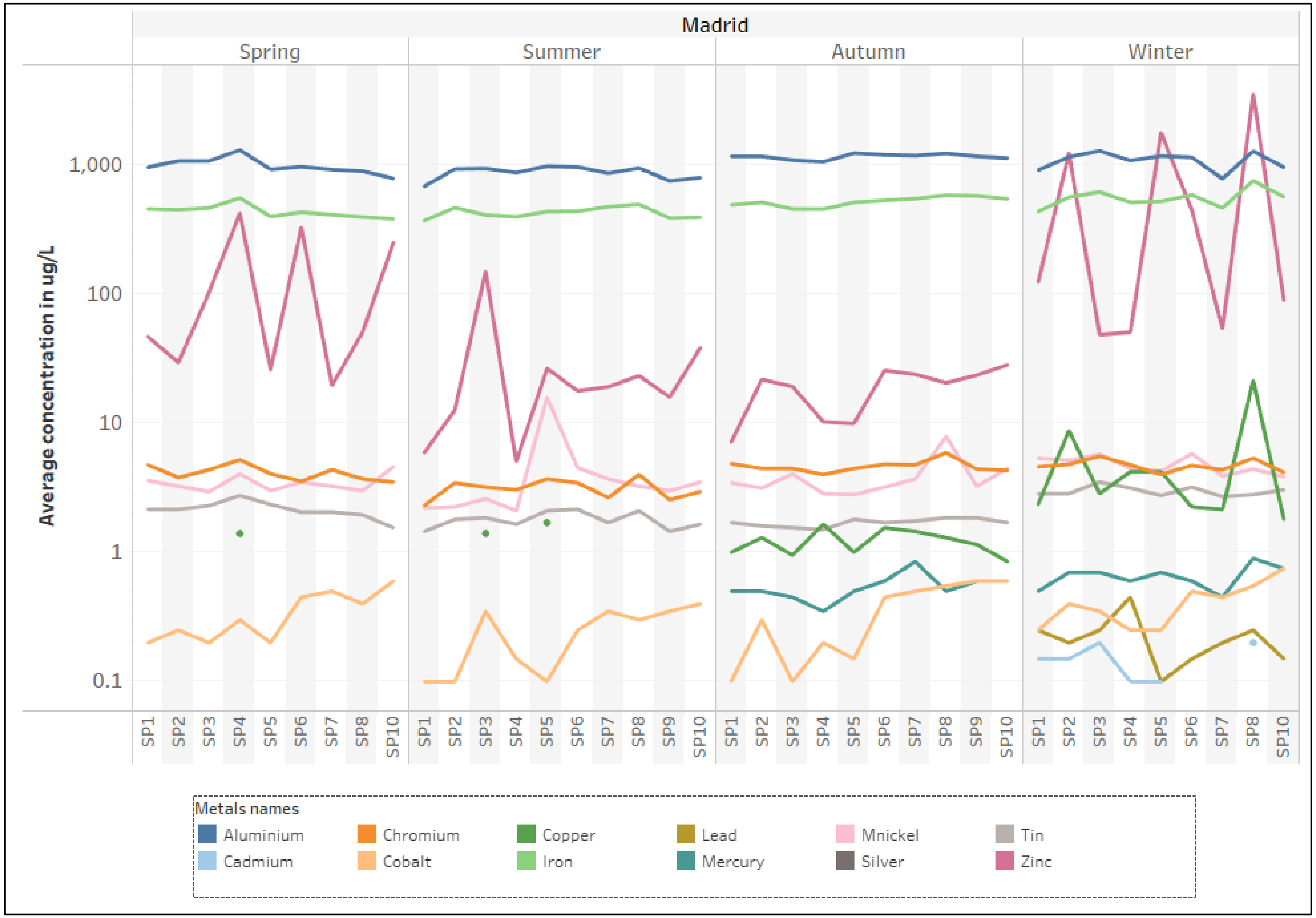


Figure 11 - Measured environmental concentrations in µg/L for metals (aluminium, cadmium, chromium, cobalt, copper, iron, lead, mercury, nickel, silver, tin and silver) quantified in the river Manzanares in Madrid in spring, summer, autumn and winter. Scale is logarithmic.

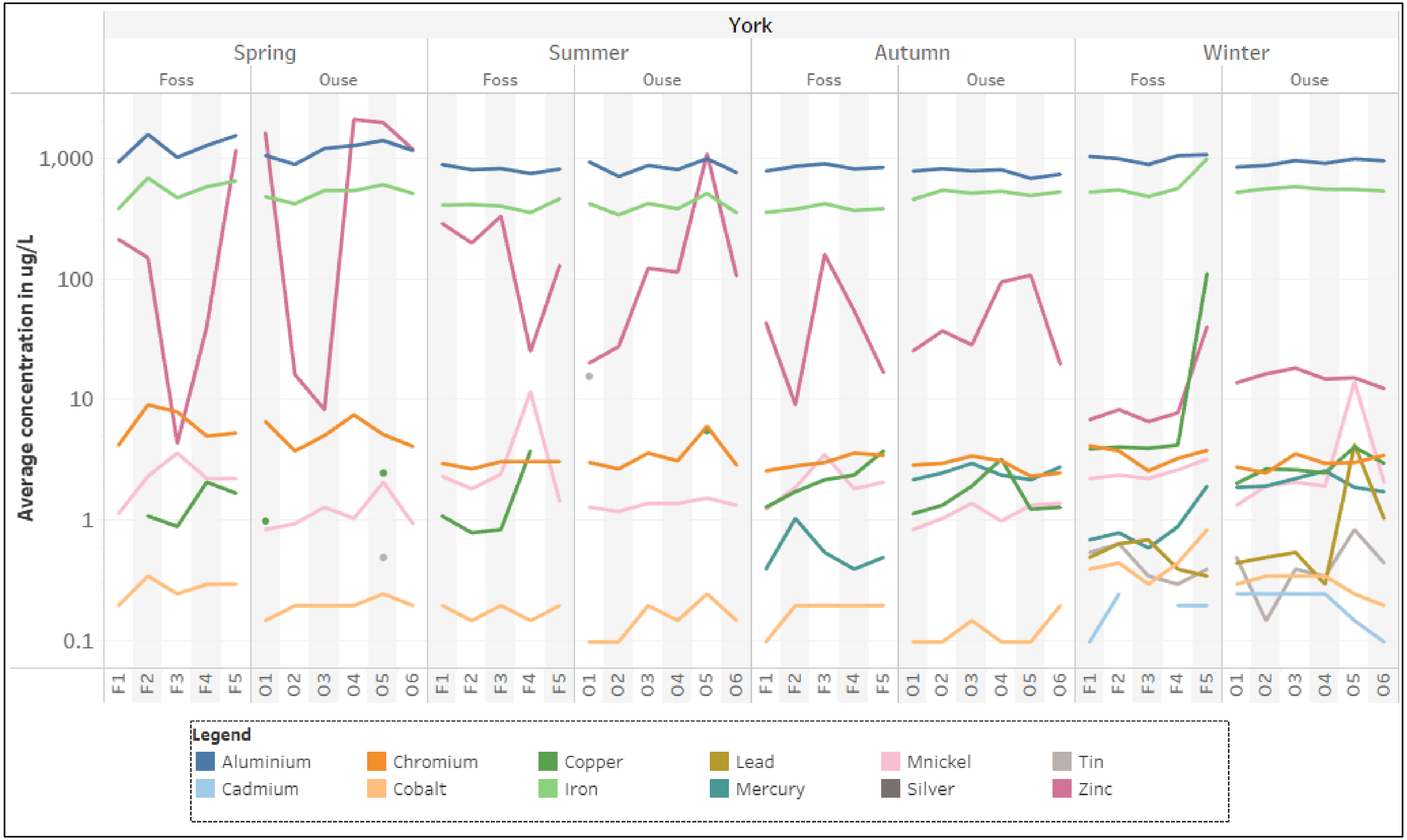


Figure 12 - Measured environmental concentrations in µg/L for metals (aluminium, cadmium, chromium, cobalt, copper, iron, lead, mercury, nickel, silver, tin and silver) quantified in the river Ouse and river Foss in York in spring, summer, autumn and winter. Scale is logarithmic.

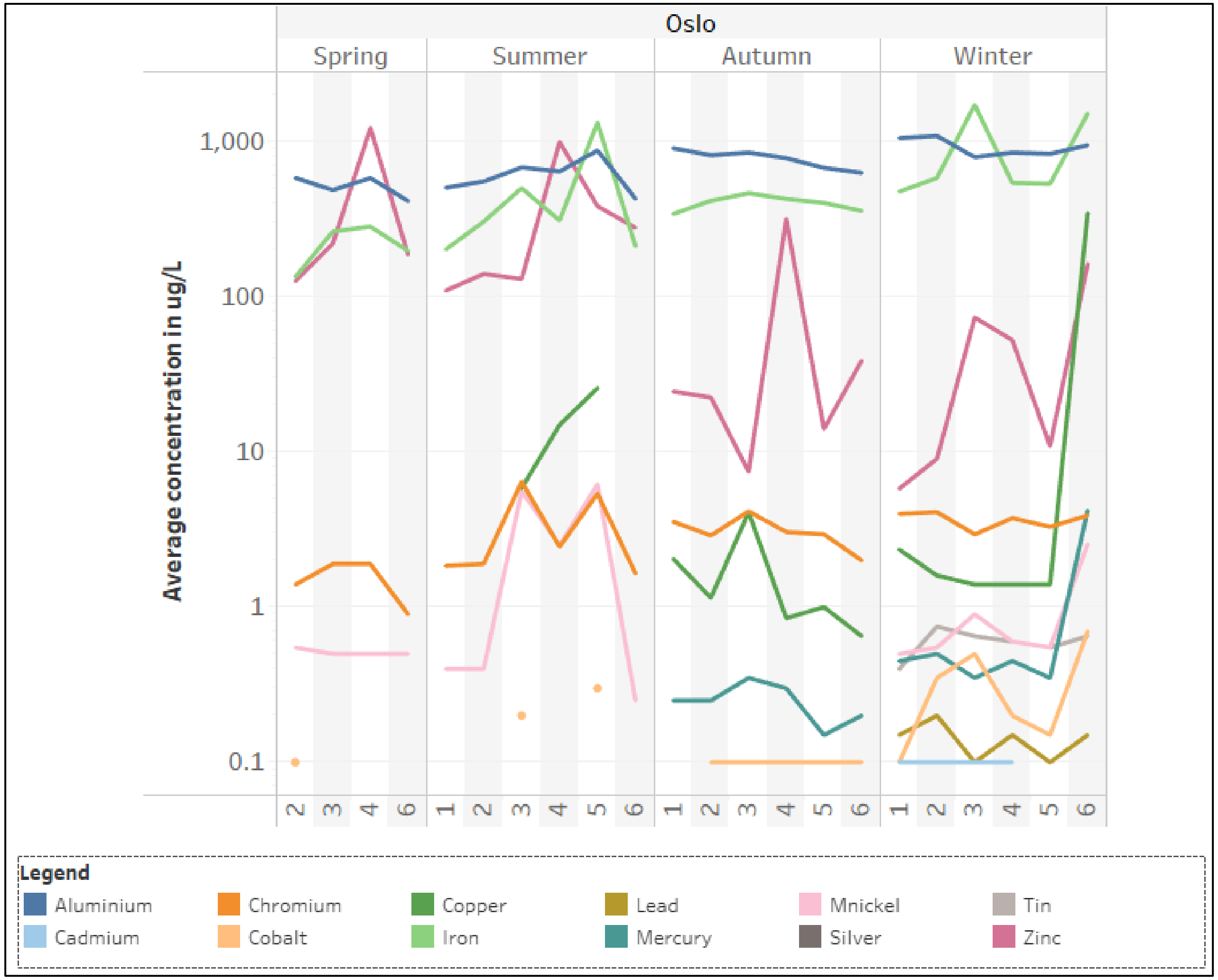


Figure 13 - Measured environmental concentrations in µg/L for metals (aluminium, cadmium, chromium, cobalt, copper, iron, lead, mercury, nickel, silver, tin and silver) quantified in the river Alna in Oslo in spring, summer, autumn and winter. Scale is logarithmic.

Sulfamethoxazole and clarithromycin were only measured in York and Madrid with both antibiotics being systematically below detection concentrations in Oslo. Measured environmental concentrations are presented in Figure 14-16.

Sulfamethoxazole concentrations ranged from 5 to 234 ng/L in Madrid. Concentrations were systematically below 100 ng/L from SP1 to SP6 and increased gradually from upstream to downstream samplings sites. Maximum concentrations were 131 ng/L in Spring in SP7, 82 µg/L in summer in SP7, 234 µg/L in autumn in SP9 and 169 ng/L in winter in SP9 (Figure 14). In York, sulfamethoxazole was in only detected at two occasions in the river Ouse: in spring in O4 (28ng/L) and in O6 in summer (28 ng/L). In the river Foss, sulfamethoxazole was measured at all locations in Autumn (5-14 ng/L). In spring and summer, sulfamethoxazole was measured at 25 ng/L in F3 in spring and at 28 ng/L in F4 in summer. In winter, concentrations ranged from 4-7 ng/L in F2, F3 and F5 (Figure 15).

Clarithromycin was not systematically detected in Madrid and York. In Madrid concentrations ranged from <LOD to 80 ng/L. Clarithromycin was detected from SP6 to SP10 in spring, autumn and winter with concentrations ranging from 27 to 80ng/L. In summer, clarithromycin was only quantified at 29 ng/L in SP7. In York, clarithromycin was mostly detected in the river Foss and at 2 samplings events the in river Ouse: at 28 ng/L in spring in O4 and at 28 ng/L in summer in O6. In river Foss, concentrations ranged from <LOQ to 80ng/L. Sulfamethoxazole was detected from F2 to F5 in spring and summer. Maximum concentrations were 74ng/L in summer and 37 ng/L in winter.

Caffeine was detected in Oslo, York and Madrid. In Oslo, caffeine concentrations gradually increased from upstream to downstream samplings sites in summer, autumn and winter. Maximum concentrations were 3 645 ng/L in summer, 1 400 ng/L in autumn and 716 ng/L in winter always in location 6. In spring, maximum concentration was 2 152ng/L in location 2 (Figure 16). In York, caffeine concentrations ranged from 63 ng/L to 5 533 ng/l in the river Foss and 46ng/L to 559 ng/L in the river Ouse. In river Foss, maximum concentrations were detected in summer in F3 (4 997 ng/L) and F4 (2 772 ng/L). Other measurements were below 579ng/L. In river Ouse, autumn had the lowest concentrations (46 to 79 ng/L) and winter had the highest concentrations (113 to 559ng/L). In Madrid, caffeine maximum concentration was 3 126 ng/L in Autumn in SP9. Caffeine concentrations were lower in spring (46-654 ng/L) and summer (46-352 ng/L), compared to autumn (62-3 126 ng/L) and winter (68- 1 006 ng/L).

Concentrations were lower than 100 ng/L from SP1 to SP6 and higher than 100 ng/L from SP7 to SP10.

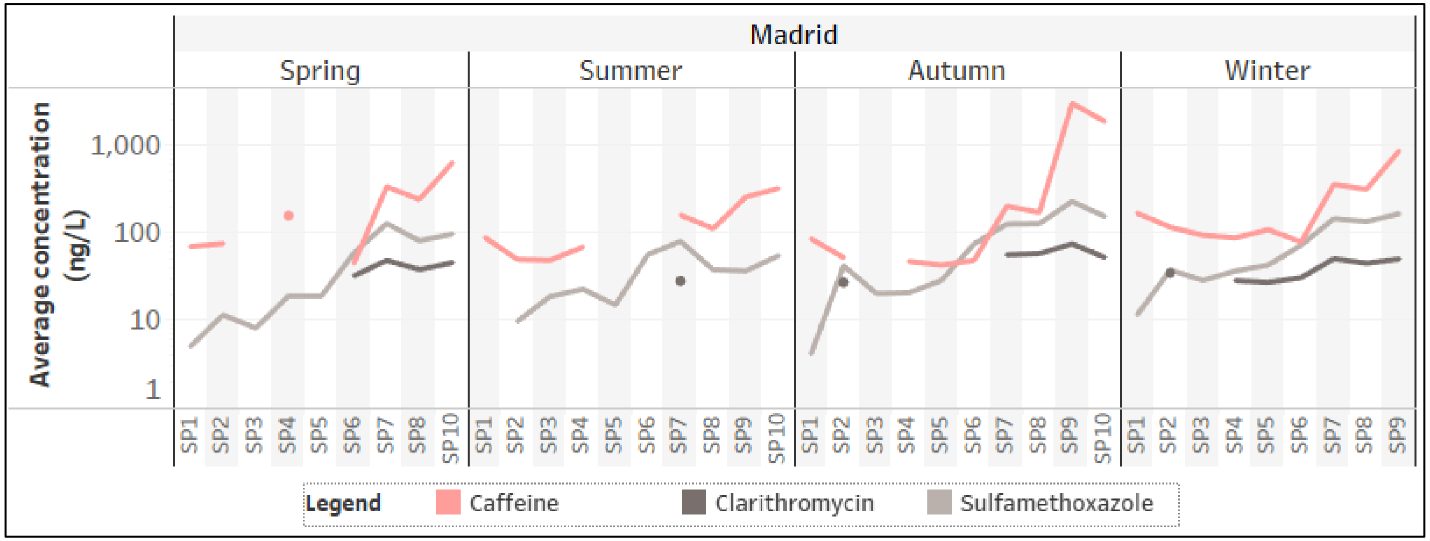


Figure 14 - Measured environmental concentrations in ng/L for clarithromycin, sulfamethoxazole and caffeine quantified in the river Manzanares in Madrid in spring, summer, autumn and winter. Scale is logarithmic.

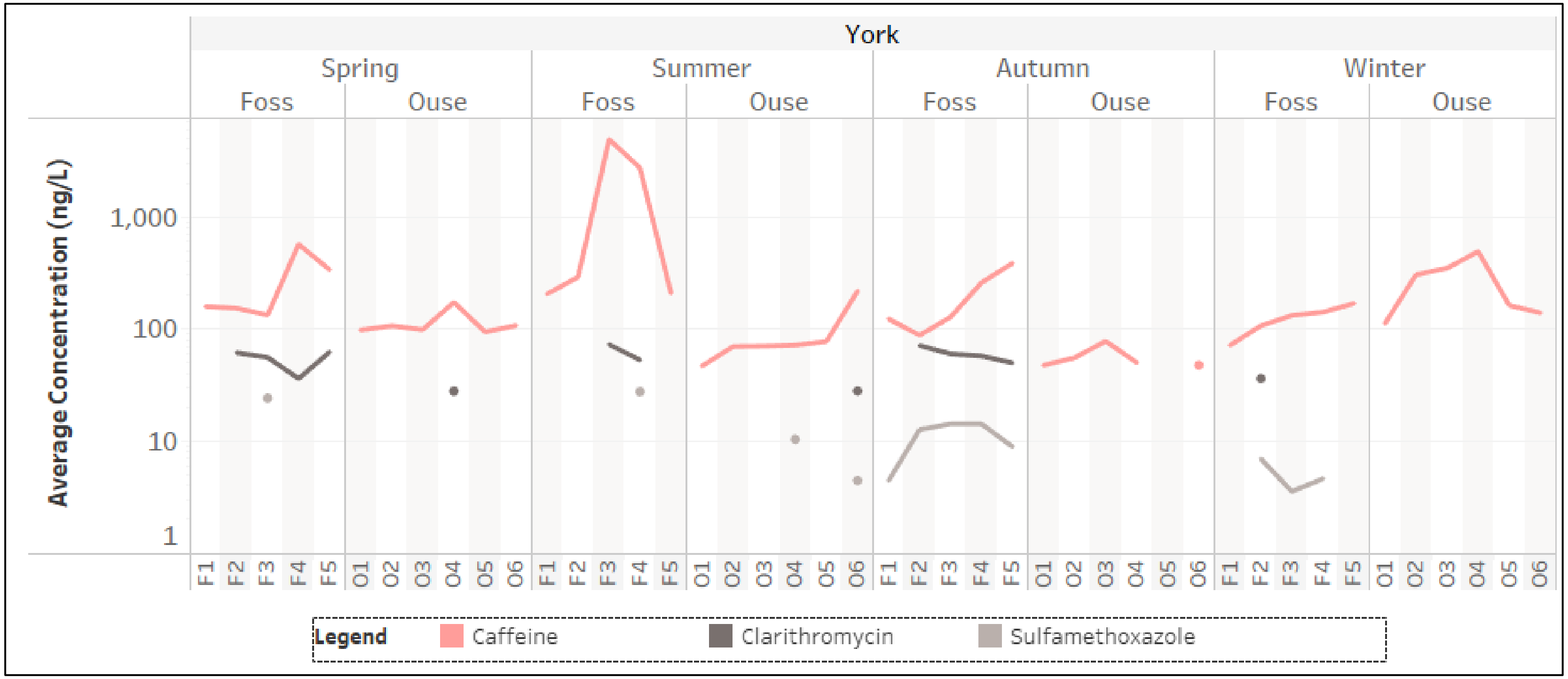


Figure 15 - Measured environmental concentrations in ng/L for clarithromycin, sulfamethoxazole and caffeine quantified in the river Ouse and river Foss in York in spring, summer, autumn and winter. Scale is logarithmic

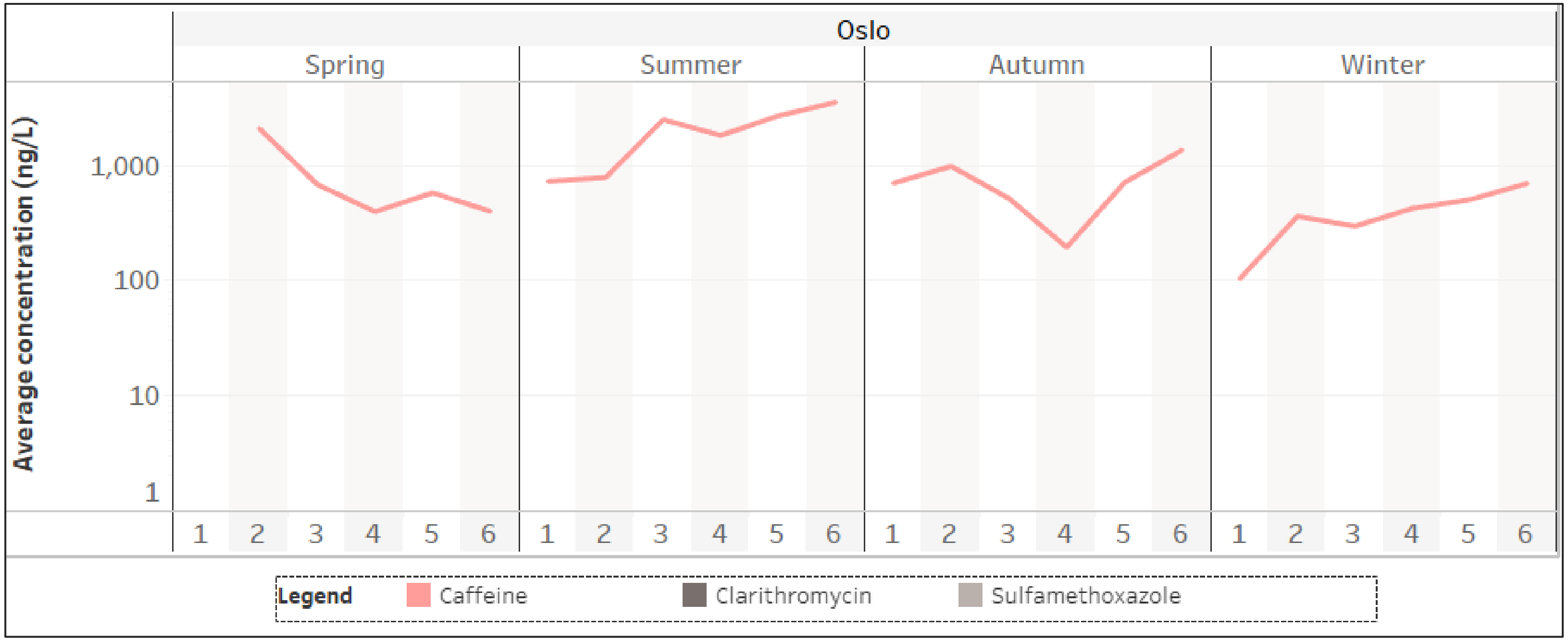


Figure 16 -Measured environmental concentrations in ng/L for clarithromycin, sulfamethoxazole and caffeine quantified in Oslo in spring, summer, autumn and winter. Scale is logarithmic

Risk quotient calculations

The risk quotient of metals, sulfamethoxazole, clarithromycin and caffeine were calculated at each location, season, and city. The average concentration of replicates was used to calculate the risk quotient (RQ). Results are presented in Figure 17.

Aluminium, iron, zinc, mercury and chromium systematically had RQ above 1.

Aluminium had the highest RQs calculated in this study. Aluminium had RQs systematically above 1000 across all locations, seasons and cities: RQs ranged from 11 323 to 21 677 in Madrid, 6 927 to 18 195 in Oslo and from 11 407 to 26 536 in York. Aluminium RQs were the highest in autumn for Madrid (average RQ = 19 256), in winter in Oslo (average RQ = 15 512) and in spring in York (average RQ = 20 291). Aluminium RQs stayed at the same level across locations and seasons.

Iron had RQs ranging from 23-47 in Madrid, 8-108 in Oslo and 21-62 in York. Iron RQ stayed at the same level across seasons and locations with one exception: in location 3 in Oslo, RQ reached 108. Zinc RQ varied greatly between cities, locations and seasons. In Madrid, most locations had RQ between 10 and 100 except for three locations with RQ above 1000: SP2 (RQ= 1 230), SP5 (RQ= 1 769), and SP8 (RQ= 3 509), all in winter. In Oslo, zinc RQs ranged between 100 and 1000 in spring and summer. The maximum RQ was 1 228 in location 4 in spring. In autumn and winter, RQs mostly ranged from 10 to 100. Similarly in York, RQs were the highest in spring with 5 locations with RQs above 1000 (F5 : RQ= 1 172; O1 ;RQ= 1 630; O4 : RQ= 2 108; O5 :RQ= 1 978). In summer zinc RQs ranged mostly between 100 and 1000 and between 10 and 100 in autumn and winter in York.

RQs of copper varied between seasons. In spring and summer, the RQs in the three cities were mostly not calculated because were lower than the LOQ. For the few locations where copper was detected, RQs ranged from 10 to 585. Looking at cities' specifications, in Madrid, copper was only detected at one location in spring (SP4 : RQ = 31) and two locations in summer (SP3: RQ=31; SP5: RQ = 38). In Oslo, copper was not detected in spring but had RQs ranging from 132-586 in summer at 3 locations (3; 4; 5). In the river Ouse in York, copper had RQs of 56 and 127 at location O5 in spring and summer. In the river Foss, however, the RQ was constantly between 10 and 50 at all locations except in F1 in spring where copper was <LOQ. In autumn

and winter though, RQ of copper was systematically above 10 and up to 485 in Madrid, 7 889 in Oslo and 2 538 in York.

Mercury was not measured in spring and summer samples. In autumn and winter, the RQ of mercury was systematically above 1 and up to 43 in York, 60 in Oslo and 19 in Madrid. In York, RQs ranged from 10-43 in the river Ouse and from 2-28 in the river Foss. In Oslo, RQs ranged from 2-7 in all locations except for location 6 in winter (RQ=60). In Madrid, RQs ranged from 5 to 19. The maximum RQ of 19 was detected in SP5 in winter.

RQs of chromium ranged from 1-9 in Madrid, Oslo and York. Tin had RQs ranging from 1-2 in Madrid. In York and Oslo, tin RQs were systematically below 1 except for O1 (RQ=10) in the summer. Cobalt had an RQ of 1-2 in one location in summer and 3 locations in winter in Oslo. Similarly in York, cobalt RQs ranged from 1 to 3 at 3 locations in spring and 9 locations out of 11 in winter. All other samplings events had RQs below 1. In Madrid, RQs systematically ranged from 1-3 from locations SP7 to SP10 across all seasons. Cadmium had RQs below 1 in autumn and between below 1-3 in the winter in the three cities. Nickel had RQs above 1 at 2 occasions in York and in Oslo across seasons: F4 in summer (RQ = 2.93); O5 in winter (RQ= 3.56) for York and in location 3 (RQ= 1.4) and 5 (RQ = 1.55) in summer for Oslo. In Madrid, nickel RQs ranged from 1-4 for a few sampling events in spring, summer and autumn. In winter, the RQs were between 1-2 in 7 locations out of 9. RQs could not be calculated for silver as this was not detected in any samples. Lead, measured in autumn and spring, had an RQ above 1 in one sampling event only: in O5 in winter in York (RQ= 3.58).

Looking at antibiotics and caffeine, RQs were above 1 on a few sampling events in the three cities and across seasons. Clarithromycin had RQs ranging from 1-2 at 2 locations in summer, 4 in autumn and 2 in winter in Madrid. Similarly in York, clarithromycin posed a risk in the river Foss only at 3 locations in spring, 2 in summer and 4 in autumn. Clarithromycin did not pose a risk in Oslo. For sulfamethoxazole, the RQ was systematically below 1 in all cities and across all seasons. Caffeine had an RQ between 1-3 in SP9 and SP10 in Madrid and between 2-4 in F3 and F4 in York in autumn only. In Oslo, RQ was between 1-3 in one location in spring (location 2), 4 locations in summer (location 3-6), one location in autumn (location 6)

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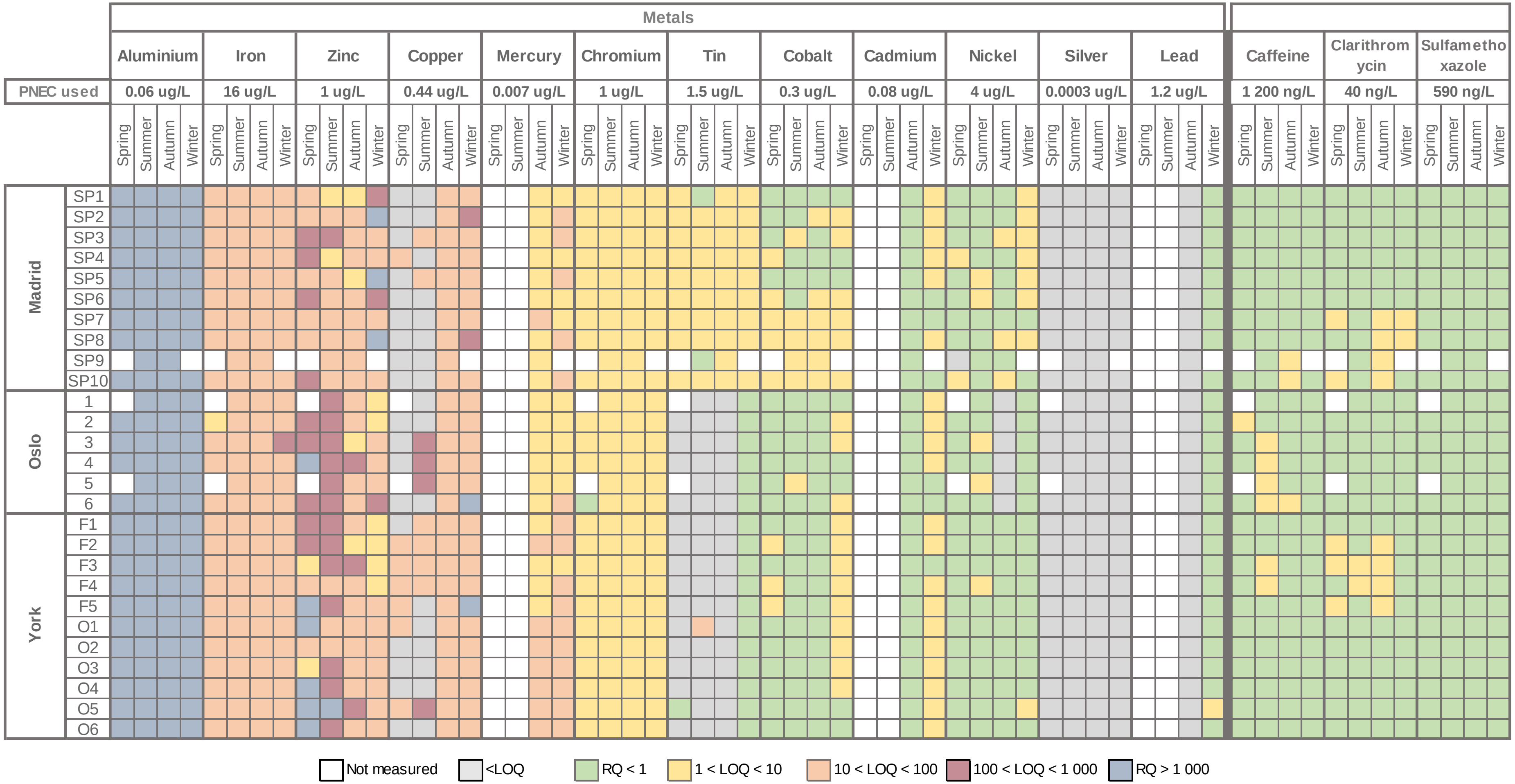


Figure 17 - Heatmap of metals' and pharmaceuticals' RQ across spring, summer, autumn and winter at all samplings locations in Madrid, York and Oslo. Green cells indicated RQ < 1; yellow 1 < RQ < 10; red 100 < RQ < 1 000; blue RQ > 1 000.

4.4 Discussion

The aim of this study was to study and compare the risks of metals, antibiotics, and caffeine for aquatic livings organisms in three urban environments. Results showed that metals posed constant and greater risks than pharmaceuticals.

Aluminium posed the greatest risk with RQ systematically above 1 000 in the three cities. Aluminium was the metal detected at the highest concentrations in this study (416 µg/L to 1794 µg/L). These concentrations are not unusual. Similar concentrations are regularly reported in the EU WaterBase River database in Italy, Austria, the United Kingdom and Finland (EEA, 2014). These concentrations cannot be explained by natural background concentrations which are estimated between 6 µg/L and 8.58 µg/L (Cheeseman *et al.*, 1989; Dixon and Gardner, 2015). Anthropogenic sources of aluminium include constructions sites, architecture, road infrastructures, outdoors paints, drinking water, personal care products, diet, vaccines, as coagulants in wastewater treatment plants (Eurometaux, 2021). In a similar study conducted in the UK, aluminium was the 2nd most toxic heavy metals in a study conducted in the UK behind copper (Donnachie et al., 2014).

Zinc, iron and copper were the next most toxic chemicals with potential impacts on fishes, daphnids and algae. Zinc concentrations ranged from 3 µg/L to 6 959 µg/L, iron from 12 µg/L to 2 291 µg/L and copper from 1 µg/L to 461 µg/L. Negative effects on aquatic living organisms were reported in the literature at lower concentrations: zinc had a LC50 of 68 µg/L for *daphnia magna* after 48 hours exposure and an LC50 of 116 µg/L for mosquito fish after 48 hours exposure (Taylor, 1978; Mount and Norberg, 1984). Iron, which was the second metal detected at the highest concentrations, had an LC50 of 1220 µg/L reported for *Cyprinus carpio (*carp) (Alam and Maughan, 2008). Similarly, for copper the lowest reported harmful concentrations (EC50) are 0.2–1.3 µg/L for *daphnia magna* and 8.6 µg/L for fatheads minnow after 48 hours exposure (De Schamphelaere, Heijerick and Janssen, 2002; Markich *et al.*, 2005; Van Genderen and Klaine, 2008). Copper, iron and zinc were the top three priority metals identified in similar study conducted in the very industrialized region in China. In another study in the UK, copper ranked 1st, zinc 3rd and iron 6th. Copper is known to be emitted by the degradation of plumbing and urban architecture. Similarly zinc and iron degrade from construction sites, transportations services and household appliances (Eurometaux, 2021; Panagos & Katsoyiannis, 2019). These metals are also found in domestic waters as they are used in health supplements and in personal care products for example (Eurometaux, 2021; USGS, n.d.).

Mercury and chromium also posed a systematic but a lower risk compared to iron, zinc and copper. RQs of mercury ranged from 2 to 60 and from 1 to 9 for chromium. Chromium and mercury were ranked 12th and 14th in a study ranking heavy metal risks in the UK and 5th and 10th in a similar study in China. Mercury can degrade from non-ferrous metals production, coal-fired power plants, appliances (batteries, electrical and measuring devices, lighting lamps, etc) and leak out of landfills (AMAP & UNEP, 2019). Mercury is well-known to bioaccumulate and biomagnified throughout the food web. This affects aquatic organisms survivals' and health of humans via consumption of contaminated animals (Liu, Cai and O'Driscoll, 2012; Lavoie *et al.*, 2018). Chromium is used in pipes, fittings and surface finishings (including kitchen sinks and domestic appliances) and constitutes 11% of steel (Rule *et al.*, 2006). Chromium was found to have an LC50 of 22 µg/L for *Daphnia magna* after 48 hours exposure (Mount and Norberg, 1984).

For cobalt, nickel and caffeine, the RQ was mainly below 1 and occasionally between 1 and 10. Similarly, for the antibiotics, clarithromycin had an RQ above 1 in York and Madrid on a few occasions, but not in Oslo. Antibiotics were not expected to be measured or pose a risk in Oslo as the river Alna in Oslo does not receive wastewater treatment plant effluent. However, caffeine was detected in the highest concentrations in Oslo (106 – 5 328 ng/L) compared to York and Madrid.

The primary source of caffeine in urban environments is usually WWTP (Li *et al.*, 2020). High concentrations of caffeine in Oslo could be because of a higher consumption by Norwegians, higher urban runoff and/or climatic conditions in comparison with York and Madrid. Norway is the second biggest consumer of caffeine with 21.82 kg/capita consumed in 2016. In comparison, Spain had an estimated consumption of 9.92 kg/capita in 2016 (ICO, 2019; WPR, 2021). Rainfall is also more important in Oslo: 1010 mm/year compared to 755mm/year in York and 415mm/year in Madrid (Climate Data, 2015). Last, climatic conditions of Oslo with lower temperature and less UV radiation could decrease caffeine degradation and therefore contribute to high concentrations in Oslo despite the absence of wastewater treatment plant effluent (Li *et al.*, 2020).

Except for copper and cadmium, there was no difference in risk posed by chemicals across seasons. Chemicals chosen in this study are not known to be used seasonally, therefore concentrations detected in the environment were also stable across seasons. Other chemicals known for seasonal consumptions (urban pesticides like insect repellants) would have however been expected to pose different risk throughout the season in the environment. For copper, RQ was constantly above 10 in autumn and winter. In spring and summer, copper was mostly below the detection limit and on a few occasions had an RQ above 10. One explanation for these high RQ variations would be COVID-19. Copper is highly associated to vehicle brake lining and tire wear in urban environments (Eurometaux, 2021; Panagos & Katsoyiannis, 2019). Samplings in Spring and summer were taken in March and August 2021 after lock-down periods in the three cities and during summer holidays. Previous studies have demonstrated low traffic during lockdown periods (Rossi, Ceccato and Gastaldi, 2020; Brown, Barnes and Hayes, 2021; Haghnazar *et al.*, 2022). Low numbers of car journeys and transportation traffic at these time could explain copper been <LQO on multiple occasions. RQ of copper would then depends on local activities/transportation.

Zinc RQ varied greatly between locations. RQ ranged from 4 to 3 510. Risk was particularly high in spring and summer in Oslo and in York. This could be because of high recreational activities happening in the water during these months. As mentioned previously zinc is used for multiples purposes in urban environments included in boat and cars' fuels. Boat rental companies and cruises ships activities are high during these months in Oslo and in York. There are multiples boat companies based at locations O4 in York which might explain the high zinc RQ in O4 and downstream sampling locations. These companies do not operate in autumn and winter, which would explain lower risk in these months.

Impacts of locations can also be seen for clarithromycin and caffeine. Clarithromycin and caffeine's RQ were higher after location SP7 in Madrid possibly because of release of effluent of "Butarque" WWTP near the sampling location. Clarithromycin also posed a constant risk in river Foss in York but not in river Ouse. This is probably because of the lower river flow (compared to river Ouse) and proximity of the sampling locations to the point of WWTP effluent discharge.

Except for tin, there was no difference between chemical profile pollution between the three cities. Metals were detected at similar levels and in the same order from highest to lowest concentrations across the three cities: aluminium, iron, zinc, copper, chromium, nickel, tin, mercury, lead, cobalt, cadmium, and silver. Except for tin, the levels of risks were the same in the 3 cities. Tin posed a systematic risk in Madrid but not in Oslo or York. Tin concentrations in Madrid ranged from 1 µg/L to 4 µg/L.

This study showed that metals present a much greater risk to aquatic organisms compared to antibiotics. The average risk quotient for aluminium was 15 000 times higher compared to the average risk quotient for clarithromycin. Similarly, Johnson et al., 2017 found that zinc posed a relative risk a million time greater compared to beta-blocker metoprolol. This can be explained by multiples reasons. First metals are detected in greater concentrations than pharmaceuticals. This is because metals are used for many purposes (in plumbing, in architecture, in construction, in transportation, in paints and household appliances to cite a few) and in higher quantities compared to pharmaceuticals (Eurometaux, 2021). In Europe 8 kilotons of copper is estimated to enter freshwater bodies per year (S. Comber et al., 2022). In comparison, 4264 tonnes of antibiotics were consumed by human in Europe in 2018 (OECD, 2022).

Second, the PNEC used for metals were more conservative in this study compared to others. While the authors chose to use the lowest PNEC value or EQS found in the literature and in regulatory report, others studies used median ecotoxicity values as the PNEC (Johnson *et al.*, 2017; Su *et al.*, 2017). This is because ecotoxicity of metals is difficult to determine and varies with water chemistry, organic contents, hardness of water and specification of metals (Gardner *et al.*, 2008). There is no general agreement between scientists and regulators on metals' ecotoxicity yet. For example the PNEC of nickel is 4 µg/L for EU WFD AA-EQS, 52 µg/L and 420 µg/L for chronic and acute exposure limits proposed by the US EPA (European Commission, 2019). Other metals like cobalt or tin have no EQS. Another example is aluminum. Aluminium is considered as a relatively low metals of concern for living organisms in water pH above 6. At pH below 6.5, aluminium occurs mainly in $Al(OH)_2^+$, $Al(OH)^{2+}$, and Al^{3+} forms. Aluminium tends then to be reactive and unstable, leading to the precipitation of aluminium on gill's surface, killing living organisms (Comber et al., 2005; Gardner et al., 2008). Because environment freshwater pH is mainly between 6.8 to 9, aluminum is therefore not always included in studied looking at toxicity of metals (Rule et al., 2005; Su et al., 2017). In this study, pH water was not measured below 7.02. Aluminium had however a LC50 of 89 µg/L for young crustacean Hyalella Azteca in pH water of 7 (Borgmann *et al.*, 2005). In comparison, PNEC of clarithromycin and sulfamethoxazole came from the AMR industry alliance based on industrial consensus agreement.

As the methodology used in this paper was mainly to be able to analyse and compare the risk of metals with antibiotics, more research would be needed to have a final and definite analysis of the risks of these chemicals. Potential additives or synergetic effects of metals and antibiotics mixtures would need to be taken into account: previous studies have showed that antibiotics resistant genes are promoted in presence of metals (Stepanauskas *et al.*, 2006; Zhang *et al.*, 2012; Ye *et al.*, 2017). The natural background concentrations should be analysed for each location and water chemistry should be included metal toxicity assessments. Moreover pH depressions in urban environments because of snow melts and acid rains was previously demonstrated (Jeffries, Cox and Dillon, 1979; Johnson, Turner and Kelly, 1982). Effects of pH variations and potential impacts of future acidification of water because of climate changes should be included in risk analysis.

Next research step

In this chapter, out of fifteen priority chemicals identified in chapter 2 and measured in this chapter in three European cities, 13 had RQ above 1 and therefore posed a risk at least at one sampling event: the metals aluminium, iron, zinc, copper, mercury, chromium, tin, cobalt, cadmium, nickel, lead as well as caffeine and the antibiotic clarithromycin. Only silver and sulfamethoxazole did not pose a risk in this study. The risks of 13 priority urban chemicals are suspected to change and potentially increase in the future because global change and megatrends such as increasing and migrating population, urban expansion, resources scarcity, climate change and technology innovation (Retief *et al.*, 2016; Van den Brink *et al.*, 2018). These megatrends will affect chemical production, usage and degradation in the environment, which will in turn change their risks.

To study how global change will affect the risk of priority chemicals in the unknown future, multiples future societies should be considered. The Shared Socio-Economics Pathways (SSPs) scenarios were developed by the IPCC to allow scientists to study environmental problematic under the same future storylines. SSPs are a set of 5 qualitative scenarios of future changes in demographics, human development, economy and lifestyle, policies and institutions, technology, and environment and natural resources (O'Neill *et al.*, 2017). SSPs have not been adapted to chemicals emissions yet.

In the next chapter (Chapter 4), a framework was developed to adapt global-SSPs and extended-SSPs (e.g. European SSPs; Agricultural European SSPs) to chemical emissions. The framework is first illustrated for antidepressants and insecticides emissions in European freshwater bodies in 2050. In chapter 5, the framework is push forward and developed with shareholders from academia, industries and regulators for antibiotics. Antibiotics were chosen to be extended in chapter 5 rather than metals for multiple reasons: 1) the literature on sources and pathways of antibiotics in urban environment is extensive. This allow a better understanding and therefore better scenario development for the future; 2) shareholders available to contribute to scenario development process were antibiotics experts and last; 3) antibiotics resistance gene in listed in the top 10 global health threat by UNEP (UNEP, no date).

Chapter 5 - A Shared Socio-Economic Pathway Based Framework for Characterising Future Emissions of Chemicals to the Natural Environment

5.1 Introduction

In the last chapter, chemicals that currently pose a risk in European urban aquatic environments were identified through a monitoring study of three contrasting European cities. In the future, the emissions and effects of these priority chemicals could alter as a result of societal changes in response to global megatrends such as climate change and urbanisation (Balbus *et al.*, 2013; Redshaw *et al.*, 2013; Hader *et al.*, 2022). However, the extent of changes in emissions, which will drive the effects, is currently unclear.

Societal changes happen rapidly and affect the consumption and emissions of chemicals (Bunke *et al.*, 2019) so in the future the use of chemicals will likely increase further. For example, despite increased human development, the prescriptions and consumption of antidepressants are continuously increasing in developed countries and are expected to be exacerbated by natural disasters in the future (Olié *et al.*, 2002; Exeter, Robinson and Wheeler, 2009; Redshaw *et al.*, 2013; Gualano *et al.*, 2014; To, Eboreime and Agyapong, 2021). Pesticides have experienced a rapid shift in usage in the last 60 years. Pesticides use has increased by 15-20-fold since the 60s to increase food production and respond to global food demand (Oldenkamp, Beusen and Huijbregts, 2019). Because they are very toxic chemicals which may affect human health and the environment, pesticides frequently receive negative media coverage in some public debate (Rani *et al.*, 2021; Le Monde, 2022; Newsbeat, 2022). However the pressure to meet food demands for the 9 billion inhabitants predicted by 2050 (Popp, Pető and Nagy, 2013; Finger, 2021) will mean that pesticide use could continue to increase. Changes in consumption will lead to changes in emissions, exposure and risks to the natural environment. For instance, the risk posed by antibiotic ciprofloxacin to aquatic species has increased by 10-20 fold worldwide in twenty years because of increasing exposure (Oldenkamp, Beusen and Huijbregts, 2019). Future societal changes will therefore affect the number, the quantity and the diversity of chemicals and subsequently chemical risks in different ways.

Few societal changes have been studied to determine their impact on chemical emissions. Advanced technologies for wastewater treatment can decrease the load of chemicals released in water bodies (Yaman *et al.*, 2017; Fairbairn *et al.*, 2018); legislation and regulation can limit the number of compounds available on the market (van Dijk *et al.*, 2020) ; chemical engineering can create genetically modified crops (GMO) that reduce the number and volume of fertilisers and pesticides used by farmers (Klümper et al., 2014). At the same time, new chemicals, designed to satisfy specific needs, can also be more persistent and more dangerous for the environment (e.g. perfluorooctanoic acid); GMO crops can promote resistant pests that will require stronger and potentially more toxic pesticides (Van Acker, Rahman and Cici, 2017). The societal changes (including socio-economic factors such as human development, urbanization, demographics change, inequalities, international agreements, economic growth, diets, etc) have not been studied together to estimate their potentials effects on chemical emissions for the future. Potentially important trends in future environmental emissions may be missed if all aspects of societal changes are not considered. This also means that mitigation and adaptation strategies to deal with future chemical pollution are based on incomplete evidence.

One approach to inform the research and management of chemical emissions in the future under global change is to use scenarios. Scenarios explore multiple alternative futures with the aim of evaluating strategies to respond to any potential adverse changes (Jones *et al.*, 2015). A very influential set of recent scenarios are the representative concentration pathways -RCPs- (van Vuuren *et al.*, 2011) and the shared socio-economic pathways -SSPs- (O’Neill *et al.*, 2017), developed by the global climate change research community. The SSPs describe five contrasting socio-economics pathways with their abilities to adapt and mitigate to global change challenges. They are based on six categories: demographics, human development, economy and lifestyle, policies and institutions, technology and environment and natural resources. Each category is further detailed with SSP elements like, among others, population growth, fertility and urbanisation for demographics or education, health investment and equity for human development. For each SSP storyline, a socio-economic situation is described with variation of SSP elements (e.g. health investment is high under

SSP1 and low under SSP3). They are meant to be used as baselines for climate change and sustainable development research. SSPs are made to serve the global climate change community, but they are also designed to be extended to multiple sectors and scales and improve consistency with all global change-related research. Different sectors and geographic scales, including land-use management in central Asia, European agriculture or more recently the United Kingdom, have downscaled scenarios based on the SSPs to explore the impacts of future climate conditions (Mitter *et al.*, 2020; Nunez *et al.*, 2020; Pedde *et al.*, 2021). Scenario development and scenario extensions are a relatively recent area of research, but the number of scenario studies has increased rapidly in recent years. An article looking at achievements of the climate change scenario framework reported 1,400 articles that used and/or developed scenarios based on SSPs since 2010 (O'Neill *et al.*, 2020). Nevertheless, such scenarios have not yet been developed for emissions to the environment from the chemical sector.

Ideally, global SSP scenarios would be extended to all the chemicals within the chemical sector. The research community focusing on chemical emissions in the future could then work under the same storylines and extend those scenarios to more specific research questions if needed. To do so, key drivers and relevant scale for all chemicals must be defined. This is not possible as key drivers and relevant scale vary between and among groups of chemicals. A single set of narratives cannot adequately cover all chemicals because of the diversity of chemicals' physical and chemical properties, environmental behaviour, human usage and future needs for society.

To be able to study chemicals in the future, here, we present a framework, based on the socio-economic and climate scenarios (combined SSP-RCPs), for the development of scenarios for emissions of single chemicals or groups of similar chemicals to the natural environment in the future. 'Chemicals', being a heterogeneous group, do not have the same drivers of emissions and relevant study scales for all classes. A 'simple' extension of SSPs cannot, therefore be made, the thematic focus of scenarios developed must be for single chemicals or groups of similar chemicals. We therefore illustrate the approach for antidepressant and insecticide emissions in Europe in the 2050s.

Antidepressants and insecticides were chosen for multiple reasons. Their usage is reported to come from different drivers in the literature. On one hand, antidepressant usage is driven by sociodemographic drivers like education, social cohesion, inequalities and/or culture

(Henriksson and Isacsson, 2006; Hiilamo, 2014; Lewer *et al.*, 2015; Park, Jang and Chiriboga, 2018; Gomez-Lumbreras *et al.*, 2019). On the other hand, usage of insecticides can be driven by cultural practices (e.g. type of crops, crops rotation, conventional vs. non-conventional practices), regulations, technology development but also by consequences of climate change like increase temperature or increase rainfall (Bloomfield *et al.*, 2006; Meissle *et al.*, 2010; Brookes and Barfoot, 2018; Wan *et al.*, 2018; Rhodes and McCarl, 2020). Consumption has consistently increased in the last 50 years and is expected to continue. However, looking at SSP storylines, the changes in antidepressants and insecticides' emissions in the future are uncertain. Global changes that are projected to occur over the next 30 years could have an effect on antidepressant and insecticide consumption and, therefore, on emissions into the environment. These future emissions must be understood in order to assess future risk and mitigate their impacts.

Here we propose a four-step framework, inspired by the approach developed by Mitter *et al.,* 2019 for the European agricultural sector, and apply it to antidepressants and pesticides to demonstrate the framework's utility as a tool to gain a better understanding of future chemical emissions and the way that societal change influences this future.

5.2 Methods

A groups of eights scientists with expertise in scenario developments, in environmental sciences, in chemistry and in toxicology gathered to develop the following four-step framework to characterise chemical emissions in the future under the SSPs. The framework, presented in Figure 18, is inspired by the methodology developed by Mitter et al., 2019 to European SSPs to Agricultural European SSPs and follow standards methodologies for scenario development (O'Brien, 2004; Rounsevell and Metzger, 2010; Rose and Star, 2013; Priess and Hauck, 2014).

Step 1: Define key characteristics of scenarios

The first step focuses on the determination of key characteristics of the scenarios required. This is an essential step to have a clear understanding of the specifications and boundaries of the scenarios, as well as to answer “why”, “for whom” and “how” are those scenarios being developed. The following questions should be addressed:

- **What is the goal and purpose of the scenario?** the goal and purpose of the scenarios must be determined: Why are the scenarios needed? What are the questions we want to answer with the output from the scenarios?
- **Which chemical or group of chemicals is being investigated?** The chemical or group of chemicals for which the scenarios are to be applied should be defined. Multiples chemicals/molecules could be considered as one group of chemicals for scenario development if molecules have the same dynamics in the society, environmental behaviours and fates within the temporal and spatial scale chosen further in step 1. If a group of chemicals is to be considered, similarities in production, usage, consumption and environmental behaviours are mandatory. Here, we want to avoid selecting multiple chemicals that would be impacted by socio-economic drivers in different ways, making the development of a scenario storyline for all chemicals included impossible.
- **Which environmental matrices are being considered?** Do the scenarios focus on air, water, or soil compartments? We recommend to only select one matrix as chemicals can behave differently in different environmental compartments.
- **What temporal scale is required?** Are the scenarios focusing on future of chemicals in 2030, 2050, 2100 etc?
- **What geographical scale is required?** Are the scenarios focusing on a city, a country or a continent? Urban environments? Urban environments in developed countries? A small geographical scale involves an easier understanding of the dynamics of the system, but literature can be limited on the system in question. Moreover large scale SSPs might be more difficult to extend because they are not specific enough for smaller scale systems. A large geographic scale has more chances to have available SSPs (e.g. Europe, United Kingdom), but the system might be more difficult to understand and to apply to a chemical or group of chemicals. Determination of temporal and spatial scale are necessary to define the system boundary in which scenario will be develop and should be primary determined by the goal and purposes of the scenarios.
- **How many and which SSPs need to be explored?** There are multiples SSPs that are available in the literature: global SSPs, European SSPs, water-sector SSPs, drought

characteristics in China SSPs to cite a few (Riahi *et al.*, 2017; Graham *et al.*, 2018; Kok *et al.*, 2019; Su *et al.*, 2021). Depending on the characteristics of the scenarios wanted, the most relevant and logical SSPs should be selected for use. The number of scenarios can range from a minimum of two scenarios to five (all SSP scenarios). A single scenario should not be developed by itself, as it should be comparable to another.

- **Which climate projections should be explored?** The use of many chemicals will be affected by weather conditions such as temperature, moisture content and flood events. For the system of interest, therefore, projections of future weather patterns associated with the selected SSPs should be obtained to provide a foundation for identifying any climate-driven changes in chemical use during Step 2.
- **Who is the target audience?** The targeted audience can be climate change scientists, social scientists, regulators, industries, public, etc. The format of the scenarios and the level of detail should be relevant to the knowledge and needs of the targeted audience.
- **What will be the form of the scenario?** How will the scenario look: an infographic? a set of storylines? a table with increasing and decreasing chemicals trends? Output scenarios can have any format, but must be relevant to the scenario's goal, purpose and targeted audience.

Step 2: Review and prioritisation of the potential impacts of changes in socio-economic and climate on chemical emissions

In step 2, a combination of literature searching and expert elicitation is used to develop an evidence-base on how chemical emissions could change in the future. This analysis considers: a) the socio-economic changes expected for the selected SSPs from Step 1; and b) the effects of projected changes in weather patterns on chemical use. The findings from the systematic review are then used in an expert consultation exercise to select the most important future changes for chemical emissions which are then used as a basis for the emission scenario development in Step 3.

These drivers can be related to socio-economics elements (similar to SSP elements in O'Neil et al, 2017) or climate change elements (e.g. natural disasters, temperature). The idea here is to understand how the thematic focus is influenced in a society and to develop a list of drivers by conducting a systematic review.

To do the systematic review, we recommend using the elements of the SSPs initially chosen in step 1 to extend to specific search terms. The driver(s) and findings should be extracted from the articles. We found that the search terms “association”, “impact”, “influence”, “effect” and “connection” might extend search results to a large number of relevant articles when looking for dynamic/interactions between drivers and the thematic focus. Direct (e.g. leakage from production site; release from road runoff) and indirect drivers (e.g. consumption; outbreaks of diseases) should be considered in the systematic review.

For some chemicals, climate change driven effects will need to be considered alongside socio-economic driven effects. For example, use of UV-filter molecules in sunscreens might be expected to increase due to projected increases in hot and dry weather. Increased pest disease pressures resulting from changes in climate could alter the use of insecticides, herbicides and fungicides. As climate change has multiple possible future outlooks, selection of climate change scenario is needed. Representative Concentration Pathways (RCPs) provide estimations of plausible future changes in greenhouse gas emissions, that translate into a different range of temperature and precipitation outputs. We recommend using RCPs for climate change integration as SSPs and RCPs can be combined in a scenario matrix architecture (van Vuuren et al., 2017). These ‘integrated scenarios’ help to understand the combined effect of socio-economic change and climate change. Relevant RCPs and related climate change impacts should be chosen and integrated in the same way as SSPs in the scenarios.

Because not all aspects of a society have been researched with respect to chemicals, relevant literature is limited. To enrich the comprehension of the thematic focus dynamic in a society and the list of drivers of the SSPs to extend and the thematic focus should be analysed one by one. The elicitation of experts’ judgement is encouraged. This allows the inclusion of multiple perspectives and opinions on the thematic focus in a society. Expert judgements can be solicitated in multiples ways (e.g. personal interview, group interviews, development of fuzzy cognitive maps, surveys) depending on cost and logistical limitations. If an SSP element is considered relevant to the thematic focus by scenario developers and/or experts, then it should be added to the list of drivers.

When the systematic review is done, prioritisation or determination of key drivers is recommended. Drivers (direct and indirect) do not have the same importance to the thematic focus. Two methodologies are recommended here:

- Scenario developers can conduct a qualitative synthesis based on literature review and, if applicable, experts' input to determine which drivers are key drivers for scenario development. A criterion could be 'a driver that influences the consumption of chemical "x" is more relevant than a driver influencing the production of "x"'.
- Experts' judgements can also be solicitated to define key drivers using the same methodology as mentioned before. A survey to experts with specific questions (e.g. Do you consider this driver to have a high, medium or low influence on the thematic focus?) could be used to identify key drivers. Experts' time involvement is then limited, and experts are free to complete the survey on their own time.

Step 3: Develop chemicals emissions scenarios:

This step of the framework is focused on the development of scenarios. We recommend doing it in two parts. The first part is to focus on each key driver and each scenario at a time. The second part is to gather all the effects of drivers, consider the drivers' direct and indirect impacts on the thematic focus and propose an overall effect on the thematic focus.

For the first part, each key driver is studied individually. For each key driver, an impact on the thematic focus must be defined following 3 steps:

A. Gather outputs from the literature review and experts' judgements from step 2 for the chosen driver

B. Identify how the driver is said to change/be in the SSP to extend in step 1 (e.g. in SSP1, the world population increases until 2100)

C. Propose an impact of the driver on the chemical or group of chemicals. The impact could be qualitative (e.g. increase/decrease) or semi-quantitative (e.g. small/medium/high increase). The proposed-impact should be consistent with the findings from literature review and with how the driver is said to change/be in the SSPs. The reasoning should be rational. The following statements should be verified:

- The driver's proposed-impact is consistent with the findings on how the driver impacts the thematic focus in the literature review
- The driver's proposed-impact is consistent with the literature review and with how the driver is said to change in the SSPs to extend
- The proposed-impact can be explicated by rational thinking

For the second part, the driver's direct or indirect impact on the thematic focus must be explained. For example: "Changing population size does not have a direct impact on the emissions of chemical X in the environment, however changing population size impact consumption of chemical of X. Increase consumption of X is found to be positively correlated to emissions of X in the environment. Therefore for the development of our scenario we consider population size to be an indirect driver positively correlated to emissions of chemical X in the environment" When all driver's impacts on the thematic focus are explicit, an overall effect can be proposed and presented in the format chosen on step 1.

Step 4: Consistency checks

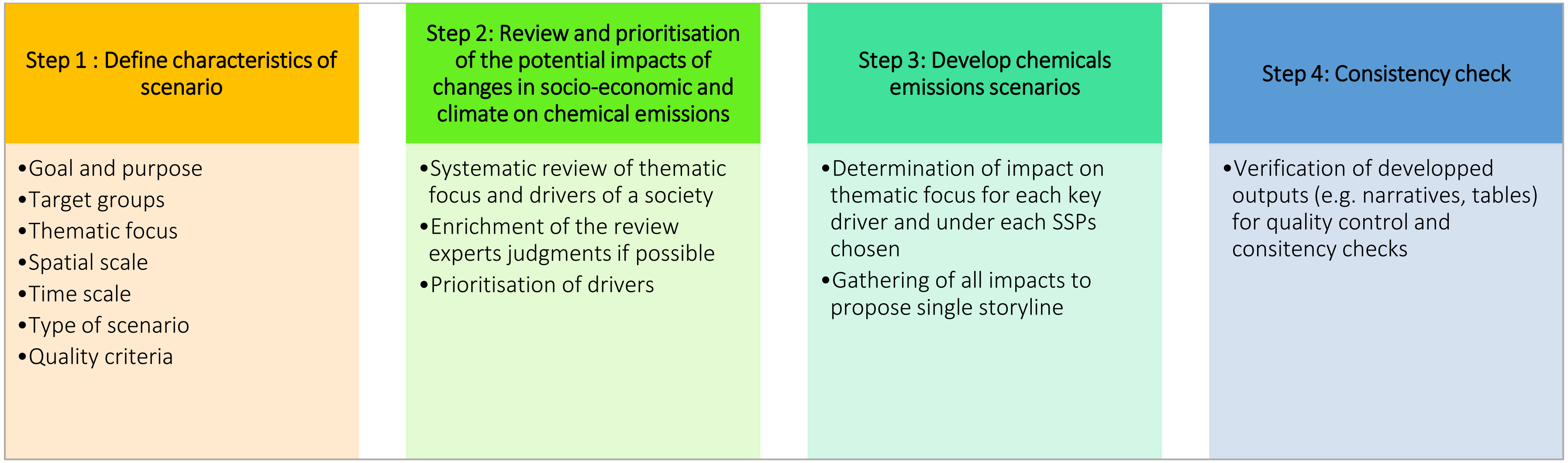
This last step aims to check consistency and to assure quality control of the developed scenarios. For this step, the scenario products developed are checked for consistency with the systematic review and with the SSPs. Consistency with the systematic review consists of verifying that a driver's dynamic in the environment and in the society are the same across the literature and scenario developed. For consistency with the SSPs, driver's evolution must be similar across SSPs chosen to extend in step 1 and in scenario developed (e.g. if population side increase in SSP1 chosen to extend, population side must decrease in the scenario developed). Conducting these consistency checks multiple times is essential for quality control of the scenario development process (Priess and Hauck, 2014). When time and financial resources permit, we recommend to conduct consistency checks with experts (Ernst *et al.*, 2018; Mitter *et al.*, 2019). Consistency checks can also be done by scenario developers by repeating and verifying step 3 multiples times.

Uncertainties

There are uncertainties when scenarios are developed. Uncertainties can arise around lack of system understanding of the thematic focus, on the thematic focus within a society and on the study of the future that is fully unknown.

In step 2, uncertainties can arise around lack of understanding on how chemicals behave in the environment or a society. This could be due to lack of data availability or literature on the chemical in question but also on the dynamics of a society. Or general

In step 3 of our framework, the SSPs' storyline and other products must be interpretated for the development of chemical emissions scenarios (e.g. population growth increases strongly). Vagueness and ambiguity of scenario terminologies make interpretations of SSPs different between researchers. Techniques to address these uncertainties can be to increase the number of scenarios to develop, to perform sensitivity analysis or to solicit experts (Gao *et al.*, 2016; Rounsevell *et al.*, 2021). The advantage of involving experts is to build consensus on uncertainties, but also to discuss and obtain diverse expertise on the chemical focus, allowing an improved understanding. Uncertainties should not deter the development of scenarios but should be considered in output scenario interpretations.



Step 1 : Define characteristics of scenario

- Goal and purpose
- Target groups
- Thematic focus
- Spatial scale
- Time scale
- Type of scenario
- Quality criteria

Step 2: Review and prioritisation of the potential impacts of changes in socio-economic and climate on chemical emissions

- Systematic review of thematic focus and drivers of a society
- Enrichment of the review experts judgments if possible
- Prioritisation of drivers

Step 3: Develop chemicals emissions scenarios

- Determination of impact on thematic focus for each key driver and under each SSPs chosen
- Gathering of all impacts to propose single storyline

Step 4: Consistency check

- Verification of developped outputs (e.g. narratives, tables) for quality control and consitency checks

Figure 18 – Framework proposal to extend SSPs storylines to single chemicals emissions or group of chemical sharing similar features

13.2 Results

The framework is illustrated for two case studies: antidepressant and insecticide emissions in European freshwater systems in 2050. The methodology followed is the same as the one presented previously except that exploratory reviews were conducted instead of systematic reviews. Moreover uncertainties on scenario developed were not investigated. The reasons are that fully developed scenarios for antidepressants or insecticides would require individual articles with more extensive reviews and engagement with experts. This does not impact the aim of this section which is to illustrate how the proposed framework can be applied.

Antidepressants emissions at European scale for 2050 (Eur-Ant-SSPs)

Antidepressants are regularly detected in European fresh water monitoring campaigns, mostly in urban environments where consumption is high and waste water treatment does not effectively remove this type of molecule (Metcalfe *et al.*, 2016; Wilkinson *et al.*, 2022). Traces of antidepressants in the aquatic environment threaten aquatic ecosystems by altering swimming and cryptic behaviours of invertebrates and behaviour and the development and reproduction of aquatic vertebrates (Sehonova *et al.*, 2018). Global changes that are projected to occur in the next 30 years will likely affect antidepressant consumption and therefore, emissions into the environment. These future emissions must be understood in order to assess future risk and mitigate their impacts. Here, we develop antidepressant emissions scenarios under global change.

Step 1: Define characteristics of scenarios of Eur-Ant-SSPs

The characteristics of the chemical emissions scenario wanted were developed:

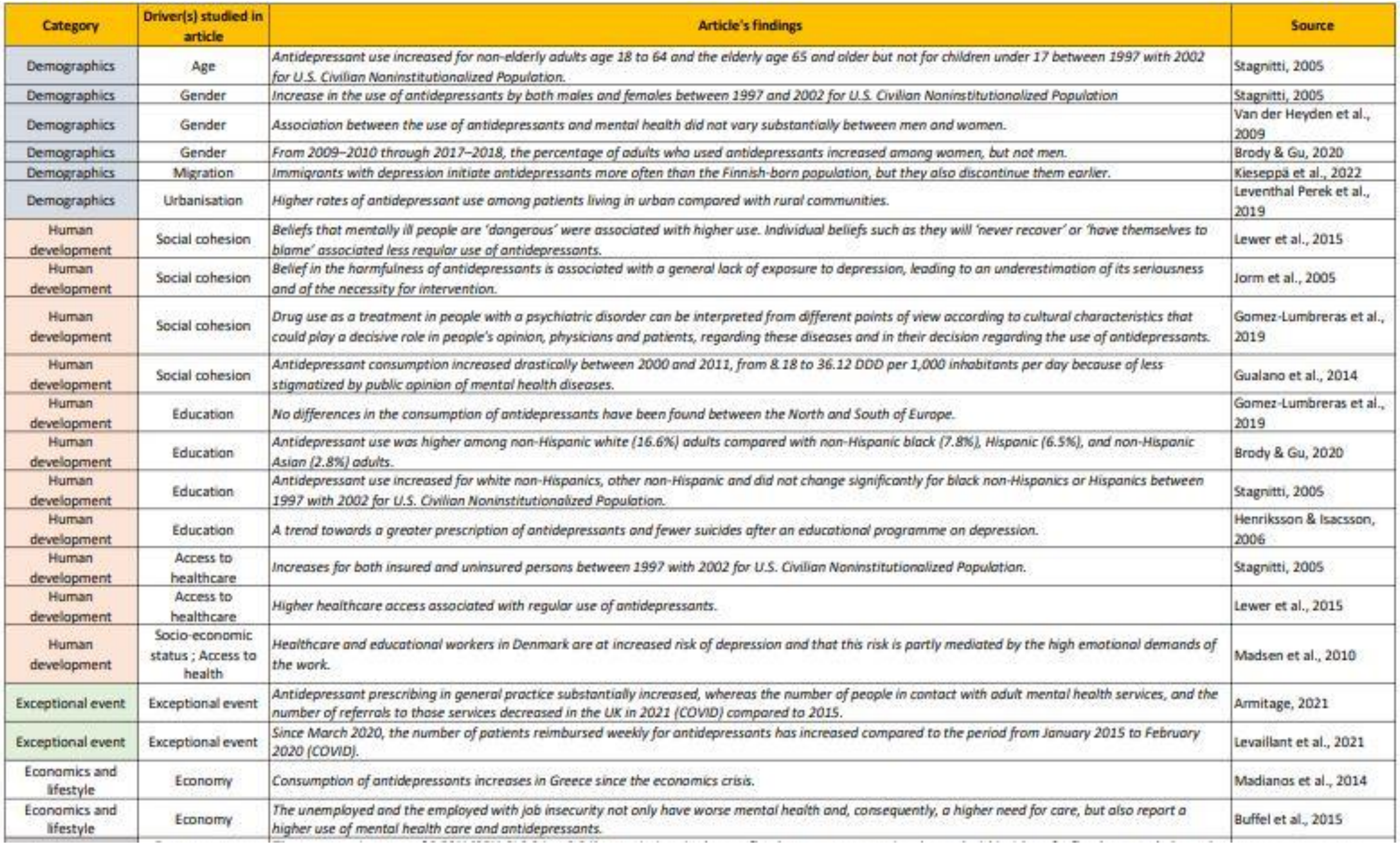
- **What is the goal and purpose of the scenario?** Extend European SSPs (Kok *et al.*, 2019) to antidepressant emissions to envision multiple scenarios of antidepressant emissions in 2050
- **Which chemical or group of chemicals is being investigated?** Within the EU market, antidepressants currently available, antidepressants currently developed but not registered yet and future antidepressants molecules developed under the green chemistry framework by Ganesh et al., 2021

- **Which environmental matrices are being considered?** European freshwater aquatic systems
- **What spatial scale is required?** Europe
- **What temporal scale is required?** 2050
- **How many and which SSPs needs to be explored?** European SSP1 (Eur-SSP1), SSP4 and SSP5 (Kok *et al.*, 2019). Eur-SSP1 is selected to study antidepressant emissions in a sustainable society with less resource-intensive lifestyles, high human investment and high social cohesion. Eur-SSP4 and Eur-SSP5 are selected to study antidepressant emissions in nuanced societies with high inequalities in human development and some environmental considerations in Eur-SSP4, and intensive lifestyle with high human investment and high environmental considerations for Eur-SSP5.
- Which climate projections should be explored? Climate change impacts human mental health in multiples ways in the literature. Increased temperature could lead to more aggressive behaviour and extreme events to stress-related psychiatric disorders (Padhy *et al.*, 2015). The consumption of antidepressants among practices located within 1 km of a flood areas increased compared to further distance lands (Milojevic, Armstrong and Wilkinson, 2017). Climate change-related declining/changing societies affect mental health with more psychiatric disorders (e.g. ecoanxiety, post-traumatic events stress, depression, survivor guilt) (Hayes *et al.*, 2018; Cianconi *et al.*, 2020; Palinkas and Wong, 2020). The impacts of climate change is therefore considered for antidepressants emissions scenarios. Climate change is considered and integrated with RCP 4.5, 6 and 8.5 combined with Eur-SSP1, Eur-SSP4 and Eur-SSP5 respectively.
- **Who is the targeted audience?** Scientists from the climate change research community like eco-toxicologists, chemists and social scientists working at European scales.
- **What will be the form of the scenario?** Tables with antidepressants trends for each key driver and qualitative storylines assessing the overall effects of the set of drivers for each scenario.

Step 2: Review and prioritisation of the potential impacts of changes in socio-economic and climate on chemical emissions

An exploratory review was conducting using the Scopus search engine. The search terms “antidepressant” in combination with the Eur-SSPs drivers’ elements. Fifty one articles were identified. Further targeted searching was conducted when cited literature yielded relevant peer-reviewed articles. Articles were kept if they confirmed the following statements: 1) the article focuses on change in trends in antidepressants use/consumption; 2) the change in antidepressants trends is related to a socio-economics, technological or climate change; 3) the article does not focus on people with medical pre-conditions; and 4) the article focused on Europe, a country in Europe or a society similar in socio-economic development as Europe. In total, 23 relevant articles were kept. Articles covered primally drivers related to demographics and human development change. The driver(s) studied and their impacts on antidepressant were extracted from each article and are presented in Table 9.

Table 9 – Drivers studied and their impacts on antidepressant in articles identified in the exploratory review



Category	Driver(s) studied in article	Article's findings	Source
Demographics	Age	*Antidepressant use increased for non-elderly adults age 18 to 64 and the elderly age 65 and older but not for children under 17 between 1997 with 2002 for U.S. Civilian Noninstitutionalized Population.*	Stagnitti, 2005
Demographics	Gender	*Increase in the use of antidepressants by both males and females between 1997 and 2002 for U.S. Civilian Noninstitutionalized Population*	Stagnitti, 2005
Demographics	Gender	*Association between the use of antidepressants and mental health did not vary substantially between men and women.*	Van der Heyden et al., 2009
Demographics	Gender	*From 2009–2010 through 2017–2018, the percentage of adults who used antidepressants increased among women, but not men.*	Brody & Gu, 2020
Demographics	Migration	*Immigrants with depression initiate antidepressants more often than the Finnish-born population, but they also discontinue them earlier.*	Kieseppä et al., 2022
Demographics	Urbanisation	*Higher rates of antidepressant use among patients living in urban compared with rural communities.*	Leventhal Perek et al., 2019
Human development	Social cohesion	*Beliefs that mentally ill people are 'dangerous' were associated with higher use. Individual beliefs such as they will 'never recover' or 'have themselves to blame' associated less regular use of antidepressants.*	Lewer et al., 2015
Human development	Social cohesion	*Belief in the harmfulness of antidepressants is associated with a general lack of exposure to depression, leading to an underestimation of its seriousness and of the necessity for intervention.*	Jorm et al., 2005
Human development	Social cohesion	*Drug use as a treatment in people with a psychiatric disorder can be interpreted from different points of view according to cultural characteristics that could play a decisive role in people's opinion, physicians and patients, regarding these diseases and in their decision regarding the use of antidepressants.*	Gomez-Lumbreras et al., 2019
Human development	Social cohesion	*Antidepressant consumption increased drastically between 2000 and 2011, from 8.18 to 36.12 DDD per 1,000 inhabitants per day because of less stigmatized by public opinion of mental health diseases.*	Gualano et al., 2014
Human development	Education	*No differences in the consumption of antidepressants have been found between the North and South of Europe.*	Gomez-Lumbreras et al., 2019
Human development	Education	*Antidepressant use was higher among non-Hispanic white (16.6%) adults compared with non-Hispanic black (7.8%), Hispanic (6.5%), and non-Hispanic Asian (2.8%) adults.*	Brody & Gu, 2020
Human development	Education	*Antidepressant use increased for white non-Hispanics, other non-Hispanic and did not change significantly for black non-Hispanics or Hispanics between 1997 with 2002 for U.S. Civilian Noninstitutionalized Population.*	Stagnitti, 2005
Human development	Education	*A trend towards a greater prescription of antidepressants and fewer suicides after an educational programme on depression.*	Henriksson & Isacsson, 2006
Human development	Access to healthcare	*Increases for both insured and uninsured persons between 1997 with 2002 for U.S. Civilian Noninstitutionalized Population.*	Stagnitti, 2005
Human development	Access to healthcare	*Higher healthcare access associated with regular use of antidepressants.*	Lewer et al., 2015
Human development	Socio-economic status ; Access to health	*Healthcare and educational workers in Denmark are at increased risk of depression and that this risk is partly mediated by the high emotional demands of the work.*	Madsen et al., 2010
Exceptional event	Exceptional event	*Antidepressant prescribing in general practice substantially increased, whereas the number of people in contact with adult mental health services, and the number of referrals to those services decreased in the UK in 2021 (COVID) compared to 2015.*	Armitage, 2021
Exceptional event	Exceptional event	*Since March 2020, the number of patients reimbursed weekly for antidepressants has increased compared to the period from January 2015 to February 2020 (COVID).*	Levaillant et al., 2021
Economics and lifestyle	Economy	*Consumption of antidepressants increases in Greece since the economics crisis.*	Madianos et al., 2014
Economics and lifestyle	Economy	*The unemployed and the employed with job insecurity not only have worse mental health and, consequently, a higher need for care, but also report a higher use of mental health care and antidepressants.*	Buffel et al., 2015

Table 9 – (continued) Drivers studied and their impacts on antidepressant in articles identified in the exploratory review

Climate change	Extreme event - Flooding	*There was an increase of 0.59% (95% CI 0.24 to 0.94) prescriptions in the postflood year among practices located within 1 km of a flood over and above the change observed in the furthest distance band. The increase was greater in more deprived areas.*	Milojevic et al., 2017
Climate change	Extreme event - Flooding	*With a relative risk (RR) of 1.54 (95% CI, 1.39-1.62) corresponding to an estimate of 409 new deliveries of psychotropic drugs during the three weeks following the storm, this study confirms the importance of the psychological impact of Xynthia. This impact is seen on all three classes of psychotropic drugs studied. The impact is greater for tranquilizers (RR of 1.78; 95% CI, 1.59-1.89) than for hypnotics (RR of 1.53; 95% CI, 1.31-1.67) and antidepressants (RR of 1.26; 95% CI, 1.06-1.40). The RR was higher for females than for males.*	Motreff et al., 2013
Climate change	Extreme event - Heatwaves	*While only incremental increases in morbidity and mortality above previous findings occurred in 2008, health impacts of the 2009 heatwave stand out. These findings send a signal that the intense and long 2009 heatwave may have exceeded the capacity of the population to cope.*	Nitschke et al., 2011
Climate change	Extreme event - Wildfires	*The results show an increased rate of PTSD, depression, and generalized anxiety at several times of follow-up post-wildfire, from the subacute phase, to years after. An increased rate of mental health disorders post-wildfire has been found in both the adult and pediatric population, with a number of associated risk factors, the most significant being characteristics of the wildfire trauma itself.*	To et al., 2021
Climate change	Global change	*Mental health impacts represent both direct (i.e. heat stress, exposure to extreme weather events) and indirect (i.e. economic loss, threats to health and well-being, displacement and forced migration, collective violence and civil conflict, and alienation from a degraded and potentially uninhabitable environment) consequences of acute, subacute and long lasting climate-related events.*	Palinkas et al., 2020
Multiples	Age ; Gender	*Antidepressants use is higher in women than in men, and increases progressively with age in both sexes.*	Gomez-Lumbreras et al., 2019
Multiples	Age ; Gender	*Antidepressant use increased with age, overall and in both sexes—use was highest among women aged 60 and over (24.3%). During 2015–2018, 13.2% of adults aged 18 and over used antidepressant medications in the past 30 days. Use was higher among women than men.*	Brody & Gu, 2020
Multiples	Age ; Education	*Disbelief in the medical model of depression and family shame reduced willingness to use mental health counseling and antidepressants in older population in Korea.*	Park et al., 2018
Multiples	Urbanisation ; Environment	*Antidepressant medication has strong associations with neighborhood conditions including socioeconomic satisfaction and the seasonality of particulate matter under 2.5 um in the air.*	Lee et al., 2022
Multiples	Urbanisation ; Education	*Lower rate of antidepressant use was found in urban and rural Arab-majority communities.*	Leventhal Perek et al., 2019
Multiples	Urbanisation ; Age	*Associations of neighbourhood socioeconomic and physical characteristics with older people's antidepressant use were small and inconsistent.*	Tarkiainen et al., 2021
Multiples	Age ; Socio-economics status	*Antidepressant medication use was higher for adults with at least some college education compared with those with a high school education or less.*	Brody & Gu, 2020
Multiples	Gender ; Education	*In men, antidepressant treatment was less common among low educational groups than among high educational groups'. 'In women, socio-economic position was not associated with antidepressant use.*	Kivimäki et al., 2007
Multiples	Gender ; Socio-Economics Status	*Use of antidepressants was significantly associated with female gender , higher socioeconomic status , and unemployment in Rio Grande do Sul State in Brazil in 2006.*	Garcias et al., 2018
Multiples	Socio-economic status ; access to health	*Socioeconomically disadvantaged respondents reported greater antidepressant use than those who were not classified as disadvantaged. These findings suggest Australia's universal health-care system does promote equitable health care across the population.*	Butterworth et al., 2013
Multiples	Age ; Gender ; Inequalities	*More young adult females used antidepressants in municipalities where relative poverty had increased. Fewer elderly females used antidepressants in municipalities where the Gini index (calculating distance between the richest and the poorest) increased. More young adults used antidepressants in municipalities where the number of those not being educated or trained had increased.*	Hiilamo, 2014
Multiples	Age ; Gender ; Social cohesion	*An increase in the number of persons over 65 years of age living alone was positively associated with an increase in the use of antidepressants among elderly females.*	Hiilamo, 2014
Multiples	Age ; Gender ; Education	*In this elder sample, taking into account depressive symptom severity and other confounds, antidepressant use is nearly half as likely among men and African Americans.*	Grunebaum et al., 2008

To prioritise drivers, nine experts on chemical emissions from academia were solicited. Based on the exploratory review provided and their expertise, experts were asked to assign a priority (high, low or uncertain) for all SSPs elements of Kok et al., 2019 and climate change drivers. If 70% of experts defined a driver as "high" priority, the driver was considered key and selected for scenario development. For antidepressant emissions, 11 key drivers were identified: population growth, inequalities, urbanization, economy, social participation, social cohesion, healthcare access, healthcare investment, education, technology development and extreme droughts and floodings events (see Annexe 4.1). Those drivers were studied exclusively in step 3 to develop emissions scenarios.

Step 3: Develop chemicals emissions scenarios

Prioritised drivers of antidepressants emissions in European aquatic freshwater systems selected in step 2 were studied individually. An emissions trend (increasing, decreasing or both) was proposed for each prioritized driver. Each driver's individual future trend is presented in section 3.1 and in Table 10, and output scenario storylines are presented in the section 3.2. Note that because of time and financial restrictions and because these scenarios storylines were mostly developed to illustrate the framework, step 3 was developed using desk-based research conducted by the authors.

Step 3.1 Antidepressants emissions trends by priority drivers in Eur-Ant-SSPs

The 11 prioritised drivers were studied one at a time based on results from the exploratory review, historical data and storylines from Eur-SSPs (Kok *et al.*, 2019). If a key driver has no specific indication in Eur-SSPs (e.g. "Inequalities"), storylines provided in global SSPs for Rich-OECD countries (high-income countries – GNI per capita above $13 205 – according to the World Bank) were used (O'Neill *et al.*, 2017; WBD, 2022). When considered relevant and useful for the general understanding of antidepressant emissions in a society, effects of key drivers were extended to mental health or depression by desk-based research.

- Population growth

The total European population was 738 million in 2010. European population growth is estimated to increase in SSP1 (up to 769 million) and SSP5 (847 million) and to decrease in SSP4 (716 million). Based on historical data, we concluded that antidepressants emissions is positively correlated to population growth, therefore antidepressants emissions increase in Eur-Ant-SSP1 and Eur-Ant-SSP5 and decreases in Eur-Ant-SSP4.

- Inequalities

In Global SSPs, inequalities were found to be "reduced across and within countries" in SSP1, "high, especially within countries" in SSP4 and "strongly reduced, especially across countries" in SSP5. Correlations between inequalities and antidepressants or mental health can be difficult to interpret as inequalities can cover poverty, unequal career opportunities or unequal access to education among others. The consensus though is that higher inequalities is correlated to low mental 122hemich (Murali and Oyebode, 2004; Yu, 2018) and indirectly to antidepressant consumption. We concluded that in Eur-Ant-SSP1 and Eur-Ant-SSP5, because inequalities decrease, antidepressants emissions decrease. In Eur-Ant-SSP4, we concluded that antidepressant use will increase.

- Urbanisation

Urbanisation is high and well-managed in global SSP1, medium with mixed type of urbanisation across and within cities in SSP4 and high and better managed over time in SSP5. The dynamic between urbanisation and antidepressants or/or mental health is unclear from the literature. Some articles showed that antidepressant use was higher in urban environments (Leventhal Perek *et al.*, 2019). Another study found that rural individuals are at increased risk to suffer from depression than people living in urban environments (Wang *et al.*, 2019). The type and quality of urbanisation also influences mental health (Triguero-Mas *et al.*, 2015; Wheeler *et al.*, 2015). For Eur-Ant-SSP1 and Eur-Ant-SSP5, because urbanisation increases with environmental considerations and desire for better management, we concluded that antidepressants emissions decrease. In Eur-Ant-SSP4, because of the infrastructure inequalities and the lack of consideration for the environment, we concluded that antidepressants emissions increase.

- Economy

Economy development in Eur-SSPs increases gradually in SSP1 and is defined as a "high economy" in SSP4 and SSP5. An exploratory review showed that high economy in terms of high employment and job security is correlated with less antidepressant consumption compared to unemployed or employed with no job security (Buffel, Dereuddre and Bracke, 2015). For Eur-Ant-SSP1, we interpreted that gradual economy in a human-based society with high and security employments result in a decrease in antidepressant emissions. For Eur-Ant-SSP4, economic competition and low consideration for human well-being was translated as employment but with insecurity. We concluded antidepressant increases for Eur-Ant-SSP4, but also in Eur-Ant-SSP5 where we concluded that competition surpasses human consideration.

- Social participation and social cohesion

Social participation is high in SSP1 and SSP5 and low in SSP4. Similar projections were determined for social cohesion in European SSPs. High social cohesion (e.g. playing sport, social encounters) is associated with lower depressive symptoms and better mental health (Almedom, 2005; Wang *et al.*, 2019). An exploratory review also showed that society divergence and malicious regards to the mental health issue discourage individuals to take antidepressants (Jorm, Christensen and Griffiths, 2005; Lewer *et al.*, 2015; Park, Jang and Chiriboga, 2018). While impacts of social participation was not directly studied with respect to antidepressants, we considered that social participation and social cohesion are positively related. We concluded that antidepressants emissions decrease in Eur-Ant-SSP1 and Eur-Ant-SSP5 and increase in Eur-Ant-SSP4 based on social participation and social cohesion.

- Healthcare investment and healthcare access

In Eur-SSPs, human health investment and access is high for SSP1 and SSP5 and high for elites and medium for lower class for SSP4. In the literature, access and investment in healthcare was positively associated with antidepressant use and better mental health outcomes (McGorry *et al.*, 2007; Chisholm, 2015). We therefore concluded that antidepressants emissions increase in all Eur-Ant-SSPs.

- Education

In Eur-SSP1 and Eur-SSP5, education is high. In Eur-SSP4, the number of highly educated people decreases. Articles found in the exploratory review showed that antidepressant consumption was less for highly educated groups. Education in terms of culture was also found to be an influencing factor (Kivimäki *et al.*, 2007; Stierman *et al.*, 2015). "Open-minded" environments with less judgement and more cohesion were found to encourage individuals to seek help and accept antidepressant treatment (Gomez-Lumbreras *et al.*, 2019). High numbers of educated and, indirectly, high support for human development was translated into antidepressant emissions decreasing in Eur-Ant-SSP1 and Eur-Ant-SSP5 and, inversely, increasing in Eur-Ant-SSP4.

- Technology development

Technology development is “high, but not persuasive” in Eur-SSP1, “High in some areas; low in labour intensive areas” in Eur-SSP4 and “strong and crucial” in Eur-SSP5. For antidepressants emissions, technology development could cover improved wastewater treatment technology or shifts in antidepressant chemistry design (Ganesh *et al.*, 2021). Green chemistry encourages the development of less toxic molecules, for instance molecules that are less persistent or less bio-accumulative (Kümmerer, 2007). We concluded that because of high investments in technology development in Eur-SSP1, Eur-SSP4 and Eur-SSP5, antidepressants emissions decrease for all Eur-Ant-SSPs.

- Extreme droughts and floodings events

Droughts and flooding are increasing in Europe RCP 4.5, RCP6 and RCP 8.5 (Tabari *et al.*, 2021). The exploratory review showed correlations between extreme weather events and mental health (Nitschke *et al.*, 2011; To, Eboreime and Agyapong, 2021). Number of antidepressants prescriptions increases after floodings events (Motreff *et al.*, 2013; Milojevic, Armstrong and Wilkinson, 2017). We therefore concluded that antidepressants emissions increase under all RCPs considered.

Table 10 – Eur-Ant-SSP1, Eur-Ant-SSP4 and Eur-Ant-SSP5 antidepressant emissions scenarios for Europe for the year 2050 for each key drivers defined

SSPs drivers	SSPs sub-drivers	Eur-SSP1[1] and other SSPs	Eur-Ant-SSP1	Eur-SSP4[1] and other SSPs	Eur-Ant-SSP4	Eur-SSP5[1] and other SSPs	Eur-Ant-SSP5
Demographics	*Population Growth*	Relatively low growth [2]	↗	Low growth [2]	↗	Relatively low growth [2]	↗
Economy and lifestyle	*Inequalities*	Reduced across and within countries [2]	↘	High, especially within countries [2]	↗	Strongly reduced, especially across countries [2]	↘
Environment and natural ressources	*Urbanization*	High and well-managed [2]	↘	Medium with mixed urbanisation type across and within cities [2]	↗	High with a better management over time [2]	↗
Human development	*Economy*	Gradual (with hiccups at the beginning) [1]	↘	High [1]	↗	High [1]	↗
	Social participation	High for rich OECD countries [2]	↘	Low for rich OECD countries [2]	↗	High for rich OECD countries [1]	↘
	Social cohesion	High [1]	↘	Low [1]	↗	High [3]	↘
	Healthcare investment	High [3]	↗	High for elites, medium for lower class [3]	↗	High [3]	↗
	Healthcare access	High [2]	↗	Medium [2]	↗	High [2]	↗
	Education	High [1]	↘	High for elites, medium for lower class [1]	↗	High [1]	↘
Technology	*Development*	High, but no pervasive [1]	↘	High in some areas; low in labour intensive areas [1]	↘	Strong and crucial [1]	↘
Climate Change	Extreme events	RCP-4.5 to 6 : droughts and floods increase [3]	↗	RCP6 : droughts and floods increase [3]	↗	RCP-8.5 : droughts and floods increase [3]	↗

[1] Kok, K., Pedde, S., Gramberger, M. et al., New European socio-economic scenarios for climate change research: operationalising concepts to extend the shared socio-economic pathways. Reg Environ Change 19, 2019, 643–65

[2] Brian C. O'Neill, Elmar Kriegler, Kristie L. Ebi, et al., The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century, Global Environmental Change, Volume 42, 2017, Pages 169-180

[3] Tabari, H., Hosseinzadehtalaei, P., Thiery, W., & Willems, P. (2021). Amplified Drought and Flood Risk Under Future Socioeconomic and Climatic Change. Earth's Future

Step 3.2. Eur-Ant-SSP1, Eur-Ant-SSP4 and Eur-Ant-SSP5 storylines

Before developing the Eur-Ant-SSPs, the authors considered the interactions between direct and indirect drivers of antidepressants on a society. While scenario development focuses on emissions, the antidepressants exploratory review focussed only on indirect drivers related to consumption and usage. The development of the scenario narratives was conducted in accordance with the following assumptions:

- Key drivers including population growth, inequalities, economy, social participation, social cohesion, healthcare investment, healthcare access and education are indirect drivers of antidepressants emissions. These drivers are related to related to consumption and usage of antidepressants.
- Consumption of antidepressants impact antidepressants loads in wastewater and sewage treatment facilities. These wastewater and sewage treatment facilities can remove/decrease antidepressants emissions release in the natural environment.
- Capacities of wastewater and sewage treatment are related to technology development. Cities connectiveness of water systems is related to urbanisation. Technology development and urbanisation are therefore considered direct drivers of emissions.
- If there is no change in technological development, then an increase in antidepressants consumption would increase antidepressants emissions in the natural environment. Similarly, if there is no change in technological development, an increase in consumption would lead to an increase in emissions.

Eur-Ant-SSP1

In 2050 in Europe, social and environmental awareness shift the European societies towards human and environment development and sustainable management of resources like water.

Despite easy access to antidepressants due to healthcare investment, consumption of antidepressants is reduced because of a supportive society with high social participation and cohesion, high investment in education, and low inequality between individuals. Urbanisation and technologies increase in line with human and environmental desires for the more sustainable- and human- friendly societies. Because of the decrease in antidepressant consumption and investment in technological development, **antidepressant emissions in freshwater systems decrease.**

Eur-Ant-SSP4

In 2050 in Europe, despite a strong economy and high technological development permitting stable economic outcomes and a low unemployment rate, the consumption of antidepressants is high because of generally poor human well-being. Antidepressant usage is triggered by low human consideration in the society. The poorer population are more likely to take antidepressants because of high inequality in the society and low investment in education, making access to higher social status and good quality of life more difficult. Investment in wastewater technology does not counterbalance the high consumption of antidepressants. Consumption of antidepressants is exacerbated by increasing extreme climate weather events. **Emissions of antidepressants increase in freshwater systems** because of low human consideration in the societies.

Eur-Ant-SSP5

In 2050 the European societies shift toward economic and human development. Economy is boosted by innovation and technological development ensuring low labour-intensive work and a low unemployment rate. There is high social cohesion and participation between individuals, and education is accessible to all. Healthcare investments make antidepressants widely available but increasing human well-being and economic stability reduce the number of antidepressant consumers. Antidepressant consumption is, however, important for individuals who do not fit to the intensive society lifestyle based on performance and for individuals concerned about natural resources. Technology development is strongly based on fossil-fuel resources, provoking anxiety and stress for the portion of the population concerned about natural resources and extreme climate events. Overall, **antidepressants**

emissions decreased in freshwater systems because of high human well-being consideration in societies and innovation in wastewater technologies.

Step 4. Consistency check

Eur-Ant-SSPs outputs scenarios narratives as well as the results represented in Table 10 were repeated and verified to ensure consistency with results from the exploratory review and with Eur-SSPs storylines by the authors. When consistency was considered satisfactory, the output narratives scenarios were considered fully developed.

Insecticides emissions at European scale for 2050 (Eur-Ins-SSPs)

Insecticides are used in agricultural production for pest control and for minimizing risk of crop loss. They are regularly detected in surface water through runoff or groundwater contamination, exposing and affecting surrounding non-target organisms (Kreutzweiser *et al.*, 2007). Usage of insecticides is predicted to be correlated to agricultural practices and climate change (Kattwinkel *et al.*, 2011; Delcour, Spanoghe and Uyttendaele, 2015; Rhodes and McCarl, 2020). Global changes that are projected to occur over the next 30 years could have an effect on insecticide usage and, therefore, on emissions into the environment.

Step 1: Define characteristics of scenarios

- **What is the goal and purpose of the scenario?** To extend European Agriculture SSPs (Mitter *et al.*, 2020) to insecticide emissions coming from agricultural fields in order to envision multiple scenarios of insecticide emissions in European freshwater systems in 2050.
- **Which chemical or group of chemicals is being investigated?** Within the EU market, insecticides currently available, insecticides currently developed but not registered yet and future insecticides molecules developed under the green chemistry framework by Ganesh et al., 2021
- **Which environmental matrices are being considered?** European freshwater aquatic systems in rural areas

- **Spatial scale:** Europe
- **Temporal scale:** 2050
- **How many and which SSPs need to be explored?** European Agriculture SSP1 (Eur-Agri-SSP1), SSP4 and SSP5 will be extended to insecticide emissions (Mitter *et al.*, 2020). Eur-Agro-SSP1 was selected to study insecticide emissions in a sustainable society with rapid technological development. Eur-Agri-SSP4 was chosen because of inequalities between urban and rural populations and because policies supporting economic development that predominantly benefit the largest industrial companies. Last, Eur-Agri-SSP5 was selected to represent a liberal society with high investment in technology by private actors. Public environmental awareness is low and public financial support for farmers is low.
- **Which climate projections should be explored?** Climatic events such as increase in rainfall, temperature or pest pressure were found to be correlated to insecticides usage in the literature (Chen and McCarl, 2001; Grünig *et al.*, 2020; Rhodes and McCarl, 2020). Climate change is considered and integrated with RCP 4.5, 6 and 8.5 combined with Eur-Agri-SSP1, Eur-Agri-SSP4 and Eur-Agri-SSP5 respectively.
- **Targeted audience:** scientists from the climate change research community with eco-toxicologists, chemists and social scientists working at European scales
- **Type of scenarios:** tables with emissions trends for each key driver with qualitative storylines assessing the overall effects of the set of drivers for each scenario.

Step 2: Review and prioritisation of the potential impacts of changes in socio-economic and climate on chemical emissions

An exploratory review was conducted in order to define the dynamic between SSP drivers listed in Mitter *et al.,* 2020 and insecticides. Articles were kept if they confirmed the following statements: 1) the article focuses on change in trends in insecticides use/consumption; 2) the change in insecticides usage trends is related to a socio-economic, technological or climate change; 3) the article focused on Europe, a country in Europe or a society similar in socio-economic development as Europe. Twenty-five articles were reviewed and major findings are in Table 11.

Table 11 – Drivers studied and their impacts on insecticides in articles identified in the exploratory review

Category	Driver(s) studied in article	Article's findings	Source
Demography	Urbanisation	*Higher concentrations occurred in the central Pearl River Delta (China) with more urbanization level than that in the Pearl River Delta's surrounding areas. Relatively higher concentrations of legacy organochlorine pesticides and current-use insecticides were found in the residency land than in other land-use types, which may be attributed to land-use change under rapid urbanization.*	Wei et al., 2015
Demography	Urbanisation	*Wash-off potential of urban use insecticides on concrete surfaces.*	Jiang et al., 2010
Environment & natural resources	Environment	*Presence of a border crop of soybeans and neighboring crops (maize, eggplant and Chinese cabbage), both without weed control, increased invertebrate predator abundance, decreased the abundance of pests and dependence on insecticides, and increased grain yield and economic profits.*	Wan et al., 2018
Environment & natural resources	Land-use	*Since the use of pesticides can negatively impact the population of farmland birds via direct poisoning or, indirectly, by affecting food availability (seeds and insects) and habitat for breeding and foraging, practices that support integrated pest management and that minimise pesticide applications can potentially reduce those negative impacts*	Stanton et al., 2018; Chiron et al., 2014
Environment & natural resources	Land-use	*At the field level, agricultural intensification, reflected by increasing chemical inputs and field areas and decreasing crop diversity, leads to increased yield, whereas at the farm level, the spread of cropped areas results in a loss and fragmentation of natural and semi-natural habitats.*	OECD, 2019 ; Doxa et al., 2012
Human development	Food Demand	*Pesticides increased by 15-20-fold since the 60s to increase food production and respond to world food demand.*	Oerke, 2006
Human development	Education	*For underdeveloped countries like Pakistan a comprehensive and well planned program targeting on alternative pest control method and use of biological agents along with insecticides need to be initiated that can reduce the total dependency on chemicals.*	Id & Afsheen, 2021
Human development	Education	*Farmers' inadequate knowledge of pesticides, the influence of pesticide retailers and lack of access to non-synthetic methods of pest control are positively associated with pesticide overuse, while the propensity to overuse decreases with higher levels of education.*	Jallow et al., 2017
Human development	Consumption and Diets	*Vegetarian and vegan diets with an increased amount of organic foods may further improve upon the toxicity potential by removing conventionally-produced products and removing pesticides.*	Martin & Brandão, 2017
Human development	Consumption and Diets	*Assessment suggests that on average the complete life cycle environmental impact of nonvegetarian meals may be roughly a factor 1.5–2 higher than the effect of vegetarian meals in which meat has been replaced by vegetable protein. Although on average vegetarian diets may well have an environmental advantage, exceptions may also occur. Long-distance air transport, deep-freezing, and some horticultural practices may lead to environmental burdens for vegetarian foods exceeding those for locally produced organic meat.*	Reijnders & Soret, 2003
Human development	Consumption and Diets	*Using a quadrant analysis, a recommended diet was identified with a 38% lower pesticide toxicity footprint. This was achieved mainly through a reduction in the discretionary food intake and by limiting the choice of fresh fruits. As the latter contradicts dietary recommendations to eat a variety of fruits of different types and colors, we concluded that dietary change may not be the best approach to lowering the environmental impacts of pesticides in the food system. Instead, targeted action in the horticultural industry may be more effective.*	Ridoutt et al., 2021

Table 11 – (continued) Drivers studied and their impacts on insecticides in articles identified in the exploratory review

Economy	Economic Model	*Our analysis shows that a 1% increase in crop output per hectare is associated with a 1.8% increase in pesticide use per hectare but that the growth in intensity of pesticide use levels off as countries reach a higher level of economic development. However, very few high income countries have managed to significantly reduce the level of intensity of their pesticide use, because decreases in insecticide use at higher income levels are largely offset by increases in herbicide and fungicide use*	Schreinemachers & Prasnee, 2012
Technology	Technology Development	*While improved seeds increase pesticide, herbicide and fungicide use, mixed cropping and row planting generally reduce these practices. Moreover, mixed cropping moderately increases expected harvest while improved seeds and row planting have the reverse effect*	Onjewu et al., 2022
Technology	Technology Development	*Adoption of GM insect resistant and herbicide tolerant technology has reduced pesticide spraying by 671.4 million kg (8.2%) and, as a result, decreased the environmental impact associated with herbicide and insecticide use on these crops.*	Brookes & Brarfoot, 2018
Technology	Technology Development	*We also report increasing applied toxicity to aquatic invertebrates and pollinators in genetically modified (GM) corn and to terrestrial plants in herbicide-tolerant soybeans since approximately 2010.*	Schulz et al., 2021
Multiples	Land-use ; public policy	*Our results indicate that the direct impacts of agricultural land use changes on pesticide use in France have varied depending on the time period considered, reflecting the influence of public regulations, notably the compulsory set-aside policy in force during the 1990s, and market conditions, particularly the context of high prices for cereal grains at the end of the 2000s. Over the six years from 2008 to 2013, this index is roughly constant, indicating that the 17% increase in French pesticide use in 2013 compared to 2008 (as assessed from annual pesticide sales) cannot be even partially attributed to agricultural land use changes*	Urruty et al., 2022
Multiples	Land-use ; Economy	*Our analysis affirms that organic farming has large positive effects on biodiversity compared with conventional farming, but that the effect size varies with the organism group and crop studied, and is greater in landscapes with higher land-use intensity. Decisions about where to site organic farms to maximize biodiversity will, however, depend on the costs as well as the potential benefits.*	Tuck et al., 2014
Multiples	Land-use ; Consumption and diets	*This investigation showed that compliance with healthy eating guidelines leads to lower energy demand and a decrease in greenhouse gas emissions, largely due to a decrease in livestock numbers. Furthermore, arable land and grassland no longer needed for animal feed production becomes redundant and can possibly be used for the production of raw materials for renewable energy.*	Fazeni & Steinmüller, 2011
Multiples	Climate change ; Economics	*Increases in rainfall increases average per acre pesticide usage costs for corn, cotton, potatoes, soybeans, and wheat. Hotter weather increases pesticide costs for corn, cotton, potatoes, and soybeans but decreases the cost for wheat.*	Chen & McCarl, 2001
Multiples	Climate change ; Economics	*Climate factors influence fungicide, herbicide, and insecticide expenditures and that this influence is heterogeneous, varying in nature across crops and pesticide categories.*	Rhodes & McCarl, 2020
Multiples	Climate change ; Regulation	*In the absence of green house gases emission and pesticide externality regulations, climate change would not only increase agricultural production in the USbut also raise pesticide use and the external environmental and human health costs.*	Shakhramanyan at al., 2013
Multiples	Climate change; Land-use	*In the long-term, indirect impacts, such as land-use change driven by changes in climate, may have a more significant effect on pesticides in surface and groundwaters than the direct impacts of climate change on pesticide fate and transport.*	Bloomfield et al., 2006
Multiples	Regulations ; Public opinion ; Urbanisation	*Denmark, Sweden, the Netherlands and Germany have, or have had, a strong public and political interest for reducing the use of herbicides to control weeds in urban amenity areas and also have very strict regulations. The UK is currently undergoing a period of increasing awareness and strengthening regulation, while Latvia and Finland do not have specific regulations for weed control in urban amenity areas or on hard surfaces.*	Kristoffersen et al., 2008

Using the same methodology applied for the determination of key drivers for antidepressant emissions, ten experts on chemical emissions in academia were solicited to determine key drivers of insecticide emissions. Ten key drivers were considered as high priority by at least 70% of our expert panel: population growth, education, consumption and diet, land-use, policy orientation, technology development (including agricultural practices) and temperature, rainfall, extreme events and pest pressure regarding climate change (see Annexe 4.2). These drivers were studied exclusively in step 3 to develop insecticides emissions scenarios.

Step 3: Develop chemical emissions scenarios

An emissions trend (increasing, decreasing or both) was proposed for each prioritized driver. Each driver's individual future trend is presented in section 3.1 and Table 12, and output scenario storylines are presented section 3.2. As mentioned for Eur-Ant-SSPs, step 3 was developed by desk-based research conducted by the authors.

Step 3.1. Insecticides emissions trends by priority drivers in Eur-Ins-SSPs

Prioritised drivers of insecticide emissions selected in step 2 were studied individually using Eur-Agri-SSPs (Mitter *et al.*, 2020).

- Population growth

European population size is stable in Eur-Agri-SSP1 and Eur-Agr-SSP4 but increase in Eur-Agri-SSP5. Insecticides usage since the 60s has increased to increase food production and answer the food demand (Oerke, 2006). We considered that an increase population is positively correlated with food demand. Therefore, we concluded that insecticides emissions are stable in Eur-Ins-SSP1 and Eur-Ins-SSP4 and increase in Eur-Ins-SSP5.

- Education

In Eur-Agri-SSP1 and Eur-Agri-SSP5, education investment increases. For Eur-Agri-SSP4, education investment stays stable. Despite being conducted in countries outside Europe, the exploratory review showed low education for farmers and food producers was associated with over-consumption of pesticides (Jallow *et al.*, 2017). We considered that similar effects would occur in European countries. We concluded that insecticides emissions decrease in Eur-Ins-SSP1 and Eur-Ins-SSP5 and stays stable in Eur-Ins-SSP4.

- Consumption and diet

In Eur-Agri-SSP1, demand for meat and feed decrease. For Eur-Agri-SSP4 and Eur-Agri-SSP5, demand for meat and feed stay stable. One article in the exploratory review showed vegan or vegetarian diets decreases pesticides usage (Reijnders and Soret, 2003; Fazeni and Steinmüller, 2011; Martin and Brandão, 2017). There are many uncertainties between diet consumption and insecticide usage though. A decrease in meat demand means a shift towards vegetable and fruit crops. Meat production is usually associated with high antibiotic treatments while vegetables and food crops are associated with high pesticide treatment including insecticides (Ridoutt *et al.*, 2021). Our interpretations of European Agriculture SSPs and the exploratory review was that in Eur-Ins-SSP1 less demand for food and feed led to less insecticide usages and emissions. For Eur-Ins-SSP4 and Eur-Ins-SSP5, insecticides emissions stay stable because the food demand stay stable.

- Policy orientation

The relative importance of agri-food policy increases in Eur-Agri-SSP1, stabilises in Eur-Agri-SSP4 and decreases in Eur-Agri-SSP5. Regarding these policies, the socio-environmental focus increased in Eur-SSP1 and stabilizes in Eur-Agri-SSP4 and Eur-Agri-SSP5. For Eur-Ins-SSP1, we concluded that utilisation of insecticides is regulated and limited, therefore emissions decrease. In Eur-Ins-SSP4, the stable agri-food policies and socio-environmental focus was translated as meaning no or limited actions are taken for the regulation of insecticides probably due to a lack of interest in environmental topics in the society. Therefore emissions increase in Eur-Ins-SSP4. Similarly, in Eur-Ins-SSP5, the decrease of agri-food policies means a free-market with no chemical regulations so insecticide emissions increase.

- Land-use

Multiple aspects of land-use are covered in Eur-Agri-SSPs: land productivity, resource depletion and resource use efficiency. In all scenarios considered here, land productivity increases. In Eur-Agri-SSP1, resource use efficiency increase and resource depletion decrease. In Eur-Agri-SSP4, resource use efficiency and resource depletion increase. In Eur-SSP5, resource use efficiency stabilizes and resource depletion increase. In our exploratory review, land use and pest management can reduce pesticides usage but is usually correlated to public policies and economic investments (Tuck *et al.*, 2014; Urruty *et al.*, 2016). We interpreted that in Eur-Ins-SSP1, insecticide emissions decrease because of conscious and well managed land and water resources, leading to increased food productivity. Conversely, in Eur-Ins-SSP4 and Eur-Ins-SSP5, insecticide emissions increase due to increased food productivity while resources are mismanaged and resource depletion increases.

- Technology Development and agricultural practices

In Eur-Agri-SSP1 and SSP5, the speed of agricultural technology development increases alongside an increase technology uptake in agriculture and an increase technology acceptance by producers and consumers. In Eur-Agr-SSP4, the difference is that technology acceptance by producers and consumers stabilizes. Technology development like GMO was said to reduce pesticide and insecticide utilisation in one article while another article stated the opposite in the exploratory review (Brookes and Barfoot, 2018; Schulz *et al.*, 2021). For Eur-Ins-SSP1, the general interest in social and environmental topics in the society means that technology developments are aimed at the reducing chemicals emissions. For Eur-Ins-SSP5, increasing investments in technical infrastructure for technology developments and technological innovations brings agricultural practices that do not require insecticides usage (e.g. indoors farming; connected farms). Therefore insecticides emissions decrease. For Eur-Ins-SSP4, we concluded that insecticides emissions increase because technology development benefits large, industrialized farms that do not have an interest in chemicals usage, but mostly focuses on low-emissions technology and nitrogen efficiency (Mitter *et al.*, 2020).

- Rainfall, temperature, extreme events and pest pressure

In the RCPs 4.5, 6 and 8.5, the climate events of temperature, rainfall, pest pressure and extreme events are increasing (Tabari *et al.*, 2021). Articles found in the exploratory review showed climatic events have a significant effect on pesticide costs depending on the type of crops. Increases in temperature, rainfall and extreme events lead to increased pesticide costs for most of the crops. The increasing costs were justified by altered pest treatments, which resulted in increased usage and increased application of pesticides (Chen and McCarl, 2001). The magnitude will depend on the type of crops, the sub-category of the pesticides and, for few cases, are location-specific (Rhodes and McCarl, 2020). Therefore we concluded that for most crops, increase temperature, rainfall, pest pressure and extreme climatic events lead to increase insecticides emissions. Insecticides emissions increase in all Eur-Ins-SSPs.

Table 12 – Eur-Ins-SSP1, Eur-Ins-SSP4 and Eur-Ins-SSP5 insecticides emissions scenarios for Europe for the year 2050 for each key drivers defined

SSPs drivers	SSPs sub-drivers	Eur-SSP1[1] or Global SSP1[2]	Ins-Eur-SSP1	Eur-SSP4[1] or Global SSP4[2]	Ins-Eur-SSP4	Eur-SSP5[1] or Global SSP5[2]	Ins-Eur-SSP5
Demographics	*Population Growth*	Relatively low growth [2]	↗	Low growth [2]	↗	Relatively low growth [2]	↗
Human Devlopment	Education	High [1]	↘	High for elites, medium for lower class [1]	↗	High [1]	↘
Economy and Lifestyle	Consumption and diet	Low growth in material consumption, low-meat diets, first in high income countries [2]	↘	Elites: High consumption life, Rest: low consumption, low mobility [2]	↗	Materialism, status consumption, meat-rich diets [2]	↘
Environment and Natural Resources	Land-use	Strong regulations to avoid environmental trade-offs [2]	↘	Highgly regulated in High income countries[2]	↗	Medium regulations lead to slow decline in rate of deforestation [2]	↗
Policies and Institutions	Policy orientation	Towards sustainable development [2]	↘	Toward the benefit of political and business elite [2]	↗	Toward development, free market, human capital [2]	↗
Technology	Technology development and agricultural practices	Improvement in agriculture productivity; rapid diffusion of best practices [2]	↘	Ag productivity high for large scale industries, low for small scale industries [2]	↗	Highly managed, resource-intensive; rapid increase in ag productivity [2]	↗
Climate Change	Temperature	RCP-4.5 to 6 : Temperature increases [3]	↗	RCP- 6 : Temperature increases [3]	↗	RCP-8.5 : Temperature increases [3]	↗
	Rainfall	RCP-4.5 to 6 : Rainfalls increase [3]	↗	RCP- 6 : Rainfalls increase [3]	↗	RCP-8.5 : Rainfalls increase [3]	↗
	Extreme events	RCP-4.5 to 6 : Droughts and floods increase [3]	↗	RCP- 6 : Droughts and floods increase [3]	↗	RCP-8.5 : Droughts and floods increase [3]	↗
	Pest pressure	RCP-4.5 to 6 : Rising pest pressure [4]	↗	RCP-6 : Rising pest pressure [4]	↗	RCP-8.5 : Rising pest pressure [4]	↗

[1] Mitter, H., Techen, A. K., Sinabell, F., Helming, K., Schmid, E., Bodirsky, B. L., Holman, I., Kok, K., Lehtonen, H., Leip, A., Le Mouël, C., Mathijs, E., Mehdi, B., Mittenzwei, K., Mora, O., Øistad, K., Øygarden, L., Priess, J. A., Reidsma, P., … Schönhart, M. (2020). Shared Socio-economic Pathways for European agriculture and food systems: The Eur-Agri-SSPs. Global Environmental Change, 65, 102159

[2] Alessandrini, R., & Bodirsky, B. L. (2020). Food futures: Storylines of dietary megatrends along the Shared Socioeconomic Pathways (SSPs). Proceedings of the Nutrition Society, 79(OCE2)

[3] Tabari, H., Hosseinzadehtalaei, P., Thiery, W., & Willems, P. (2021). Amplified Drought and Flood Risk Under Future Socioeconomic and Climatic Change. Earth's Future, 9(10), e2021EF002295

[4] Grünig, M., Calanca, P., Mazzi, D., & Pellissier, L. (2020). Inflection point in climatic suitability of insect pest species in Europe suggests non-linear responses to climate change. Global Change Biology, 26(11), 6338–6349

Step 3.2. Eur-Ins-SSPs storylines

Before developing the Eur-Ins-SSPs, the authors considered the interactions between direct and indirect drivers of insecticides on a society. While scenario development focuses on emissions, the exploratory review focused mostly on indirect drivers related to consumption and usage. The development of the scenario narratives was conducted in accordance with the following assumptions:

- Socio-economics drivers (population growth, education, consumption and diet, land-use, policy orientation and technology development) are indirect drivers of insecticides emissions as they impact consumption and usage. Climate drivers (temperature, rainfall, extreme events and pest pressure) can have direct and indirect impacts on insecticides emissions.
- Because agriculture fields are open-systems and because there is no treatment of agriculture effluent, we consider that an increase in insecticides consumption/usage causes an increase of insecticides emissions in the surrounding environment.

Eur-Ins-SSP1

In Europe in 2050, social and environmental awareness encourages the usage of insecticides to be largely reduced. Consumers are educated on environmental problems and prefer buying products that do not require pesticides or insecticides. Farmers are encouraged financially and by new technologies to shift towards no or low pesticide and insecticide use in farming. Climate change does increase pest pressures but adaptation strategies are developed to avoid insecticide usage. **Insecticide emissions to freshwater systems decrease**.

Eur-Ins-SSP4

In Europe in 2050, agricultural policies are developed by the wealthy upper class. The larger portion of the population is not represented in public institutions. Policies and regulations are developed for the advantage of large, industrialized companies. Environmental issues like insecticide usage are considered low importance topics compared to social inequalities happening in the society. The large majority of individuals in the society are unaware of environmental problems related to insecticides. Climate change increases pest pressure and usage of insecticides is the only adaptation strategy available. **Insecticide emissions to freshwater systems increase.**

Eur-Ins-SSP5

In Europe in 2050, individuals are educated on environmental issues but technology is believed to be the solution to these issues. Investments in innovation and technology development in agriculture is high and towards new technology farming like connected or indoors farms. The free market 138hemi that there is no environmental policy, regulation or financial support to agriculture and food systems. A part of innovation and technology development reduces insecticides usage, but the pressure of climate change and the absence of regulations results in insecticides being the chosen adaptation solution to secure food production for the increasing population. Public awareness for the impact of insecticides in the environment is limited. **Insecticide emissions to freshwater systems increase.**

Step 4. Consistency check

Similar as for the development of Eur-Ant-SSPs, Eur-Ins-SSPs output narratives scenarios as well as the results represented in Table 12 were repeated and verified to ensure consistency with results from the exploratory review and with Eur-SSPs storylines. When consistency was considered satisfactory, the output narratives scenarios were considered fully developed.

13.2 Discussion

Comparison of our results with the literature was difficult because, to our knowledges, this represents the first attempt at developing future chemical emission scenarios. Nevertheless, possible change in antidepressants and insecticides emissions in the future have been studied in the literature. Articles usually focus on a single future situation. There is, to be best of our knowledge, no consideration of multiple alternative futures.

Human health or diseases was studied under the influence of climate change (McMichael, Woodruff and Hales, 2006; Epstein, 2009; Mills, Gage and Khan, 2010; Barrett, Charles and Temte, 2015). More specifically to antidepressants, similar dynamics between key drivers and antidepressant consumption or emissions were found in the literature. Antidepressant consumption was found to increase in the future because of climate change, and more specifically because of increase in floods and naturals disasters (Redshaw *et al.*, 2013). Projections of population size and gender was found to increase consumption by 61% by 2090 in a study conducted in the Netherlands (Van Der Aa *et al.*, 2011). Schlüsener *et al.*, 2015 found an increase of antidepressant consumption in the future due to climate change but concluded that demographic development and change in lifestyle was probably more important. In our scenarios, demographic change was considered to have a bigger impact on antidepressant emissions in the environment as well, but a lesser impact compared to human developmental drivers.

Regarding insecticides, usage and costs were found to increase under extreme weather events (Rhodes and McCarl, 2020), precipitation and rainfall (Chen and McCarl, 2001), pesticide efficacy (Matzrafi, 2019) and climate change and land-management (Kattwinkel *et al.*, 2011) in the future. The influence of technological change was debated in a study looking at pesticide efficiency: authors found that increased pesticide consumption could be related to pesticide decreases in efficiency. Consistent with our findings, change in molecule design could therefore play an important role in reducing pesticide consumption and, consequently, pesticide emission in the future (Matzrafi, 2019).

These studies are relevant to understand the influence of a single or few key drivers on a thematic focus. They are, however, less informative of future conditions as they do not consider a society as a complex system where socio-economics, technological and climate change interact and influence each over. They, by default, disregard current societal debates (e.g economics degrowth), actions (e.g. Fridays for Futures and Extinction Rebellion movements) on global change and their impacts on the society. Despite being uncertain, those societal dynamics should be included in future research. In our framework the society is considered as a whole. Socio-economics, technological and climate change drivers interact with each other and can be weighed against each other. In Eur-Ant-SSPs, human development drivers were considered to have the greatest impact on antidepressants emissions. For Eur-Ins-SSPs, land-use, policy and climate drivers had the greatest impacts on insecticides. This framework adapted from the methodology of Mitter et al., 2019 permits for the first time the study 140hemicall emissions in the future under the shared socio-economics pathways scenarios and in dynamic complex socio-economics societies. The framework is applicable to single molecules or groups of chemicals sharing similar features with an easily applicable methodology.

The two sets of scenarios developed demonstrates the ability of the framework to fit different chemicals. We studied antidepressants with an exploratory review of 23 relevant articles and insecticides, with 25 articles. Antidepressants and insecticides had 10 and 9 key drivers defined respectively. Population growth, technological development and education were key drivers in common for both examples. Our final scenario showed that antidepressants and insecticide emissions both decreased in SSP1 and increased in SSP4. SSP5 had opposite future trends: antidepressant emissions decreased while insecticide emissions increased. The reason is that human development and wellbeing are highly emphasised in SSP5 (which decrease consumption of antidepressants), but environmental regulations and financial investment in the agricultural sector are low due to a desired-liberal society (which increase insecticide usage). Moreover, the impact of climate change is more relevant to insecticide usage and socio-economic trends do not permit an overall reversal of insecticide emissions trends. For Eur-Ins-SSP1, climate change makes the reduction of insecticide usage difficult but is compensated by socio-economic trends.

Scenario development, whether it is for the development of single future trends for each key driver or for the development of storylines, involves uncertainties. There are more uncertainties when literature is limited and when there are multiple sources of chemicals in the environment. For future chemical scenarios, we recommend involving experts and shareholders to discuss the thematic focus and to develop scenarios. Involvement of shareholders from academia, regulatory agencies, and industry is highly encouraged in all steps of the framework. Depending on scenario developers' financial and time resources, experts' judgement can be collected by various methods from surveys sent online to individual interviews where the thematic focus can be discussed in detail. Note that involvement of experts and shareholders also introduces other challenges, for instance, motivate shareholders' participation or maintain this motivation (Alcamo and Henrichs, 2008; Mcbride *et al.*, 2017).

To evaluate our output scenarios, we used the six quality criteria (plausibility, consistency, salience, legitimacy, richness and creativity) proposed by Mitter *et al.,* 2019. These quality criteria were developed to enhance plausibility and consistency with other scenarios. Plausibility of our scenarios is established by the systematic review. Incorporation of the systematic review ensures the storyline is consistent with evidence-based results. Consistency with global SSPs or other scenarios is ensured by the inclusion of these scenarios' outputs within the scenario development. European SSPs or Global SSPs outputs were directly considered on the future of the thematic focus, ensuring consistency with their storylines. Salience, defined as social and/or political relevance of the output scenarios is possible with the characteristics of scenarios wanted in step 1. A scenario's characteristics should focus the framework on a defined goal to ensure salience. Output scenarios should then relate to a specific context within the chemical sector, which would ensure their utility to the targeted audience. Richness of the scenario is emphasized by the consideration of all global SSP drivers in the systematic review covering socio-economic, technological and climate drivers. Inclusion of expert's judgements largely increase richness of the output scenarios with the inclusion of expertise and opinions on the thematic focus. Legitimacy, defined as the inclusion of multiple stakeholders and multiple visions, will depend on scenarios developers' resources and time. In the scenarios we developed, we solicited academic experts for the determination of key drivers, but, as mentioned before, involvement is encouraged in all steps of our framework. The final quality criteria is creativity. Creativity is limited in our framework. The structural approach of linking already defined SSPs drivers to a thematic focus and including results from previous studies restricts out-of-the-box thinking. As mentioned in Mitter et *al.,* 2019, trade-off between quality criteria can happen. In our framework, plausibility and consistency are prioritised over creativity.

A key step in the process of scenario development is comprehending the current situation. This requires the understanding of the past and current trends in chemical release and occurrence. However, the data needed to assess chemical emissions (e.g. production, consumption and trade) are limited to select regions of the world and are often only available for select groups of chemicals such as pharmaceuticals and pesticides. Where data does exist, this is often commercially sensitive so is not always freely available. There is a need to generate data on chemical usage in regions where these data do not exist and for increased data transparency so that researchers can more easily access existing datasets. Access to improved emissions data will facilitate the development of chemical emissions scenarios and, subsequently, support the development of mitigation and adaptation strategies to avoid the negative impacts of chemicals in the future.

In the next chapter, the framework is enhanced and used to forecast antibiotics emission in European freshwater systems in 2050.

Chapter 6: Antibiotics emissions scenarios under 3 European SSPs: Eur-SSP1, Eur-SSP4 and Eur-SSP5

6.1 Introduction

In the last chapter, a framework to extend already existing SSP scenarios to chemical emissions was developed and illustrated using two proof of concept case study groups of chemicals. In this Chapter, the SSP Scenario/Chemicals emissions approach is extended and applied to antibiotic emissions ; a group of molecules highlighted of concern in Chapter 3. The development of scenarios for the most toxic metal identified in Chapter 3 (aluminium) was attempted but limited time and level of engagement from experts in this area, it was not possible to develop future emission scenarios for metals. This limitation is further discussed in the discussion section.

The framework in this chapter is enhanced. First, a system diagram is created based on the results of systematic review of step 2 of the framework. The system diagram is a visual representation of complex and numerous interactions of socio-economic, climate and technological drivers on chemical emissions. System diagram helps to identify feedback loops and societal mechanisms (e.g. regulatory mechanism) within the system: this allows the comprehension of how the system works (here, what is the pathways of chemicals emissions to freshwater bodies) and study how the system could change with socio-economics, climate and/or technological changes. System diagrams are frequently used in future scenario development research, policy making and business planning to visualise complex systems, develop future strategies and to communicate (Ghaffarzadegan, Lyneis and Richardson, 2011; Jetter and Kok, 2014). Second, experts are solicitated in this chapter to determine how chemicals emissions could be impacted in the future because of drivers' changes. This is interesting as experts' opinions can be compared.

Antibiotics are essential to fight bacterial and other microbial infections. Previous deadly diseases can now be cured through short antibiotic treatment (European Comission, 2017).

Despite clear benefits for human and veterinary health, high consumption of antibiotics leads to high antibiotic pollution in freshwaters systems which potentially contributes to the selection of antimicrobial resistance genes (AMR) worldwide (WHO, 2014). Antibiotic emissions with the development of antimicrobial resistance genes threaten global health and stability and potentially resulting in a future pandemic where antibiotics will not be efficient anymore (WHO, 2014).

Emissions of antibiotics into freshwater systems are thought to be causing harm to living organisms, on the stability of ecological systems and on the quality of water (Polianciuc *et al.*, 2020). These risks are expected to change in the future under global change. Societies are going though global changes (socio-economics, technological and climate change) that are affecting all aspects of our lives, including how chemicals are consumed (Retief *et al.*, 2016; Van den Brink *et al.*, 2018). For example climate change is affecting diseases patterns which, in turn, affects pharmaceutical demand (Redshaw *et al.*, 2013). At the same time actions are taken worldwide by regulators and industries to limit antimicrobial resistance genes. For example: in April 2023, the European Union adopted actions to combat antimicrobial resistance in a One Health approach; and the AMR Industry Alliance (more than 100 biotech, diagnostics, generics and research-based pharmaceutical companies and associations) is a taking a united front to promote sustainable solution to curb antimicrobial resistance genes (AMR Industry Alliance, no date; UE, 2023). However, global societal and climate change will impact emissions and risks of antibiotics to an extend that is currently unknown.

Therefore the aim of this chapter was to extend three Europeans-SSPs scenarios (Eur-SSP1, SSP4 and SSP5) to antibiotics emission scenarios for European urban freshwater systems in 2050 using an enhance version of framework developed in Chapter 5.

6.2 Methods

Methodology used for scenarios development

To develop antibiotic SSP scenarios for 2050, the framework described in Chapter 4 was used.

Systematic reviews of antibiotics

A systematic review of the impacts of socio-economic drivers on antibiotic use and emissions within a socio-economics societies was conducted. The systematic review was conducted using the Web Of Science database using the following key words: (“surface water” or “freshwater”) AND (“urban” or “city”) AND (“influence” or “impact*” or “effects*” or “source*”) AND (“anthrop*” or “human*”) and (“Antimicrobial*” OR “antibiotics*”). For each article that was identified, the socio-economics drivers studied and its impacts on antibiotics was noted in an excel file. A list of key drivers was then developed for antibiotics.

System diagrams were developed to visualise key socio-economics drivers and pathways of antibiotics towards freshwater systems in urban environments. All drivers identified were placed on a virtual board. Relationship between drivers were determined based on the literature and dynamic of an European democratic society. Relationships were represented with arrows. Final system diagram was copied on diagrams.net.

Experts’ selection and participation

Seventeen experts were solicitated to collect their opinions on future impacts of socio-economics drivers on antibiotics . Four experts worked in chemical regulation and legislation, three in production companies, and ten in academia. The experts from academia specialized in antibiotics design development, antibiotics emissions, science behaviours, and/or were practitioners. Experts were identified using online research and via professional networks.

Three experts answered positively to participate to this research: Expert 1 is an advisor to an association of industries fighting AMR, expert 2 is an Associate Professor specialising in behaviour science and a UK Government advisor on antimicrobial resistance and prescription and last, expert 3 is a medical doctor and Research Professor in antibiotic resistance. Further information on expert’s background, past and present positions are available in Table 13.

Selected experts were contacted by email. Experts were asked to complete one excel table for each scenario developed. Tables had list of antibiotics key socio-economics drivers and how these drivers are expected to change under European SSPs storylines (Kok *et al.*, 2019). For each key driver, experts had to choose an impact on emissions (from very high decrease to very high increase). The expert was also asked to rank his/her level of confidence regarding his answers from 1 to 5: 1 corresponded to very low/no confidence and 5 to high confidence/ certainty. The level of confidence to a given answer was also collected. Tables sent are available in annexe 5.1.

Table 13- Background, past and current positions of experts participating to scenario development

Expert Number	Education	Past Position(s)	Current position	Home country
1	**- BSc Chemistry**	**- Chemist at a multinational pharmaceutical and biotechnology - Head of Environment, Health and Safety at multinational pharmaceutical and biotechnology**	**Advisor to an antimicrobial resistance industry alliance**	**USA**
2	**- BSc in Psychology - MSc Health Psychology - PhD Health Psychology**	**- Health Psychologist at Oxford University**	**- Associate Professor and Health Psychologist at Oxford University - Expert member of the UK Advisory Committee on Antimicrobial Prescribing, Resistance and Healthcare Associated Infection (APRHAI)**	**UK**
3	***not communicated***	**- Expert in Global Antibiotic R&D Partnership - Expert in National Mission on Healthcare-Associated Infections - Head of the Frencg Ministerial Mission for Infection Prevention and Antimicrobial Resistance**	**- Expert at WHO - Hospital Practioner - Research Professor at Université de Lorraine**	**France**

Output scenario development

Development of output scenarios with results from the systematic review and expert opinions followed the methodology described in Chapter 5. Briefly all experts' answers were compiled and analysed. The objective was to develop storylines that would represent the opinions of the three experts. Potential differences in opinions were resolved by more specific and detailed storylines elements. For example, differences in opinions for the impact of "technology development" could be resolved by the specification "technology development in WWTP antibiotics removal capacity and in antibiotics chemical design". If experts' opinions differed too greatly, then I made the final decision based on results of the systematic review and my interpretation of expert's answers. The overall impact on antibiotics emissions developed in the storylines were determined by myself based on the systematic review and expert opinions.

6.3 Results

Step 1: Goal and Characteristics of Europeans Antibiotics SSPs (Eur-Antibiotics-SSPs)

The characteristics of the European Antibiotics SSPs (Eur-Antibiotics-SSPs) were developed as follows:

- **Goal and purpose of the scenario:** Extend European SSPs (Kok *et al.*, 2019) to antibiotics emissions to envision multiple emissions scenarios emissions for 2050
- **Chemical and group of chemical focus:** Within the EU market, antibiotics currently available, antibiotics currently developed but not registered yet and future antibiotics molecules developed under the green chemistry framework by Ganesh et al., 2021
- **Environment matrices**: European freshwater aquatic systems
- **Number and selection of SSPs to extend:** European SSP1 (Eur-SSP1), SSP4 and SSP5 (Kok *et al.*, 2019). Briefly, Eur-SSP1 is a sustainable society with less resource intensive lifestyles, high human investment and high social cohesion. Eur-SSP4 and Eur-SSP5 are nuanced societies with high inequalities in human development and some environmental considerations in Eur-SSP4, and intensive lifestyle with high human investment and high environmental considerations for Eur-SSP5.
- **Climate change integration**: Climate change is considered and integrated with RCP 4.5, 6 and 8.5 combined with Eur-SSP1, Eur-SSP4 and Eur-SSP5 respectively.
- **Targeted audience:** scientists from the climate change research community like eco-toxicologists, chemists and social scientists working at European scale.
- **Spatial scale**: Europe
- **Temporal scale:** 2050
- **Type of scenarios**: tables with antibiotics trends for each key driver and qualitative storylines assessing the overall effects of the set of drivers for each scenario.

Step 2.1: Antibiotics systematic review and key socio-economics drivers

Fifty three articles were reviewed to identify socio-economics drivers that have an impact on antibiotic emissions in urban freshwaters systems. Five drivers were predominantly identified as major drivers of antibiotics consumption and emissions, namely: education, access to antibiotics, regulation, wastewater treatment plant connectivity and technology and design of manufactured antibiotics.

Increased education of clinicians, pharmacists, and consumers has been identified as a major driver for reducing antibiotic consumption (Huttner *et al.*, 2010, 2019; Tan *et al.*, 2018; Muloi *et al.*, 2019). Education encompasses here academic courses, specialized training, workshops, communication campaigns, and intervention strategies. Providing clinicians with education regarding antibiotic misuse, antimicrobial resistance (AMR), and the spread of AMR results in a decrease in antibiotic usage within hospitals and in prescriptions within general practices (Tan *et al.*, 2018; Muloi *et al.*, 2019). Similarly, education for pharmacists leads to a reduction in antibiotic sales, particularly in countries where prescriptions are not required for individuals to obtain antibiotics. For consumers, public campaigns addressing the unnecessary use of antibiotics have been effective in reducing consumption, particularly in high-income countries (Huttner *et al.*, 2010, 2019).

Easy access to antibiotics either online via unregulated pharmaceutical dispensers or directly from pharmacies in countries where prescriptions are not mandatory were found to increase antibiotic consumption (Anderson *et al.*, 2020). Similarly strict regulations, policies and enforcements for human and veterinary used decrease antibiotics consumption (Yevutsey *et al.*, 2017; Porter *et al.*, 2021).

Emissions of antibiotics in freshwater systems were driven by wastewater treatment plant connectivity and technology. Absence or low connectivity to WWTPs to collect wastewater results in increased antibiotic emissions(World Health Organization, 2021) Specific advanced technologies (e.g. advanced treatment processes, ozonation, UV-irradiation) were found to be more efficient to remove antibiotics from wastewater and therefore reduce antibiotic emissions into freshwater systems (Phoon *et al.*, 2020; Langbehn, Michels and Soares, 2021; T. Zhu *et al.*, 2021).

Technology development in antibiotic design and in advanced therapies shows great potential to drastically reduce antibiotic consumption. Reserve vaccinology, structural vaccinology, artificially designed bacterial outer membrane vesicles, antibiotic adjuvants are all new biotechnologies to treat and prevent bacteria that do not cause AMR (Tagliabue and Rappuoli, 2018; Micoli *et al.*, 2021; Z. Zhu *et al.*, 2021). Moreover research and development in the form of AI or other data technologies for surveillance, prevention, diagnosis and treatment could significantly reduce antibiotic consumption (Chindelevitch *et al.*, 2022).

Other drivers less studied were identified as drivers of antibiotics consumption or emissions including international cooperation, pandemics, access to clean water, sanitation and quality antimicrobials and diagnostics. For antibiotic emissions to the environment, other drivers included hydrological events, climate change and landfill leakage (Samreen *et al.*, 2021; Kumar *et al.*, 2023).

Step 2.2: System diagram

A system diagram was created to show sources and pathways of antibiotics emissions in an European urban systems (Figure 19). Main drivers identified in the systematic review are categorised into four areas: “antibiotics consumption” “societal organisation”, “city organisation” and “climate change”.

“Antibiotic consumption” represents the traditional system through which medicine sellers provide antibiotics to consumers. Medicine sellers rely on professional prescriptions and the availability of antibiotics. Antibiotics are sold and consumed by various actors, including individuals, individuals in health institutions, domestic pets, or livestock.

“Antibiotics consumption” and “city organisation” are linked by the management of consumed antibiotics and leftover medications. Consumed antibiotics and leftover medications can end up in city wastewater systems, landfills, or are directly released into freshwater bodies if improperly disposed of. Within wastewater treatment plants, antibiotics are released either as metabolisms or active ingredients in WWTP effluent or in WWTP sludge.

“City organisation” is connected to “Societal organisation” area by waste and wastewater regulations. “Societal organisation” area represents human development, policies and institutional, technological and demography drivers. For policies and institutional three main drivers were identified: medicines regulations, human development and environmental policies. Human development policies had impacts on access to health facilities, water and sanitation, health investment and professional and public education (human development drivers). Human development policies alongside with environmental policies had an impact on technology investment and consequently on technology development. Technology development was connected to the “antibiotics consumers” areas of the diagram by “antibiotics design/availability” and to “sewage and water systems” in the “city organisation” area.

Last, “climate change” considers four climate events: temperature change, extreme-weather events, floods and precipitations. “Climate change” drivers are connected to “population health” and to “antibiotics availabilities” in the diagram.

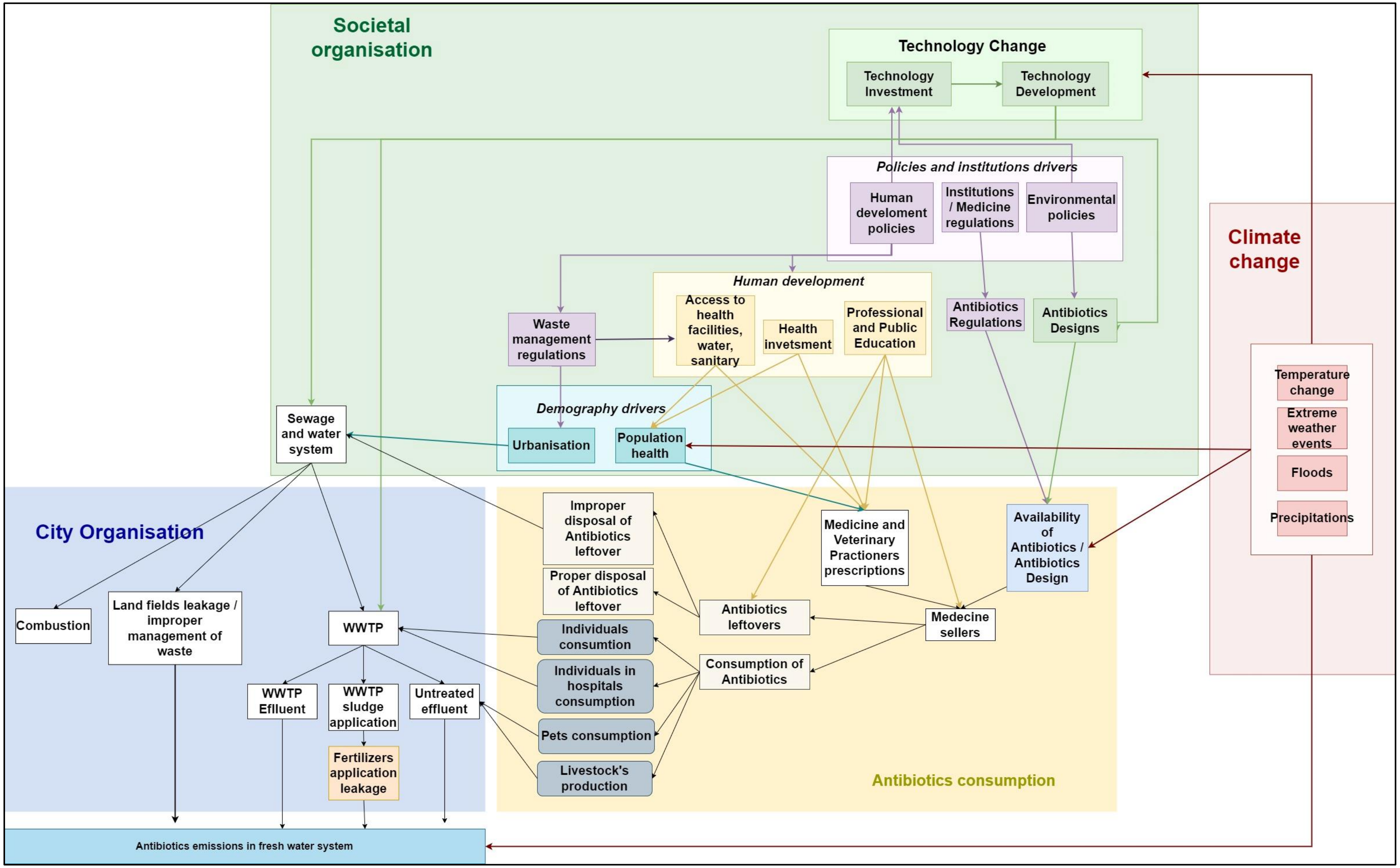


Figure 19 - System diagram depicting the emissions of antibiotics into freshwater systems. The diagram illustrates the connections between socio-economic drivers and the direct and indirect sources of emissions that contribute to the contamination of freshwater systems. The diagram is based on the findings of an exploratory review

Step 3: Present impacts of drivers on emissions of antibiotics under SSP1, SSP4 and SSP5

Based on results from the systematic review and diagram development, 11 key drivers were identified to focus on for antibiotics emissions scenario development, namely: precipitation, floods, temperature, extreme weather events, population growth, education, health investments, access to health facilities, environmental policies, regulations and quality of government and, lastly, technology development.

Three experts from industries and academia were contacted to study how the key drivers identified in step 2 will affect antibiotics emissions under Eur-SSP1, Eur-SSP4 and Eur-SSP5 (Kok *et al.*, 2019). The responses obtained and the level of confidence of the experts for each key driver are presented in Table 14.

The three experts agreed that increasing floods, temperature and extreme weather events would increase antibiotic emissions in Eur-SSP1/RPC2.6, Eur-SSP4/RCP6 and Eur-SSP5/RCP8.5. Because climatic events are more intense in Eur-SSP5/RCP8.5, the experts believe that antibiotic emissions could increase more in Eur-SSP5 compared to other scenarios. For increasing precipitation, the experts had different opinions. For all scenarios, expert 1 believed antibiotic emissions could slightly increase while for expert 3, emissions could slightly decrease. Expert 2 believed that precipitation in Eur-SSP1 could induce a small decrease in antibiotics emissions but result in a slight increase in Eur-SSP4 and Eur-SSP5. For experts 2 and 3, increasing precipitation could "wash-off" urban environments and lead to less bacterial infection and decrease antibiotic emissions. For expert 1, increasing precipitations could challenge WWTP capacity, increase the release of untreated wastewater into freshwater bodies and lead to small increases in antibiotics emissions.

The three experts agreed that high investments in human development (education, access to health and health facilities) could decrease emissions of antibiotics under Eur-SSP1 and Eur-SSP5. In SSP4 high health investments mainly benefit the elite: expert 2 and 3 believed that antibiotic emissions could slightly increase while expert 1 believed emissions could slightly decrease.

For policies and institutional change, experts 2 and 3 believed that high investments could lead to a strong decrease of antibiotics emissions in Eur-SSP1 and a medium decrease in Eur-SSP4. For expert 1, a focus on the environment and on sustainability in SSP1 was considered too broad to specifically address social and economic issues related to antibiotics emissions: policies change would lead to a small increase of antibiotic emissions for expert 1. For Eur-SSP4 however, expert 1 believed that because environmental policies are high in pockets, policy development could specifically target antibiotics emissions reductions and could lead to slightly decreasing emissions. All experts believed low environmental considerations and the business focus of regulations and quality of governance in SSP5 would lead to medium to strong increase of antibiotic emissions.

Lastly for technology development, the experts answers differed. For expert 2, technology development would lead to a small decrease of emissions under Eur-SSP1 and Eur-SSP4 and a medium decrease for Eur-SPP5. Experts 1 and 3 only gave answers for Eur-SS1 and Eur-SSP5. Expert 1 believed that high but not pervasive technology development in Eur-SSP1 would lead to a small increase in emissions but strong and crucial technology development in all domains in Eur-SSP5 would lead to a small decrease in emissions. Expert 2 believed the opposite: emissions would slightly decrease under Eur-SSP1 and slightly increase under Eur-SS5.

Expert 2 and expert 3 provided a level of confidence in their answers. Expert 2 considered that there were high uncertainties concerning the potential effects of drivers on antibiotics emissions and gave a level of confidence of 1 (very low confidence). Expert 3 had levels of confidence ranging from 2 to 4. Expert 3 had the highest level of confidence to propose a potential impact on antibiotics emissions for drivers of precipitation, access to health facilities, water and environmental regulations in Eur-SSP1 and precipitation and regulations and quality of governance in Eur-SSP4. In Eur-SSP5, expert 3 had a level of confidence ranging from 2 to 3.

Table 14 – Answers and level of confidence of three antibiotics experts for future emissions of antibiotics in European urban freshwater systems under Eur-SSP1 (panel a), Eur-SSP4 (panel b) and Eur-SSP5 (panel c)

(a)

			Expert 1		Expert 2		Expert 3	
Key drivers category	**Key drivers of antibiotics emissions in freshwater systems**	**Assumption on how the driver will change under Eur-SSP1**	**Effect on antibiotics emissions**	**Level of confidence**	**Effect on antibiotics emissions**	**Level of confidence**	**Effect on antibiotics emissions**	**Level of confidence**
Climate Change	Precipitation	Relatively small increase in Northerm Europe and small decrease in Southern Europe	+	*nd*	-	1	--	4
	Floods	Increase in Western Europe, decrease in Eastern Europe	++	*nd*	+	1	++	3
	Temperature	around 1.5°C above pre-industrial levels by 2050	+	*nd*	+	1	+	2
	Extreme Weather Events RCP2.6	Increase frequency and duration	+	*nd*	+	1	++	3
Demographic Change	Population Growth	Relatively low growth	+	*nd*	+	1	-	3
Human Development Change	Education	High investments	-	*nd*	-	1	-	2
	Health Investment	High investments	--	*nd*	--	1	--	3
	Access to health facilities, water, san	High investments	--	*nd*	--	1	---	4
Policies and Institutions change	Environmental Policies	High environmental investments	+	*nd*	---	1	---	4
	Regulations and quality of governanc	High quality with focus on sustainability	+	*nd*	--	1	---	3
Technology development	Development	High, but not pervasive	+	*nd*	-	1	-	2

Table 14 – (continued) Answers and level of confidence of three antibiotics experts for future emissions of antibiotics in European urban freshwater systems under Eur-SSP1 (panel a), Eur-SSP4 (panel b) and Eur-SSP5 (panel c)

(b)

Key drivers category	Key drivers of antibiotics emissions in freshwater systems	Assumption on how the driver will change under Eur-SSP4	Expert 1		Expert 2		Expert 3	
Climate Change	Precipitation RCP6	Small increase in Northerm Europe and small decrease in Southern Europe	+	*nd*	+	1	-	4
	Floods RCP6	Increase particularly in northern and central Europe	+	*nd*	+	1	+	2
	Temperature RCP6	around 2.4°C above pre-industrial levels by 2050	++	*nd*	+	1	++	2
	Extreme Weather Events RCP6	Increase frequency and duration	+	*nd*	+	1	++	3
Demographic Change	Population Growth	Low growth	+	*nd*	+	1	-	3
Human Development Change	Education	High investments for elites, medium for lower clas	-	*nd*	+	1	+	3
	Health Investment	High investments for elites, medium for lower clas	-	*nd*	+	1	+	3
	Access to health facilities, water, san	High investments for elites, medium for lower clas	-	*nd*	+	1	++	3
Policies and Institutions change	Environmental Policies	High in pockets	-	*nd*	--	1	--	
	Regulations and quality of governanc	High and effective	-	*nd*	--	1	-	4
Technology development	Development	High in some areas; low in labor intensive areas			-	1		

Table 14 – (continued) Answers and level of confidence of three antibiotics experts for future emissions of antibiotics in European urban freshwater systems under Eur-SSP1 (panel a), Eur-SSP4 (panel b) and Eur-SSP5 (panel c)

(c)

Key drivers category	**Key drivers of antibiotics emissions in freshwater systems**	**Assumption on how the driver will change under Eur-SSP5**	**Expert 1**		**Expert 2**		**Expert 3**	
Climate Change	Precipitation RCP8.5	Small increase in Northerm Europe and small decrease in Southern Europe	+	*nd*	+	1	-	3
	Floods RCP8.5	Increase particularly in northern and central Europe	+	*nd*	+	1	+	2
	Temperature RCP8.5	around 6°C above pre-industrial levels by 2050	+++	*nd*	++	1	++	3
	Extreme Weather Events RCP8.5	Increase frequency and duration	++	*nd*	+	1	++	3
Demographic Change	Population Growth	Relatively low growth	+	*nd*	+	1	-	3
Human Development Change	Education	High investments	-	*nd*	--	1	--	3
	Health Investment	High investments		*nd*	--	1	--	3
	Access to health facilities, water, san	High investments	-	*nd*	--	1	---	3
Policies and Institutions change	Environmental Policies	Low environment respect, with high 'not in my backyard	+	*nd*	++	1	++	3
	Regulations and quality of governanc	High quality with focus on businesses	++	*nd*	++	1	+	3
Technology development	Development	Strong and crucial	-	*nd*	--	1	+	2

Step 4: Present qualitative storylines for Antibiotics Europeans-SSP1, -SSP4 and -SSP5

Based on the systematic review of step 2 and the expert opinions collected in step 3, storylines were developed for Eur-Antibiotics-SSP1, Eur-Antibiotics-SSP4 and Eur-Antibiotics-SSP5. These are described below.

European Antibiotics SSP1

In 2050 in Europe, high environmental concerns within government and a high understanding of the threat of antimicrobial resistance genes will lead to strong policies and regulations to limit antibiotic emissions to the environment. Health investments will be high and are made particularly in least-developed Europeans countries and in isolated areas without access to good health facilities, clean water and sanitation. Practitioners are educated to limit unnecessary antibiotic prescriptions and individuals are informed on the necessity to "finish their treatments" and on how to dispose of unconsumed tablets. Governments encourage green technology development for new treatments that require fewer antibiotics and for the development and implementation of more effective wastewater treatment plants. At the same time policies are strong with strict regulations of the antibiotics markets and a reactive European surveillance system. Climate change events likes floods or extreme weather events increase the number of infections and therefore the demand for antibiotics but fast societal nd relevant adaptations capacities mean that overall, **antibiotic emissions strongly decrease** to European freshwater systems.

European Antibiotics SSP4

In 2050 in Europe, Governments are committed to solving the problems of environmental pollution and antimicrobial resistance through high investment in technology development. These high investments encourage green technology and green chemistry research, especially by businesses. Despite good technological strategies to mitigate antibiotics emissions, adaptation of societies and implementations of solutions is limited due to high inequalities in society. New wastewater technologies are implemented in a few areas only and new advanced treatment are costly and only accessible to a small elite group. The majority of the European population have medium access to health facilities, clean water and sanitation, which, alongside increasing climate change events, increase the number of bacterial infections and the consumption of antibiotics. Overall, **antibiotic emissions greatly increase** in European freshwater systems.

European Antibiotics SSP5

In 2050 in Europe, there is a strong faith in the potential for technology to resolve any human or environmental issue like antimicrobial resistance. Technology developments in wastewater technology or new advanced treatments that requires fewer antibiotics are strong and easily implemented within the society. There is high investment to increase human well-being which includes access to good health institutions, clean water and sanitation for all provided by strong institutions. Regulations does not play part as technology development is considered stronger on a free-market without institutional barriers. The environment degrades and the frequency and duration of climatic events increase with constant fossil fuels explanations. Despite strong technology development, the absence in regulations in a world where bacterial infectious diseases increase greatly makes that antibiotics consumption for human and veterinary used increased. Overall, **antibiotics emissions increase** in the European freshwater systems.

6.4 Discussion

The Eur-Antibiotics-SSPs developed in this chapter described plausible futures of how antibiotic emissions to European freshwater systems could change by 2050. Antibiotics were identified as priority compounds in chapter 4 and is part of the top 10 global health threat by the WHO because of antibiotics resistance genes (World Health Organization, 2021). In chapter 4, the risk quotient of antibiotics ranged from 1 to 10 in the cities of York, Madrid and Oslo. For Eur-Antibiotics-SSP1, the risk of antibiotics in freshwater bodies would decrease while for Eur-Antibiotics-SSP4 and Eur-Antibiotics-SSP5, risks would increase.

The different scenarios outcomes were explained by positive or negative causal loop identified in the systems diagram. For Eur-Antibiotics-SSP1, the combination of increased education of practitioners and general public, increased access to health facilities for all individuals and strong regulation and policies on antibiotics production, uses and disposal led to the decrease of antibiotics consumptions and emissions. For Eur-Antibiotics-SSP4 and Eur-Antibiotics-SSP5, despite high technology development, the emissions of antibiotics increased. This is because other societal changes need to happen alongside with high technology development to have a positive impact on antibiotics emissions. First, antibiotics technology development is financially unattractive for developers because of multiples characteristics of the antibiotics market: regulation limit sales; regulation can easily change; antibiotics become rapidly ineffective; treatments are brief; cheaper and better-reimbursed genetics flood the market when patent expired (Projan, 2003; Power, 2006; Mossialos *et al.*, 2010). Therefore research development companies need to be have tax or markets incentives to invest in antibiotics developments (Renwick, Brogan and Mossialos, 2015). Moreover social developments towards access to all for new technology development, clean water and sanitary are necessary. New antibiotics technology accessible only to a small elite part of the population would not permit a positive impact on antibiotics emissions. We argue here that technology development can have a positive impacts on antibiotics emissions only if economics and social development are co-occuring.

The participation of the three experts highlighted consensus and uncertainties in future antibiotics emissions trends. In Eur-Antibiotics-SSP1, experts agreed that increased human development in pair with high environmental policies and strong sustainable-orientated regulations would decrease antibiotics emissions. Similarly for Eur-Antibiotics-SSP4, experts agreed that human development for a limited elite class could not counterbalance the effects of increasing antibiotics consumption for the general population because of strong climate change, even with high technology development. For Eur-Antibiotics-SSP5, the potential power of technology development with climate change brought more uncertainties and cleavages between experts. For the development of UK-SSPs scenarios, UK-SSP5 was also the scenario were shareholders' confidence in impacts of technology development was the lowest compare to other scenarios (Pedde *et al.*, 2021).

Uncertainties are always part of scenarios development. Societal uncertainties that already existed in Global-SSPs and Eur-SSPs stay the same for Eur-Antibiotics-SSPs (Kok *et al.*, 2019; Mitter *et al.*, 2020). Uncertainties about impacts of socio-economics drivers were demonstrated by levels of confidence of experts. While expert 3 had more confidence in his/her answers, expert 2 believed that potential future impacts are mostly speculative and should be considered carefully. Expert 3 had more confidence for impacts of Eur-SSP1 drivers and had less confidence for impacts of technology development in all scenarios. A higher number of experts would have permitted more comparison.

Experts are essential to increase legitimacy, creativity, richness, horizontal consistency (consistency with higher-scale scenarios like Global SSPs) and salience (relevance of scenarios developed for the targeted audience) of scenario developed (Alcamo and Henrichs, 2008; Mitter *et al.*, 2019). Antibiotics scenarios were developed here based on literature review and on elicitations of experts. Participation is difficult to obtain as experts are not always eager or have only limited amount of time for scenario developers. In this study, opinions from experts were collected by completions of excel tables via email. This format was considered the most adequate to obtain answers in the limited amount of time of the thesis. This format however limited discussions and agreements on terms. For exchange, expert 1 interpreted "high quality of governance with focus on sustainability" as a driver that could increase antibiotics emissions because the term "sustainability" was too broad to include or target the threat of antimicrobials resistance gene. The focus on sustainability would actually, in his/her opinion, distract the governance from focusing on antibiotics emissions and microbials resistance. For expert 2 and 3, "focus on sustainability" term was definitely including microbials resistance and could decrease antibiotics emissions. A larger group with diverse antibiotics expertise would have logically permitted to include more opinions based on more expertise but another format would have been necessary (e.g. interviews, virtual workshop) to prevent different interpretations of terms and allow consistency in answers.

Regarding the methodologies, framework developed in Chapter 4 fitted well for the development of antibiotic emissions scenarios and was enhance by system diagram development and expert elicitation for future trends of antibiotics. The advantages of antibiotics and other pharmaceuticals is that, unlike other chemicals like metals or industrials addictive, the sources and pathways of pharmaceuticals towards freshwater bodies are easier to identify and have been agreed on by the scientific community. This mean that experts usually agree on the "baseline situation" and can easily discuss impacts of socio-economics drivers and how they could have in the future. Another attempt to develop similar scenarios for aluminium failed because of the numerous sources and items with aluminium in modern societies and multiples pathways of aluminium towards freshwater bodies. Development of aluminium scenarios using the same methodology was not possible. Group workshops would permit more direct discussions between experts and more possibilities to agree on "baseline situation" and impacts of socio-economics drivers. This was not possible with email contacts only.

Conclusion and recommendations

Key Findings

The aim of the work described in this thesis was to explore how the emissions of chemicals of concern in European urban aquatic systems might change in the future due to climate change and other global megatrends.

Initially, a systematic review was conducted to identify chemicals that have been measured in urban environments worldwide. More than 1 100 chemicals belonging to 19 class categories were identified across 110 urban environments. Comparisons between urban environments across continents and countries or across class categories was limited because of the large differences in the availability of monitoring data for each continent. Generally, more chemicals and more data were available for Western Europe, Central and Southern Asia and North America (Chapter 2).

In Chapter 3, a risk assessment of chemicals identified in the systematic review in Chapter 2 was conducted. The approach involved the comparison of measured concentrations for individual chemicals with predicted no effect concentrations to generate risk quotients. If an RQ exceeded one then the chemical was considered of potential concern. In total, 168 chemicals belonging to 16 class categories had an RQ above 1 in at least one urban environment and these were therefore considered priority chemicals. For 191 chemicals a risk quotient could not be calculated because of the lack of experimental and/or predicted toxicity data needed to derived Predicted-No-Effect- Concentrations. In terms of the number of priority chemicals identified by continent, Asia had 75 chemicals, Europe 67, Africa 46, North America 43 and South America 18. Seven class categories had chemicals with RQs above 1 000 namely PAHs, pesticides, metals, petrochemicals, sterols, PFCs and biocides. Six chemicals had risk quotients above 10 000, namely bifenthrin and cypermethrin (biocide), hexacosane and tricosane (petrochemicals), aluminium (earth elements) and benzo(b)fluoranthene and fluoranthene (PAHs). The risk assessment work also revealed that out of 118 urban environments initially identified on 6 continents, 74 had at least one chemical with an RQ above 1.

Building on the results from chapter 3, concentrations of two priority antibiotics and ten priority metals from the European priority chemicals list were monitored in rivers in York (UK), Madrid (Spain) and Olso (Norway) for one year (Chapter 4). Results showed that metals posed the highest risks in aquatic systems with aluminium, zinc, iron, copper, mercury and chromium systematically having RQ values above 1. Aluminium was the metal that posed the greatest risk with risk quotients exceeding 1 000 across all cities and locations. The antibiotics clarithromycin was also found to pose a potential risk although the risk quotient for this molecule was significantly lower than for aluminium (Chapter 4)

Chapter 5 and 6, looked to the future and developed a novel approach for forecasting future chemical emissions and then applied this to selected priority chemicals. The emissions forecasting framework was developed by adapting shared socio-economics scenarios (SSPs) to generate chemicals emissions scenarios (Chapter 4). The framework has 4-steps and allows the extension of already existing SSPs scenarios to single chemicals or groups of chemicals sharing similar features. In Chapter 5, the framework was then applied to explore how emissions of antibiotics to European freshwater systems could change by 2050. Experts from academia, industry and medical practice were involved in the determination of potential impacts of key drivers on antibiotics emissions for each SSP scenarios While experts did not always have the same opinions, Eur-SSP1, Eur-SSP4 and Eur-SSP5 were adapted based on their answers. Only one scenario (Eur-antibiotics-SSP1) showed a plausible decrease in emissions because of a combination of high education, high and easy access to health facilities and strong regulation/policies. In Eur-SSP4 antibiotics emissions increase primarily because of limited access to health facilities, clean water and sanitation for the majority of the population. In Eur-Antibiotics-SSP5, emissions are forecast to increase due to the strong impact of climate change, resulting in a higher prevalence of diseases that cannot be mitigated through technological advancements.

Implications for research

The work presented here contributes to advancing our understanding of the risks associated with chemical pollution in urban environments and highlights the insufficient research conducted on the potential impact of global change on these risks.

While an estimated 350,000 chemicals are available on the market, this study confirmed the presence of only 1,098 of these chemicals in urban environments. (Wang *et al.*, 2020) The diversity of chemical classes observed indicates that urban chemical pollution extends beyond pharmaceuticals or other active ingredients that have been primarily studied in the literature. Disparities in data availability were also noted between different class categories, as highlighted in Chapter 3, where obtaining ecotoxicity data for non-active-ingredient categories was more challenging or sometimes not possible. This thesis highlights the presence and concerns associated with chemicals from less-studied categories such as industrial chemicals, petrochemicals, and flame retardants.

Research in this thesis focusing on future chemical emissions in urban environments has the biggest implications in the field of freshwater ecotoxicity. Multiples risk assessments exist to manage chemicals, but none are considering global change (climate, technological and socio-economics change) as drivers that could change the future risk of chemicals. Here, we propose a framework that can identify the key socio-economic drivers of chemical emissions, identify virtuous circles of socio-economic development to reduce chemical emissions, and envision multiple scenarios of chemical emissions. Scenario development could be integrated into chemical risk assessment to further identify how the risks of chemicals could change in the future, determine the areas that could be most impacted, and identify the actors within society who could develop and apply mitigation actions.

Recommendations for policy makers

There are numerous chemicals risks assessments currently in place for different forms of chemicals management: management of global chemical pollution (e.g. Stockholm Convention, management of regional chemical pollution (e.g. ECHA), management of local chemical pollution (e.g. EU water framework), management of contaminated sites (e.g. UK Contaminated land regulations) and many others. These chemical risks assessments which aim at reducing chemicals pollution do not currently integrate global change or any potential change in the future. The research conducted in this thesis can be summarised with the following statements and recommendations for policy makers to enhance the precision and relevance of chemical risk assessments:

- It's crucial to recognize that global changes will impact chemical emissions and, consequently, future risks. While the risk for some chemicals may decrease, in most cases, it's likely that risks will increase.

- Currently, the impact of global change on chemical risk isn't taken into account in risk assessments. This means that chemical risk assessments will quickly become outdated and inefficient in safeguarding human and environmental health.

- Scenarios are commonly used in the private sector to explore multiple potential futures and anticipate future developments. Similarly, scenarios can be employed to anticipate various future chemical risks and adapt chemical risk assessments.

- In this thesis, a four-step framework has been proposed to develop multiple scenarios for plausible future chemical risks. These scenarios are built upon pre-existing socio-economic scenarios known as the Shared Socio-Economic Pathways scenarios (SSPs). The IPCC developed SSPs in 2017 to examine various plausible future scenarios in the context of global change.

- When integrate into chemical risk assessments, the output of these scenarios such as storylines, system diagrams, and images will aid policymakers in considering multiple potential future chemical risks and integrating them into assessments accordingly.

- In the author’s opinion, integrating scenarios in chemicals risks assessment is the best way to integrate the future and to develop relevant and precise chemical risk assessments on the long run.

Recommendations for further research

While this thesis provides important insights and tools for understanding the future risks of chemicals in urban environments, there is still much to do if we are really going to understand the future risks of chemical pollutants. Moving forwards, efforts should be made to build and extend this work by focusing on the following areas.

Generation of data on urban chemicals pollution profiles worldwide

The identification of chemical contaminants in cities, along with the sources and pathways of these contaminants towards freshwater bodies, is essential for studying future chemical emissions. The lack of chemical pollution data in developing countries hinders the identification of the baseline situation. More spatial and temporal data are necessary to understand chemical pollution in these regions and to develop appropriate adaptation and mitigation strategies.

Secondly, this PhD was based on measured concentrations of chemicals, which, by definition, excluded chemicals that current technology cannot measure. In Chapter 2, over 1,110 chemicals were identified in urban environments, indicating the presence of other chemicals in the water. Methodologies are needed to further analyse the broader profile of chemical pollution in urban environments. One approach could involve non-target analysis of chemical pollutants in water samples to obtain a more comprehensive and detailed profile of chemical pollution in cities.

Another possibility is the development of exposure models to predict concentrations of chemicals in urban environments across the world. Models offer a real opportunity to obtain quantitative concentrations without the need to sample water or analytical materials. A range of river models are available but these have been typically developed for catchments in Europe and North America. There is a need to extend these models to other regions of the world. If they are to provide accurate predictions, these models also require good input data e.g. on product sales, prescriptions, or information on the chemical proportion in final products. Obtaining such data for certain categories like industrial chemicals, PFCs, or additives can be extremely challenging.

If a comprehensive profile of urban chemicals can be developed (with measured or predicted concentrations), then it should be possible to identify key pathways and sources of these contaminants within urban environments. Successful source apportionments from environmentally measured concentrations in urban environments have already been achieved for metals (Comber *et al.*, 2014). This would enable a better analysis of current and future chemical pollution in freshwater systems.

Improved prediction and methodologies for single chemical and chemical mixture risk assessment

When it comes to chemical prioritization, methodologies should be developed to prioritize chemicals with little or no measured or predicted toxicity data. In this thesis, over 190 chemicals could not be prioritized due to a lack of data and the fact that they were outside the prediction domain of existing models. While experimental toxicity testing is not desirable due to the need for live animals and the impracticality of testing thousands of chemicals, the development of improved in-vitro approaches and predictive toxicity models could provide a solution. Advances in *in-vitro-to-in-vivo* extrapolation (IVIVE), machine learning or could enable the prioritization of a larger number and more diverse chemicals (Mangold-Döring *et al.*, 2022; Stadnicka-Michalak and Schirmer, 2022; Wu *et al.*, 2022). Furthermore, methodologies to prioritize chemical mixtures containing chemicals from different class categories would allow for better risk assessment for aquatic species that are constantly exposed to chemical mixtures.

Improved forecasting of chemical emissions with socio-economics scenarios

While this thesis has provided a framework for chemicals emissions forecasting, the application of this framework to priority chemicals was inhibited by a lack of stakeholder engagement – particularly for the metals.

Improved approaches to engage stakeholders in emissions forecasting are needed. Experts may be hesitant to provide opinions on topics they consider to be outside their expertise, particularly when it involves the future. Methodologies should be developed to involve stakeholders based on the possibilities for expert involvement and the output required by scenario developers. The format of in-person workshops has proven to be highly effective in achieving consensus and reducing uncertainties within scenarios. However, this type of format requires organizational time, financial support, and the availability of experts. Questionnaires and interviews can be easily developed, but they do not allow for direct conversations between experts. Therefore, other innovative formats, possibly specific to chemical emissions, should be developed.

Second, the use of SSPs for chemicals emissions scenarios should not be limited to qualitative scenarios. As recently developed for the UK-SSPs, semi-quantitative trends scenarios over time should be developed (Pedde *et al.*, 2021). With stakeholder, the elaboration of semi-quantitative trendlines enriches storylines and provides better visualisation for decision-making. Semi-quantitative scenarios can also be used as baseline for model developments.

The Shared Socio-Economic Pathways (SSPs) should be used more generally in future chemicals emissions. Socio-economic and technological changes should be given equal consideration to climate change, as they can equally have significant impacts. To facilitate the seamless integration of SSPs, methodologies should be developed for easy implementation in various domains of future chemical research, while also being applicable to chemical risk management directly.

Forecasting future urban chemical pollution is highly challenging. Not only do we lack knowledge regarding current chemical emissions and their associated risks, but it is also crucial that we recognise the impacts of global megatrends on chemical use, emissions, fate and risks shift and anticipate various scenarios of chemical pollution in the future. The research presented in this thesis provides a method to combine environmental and social sciences for the development of future chemical emissions scenarios. The approach developed should now be integrated into chemical risk assessment practices to ensure that chemical risks are minimised in the future while ensuring that society is able to benefit from access to chemical products.

Appendix

Annexe 0.1: A shared socio-economic pathway based framework for characterising future emissions of chemicals to the natural environment

Futures 144 (2022) 103040

Contents lists available at ScienceDirect

Futures

journal homepage: www.elsevier.com/locate/futures

A shared socio-economic pathway based framework for characterising future emissions of chemicals to the natural environment

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ARTICLE INFO

Keywords:
Scenario development
Chemicals emissions
Global change
Future
Shared socio-economics pathways (SSPs)
Representative concentration pathways (RCPs)

ABSTRACT

Chemicals are used in all aspects of our lives and are either intentionally or unintentionally released into the natural environment, leading to chemical pollution which negatively effects biodiversity and ecosystem and human health. The world is going through socio-economic, climate and technological changes that will affect chemical emissions to the natural environment but the extent of these affects is unknown. Scenarios of future chemical emissions are therefore needed to inform research and policy decisions to protect the health of humans and ecosystems into the future. In this article, we present a framework, based on Shared Socio-economics Pathways (SSPs) in combination with Representative concentration pathways (RCPs), to develop future chemical environmental emissions scenarios for single molecules or groups of chemicals sharing similar features. The framework has 4 steps: 1) determination of the characteristics of the scenario; 2) review and prioritisation of socio-economics and climate drivers; 3) development of scenarios; and 4) consistency checks. The framework is demonstrated for antidepressant and insecticide emissions into European freshwater-systems in 2050. Output narratives provide multiple pathways of chemical emissions in the future and can be used by researchers, regulators, politicians, governments, and the private sector to develop mitigation and adaptation strategies to chemical pollution issue.

1. Introduction

Chemicals are used in all aspects of our lives including as pesticides in agriculture, pharmaceuticals for health care, preservatives for processed food, personal care products for hygiene and well-being, and flame-retardants for textiles (CEFIC, 2021). During production, usage, and disposal, chemicals are released into the environment either intentionally e.g. via the application of agrichemicals to crops or unintentionally e.g. via urban run-off or from wastewater effluent when chemicals are not effectively removed by wastewater treatment plants (WWTP) (Burns et al., 2018; Domercq et al., 2018). The negative effects of chemicals in the environment

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https://doi.org/10.1016/j.futures.2022.103040
Received 15 July 2021; Received in revised form 16 September 2022; Accepted 22 September 2022

are well documented including: depletion of the ozone layer by compounds used as refrigerants; feminisation of fish by endocrine disrupting chemicals; selection of antimicrobial resistance by antibiotics; accumulation of heavy metals in fish tissues; and biomagnification of brominated compounds through food chains resulting in human exposure via the diet (Aslam et al., 2018; Baldigo et al., 2006; Dong et al., 2014; Roy et al., 2018; Thompson & Darwish, 2019; Zhang et al., 2018). The effects of chemical pollutants could alter in the future as a result of societal changes in response to global megatrends such as climate change and urbanisation (Balbus et al., 2013; Hader et al., 2022; Redshaw et al., 2013). However, the extent of changes in emissions, which will drive the effects, is currently unclear.

Chemical consumption has doubled in volume in the last decades (United Nations Environment, 2019). This increased usage has resulted in a range of benefits. For example, advances in the development of medicines, technology and health care have drastically modified the world. The number of people suffering from hunger, poverty and disease has reached unprecedented low levels and, for the wealthiest countries, living standards have never been higher (United Nations Development Programme, 2019). However, societal changes happen rapidly and affect consumption and emissions of chemicals (Bunke et al., 2019) so in the future the use of chemicals will likely increase further.

For example, despite increased human development, the prescriptions and consumption of antidepressants are continuously increasing in developed countries and are expected to be exacerbated by natural disasters in the future (Exeter et al., 2009; Gualano et al., 2014; Olié et al., 2002; Redshaw et al., 2013; To et al., 2021). Pesticides have experienced a rapid shift in usage in the last 60 years. Pesticides use has increased by 15–20-fold since the 60 s to increase food production and respond to global food demand (Oldenkamp et al., 2019). Because they are very toxic chemicals which may affect human health and the environment, pesticides frequently receive negative media coverage in some public debate (Le Monde, 2022; Newsbeat, 2022; Rani et al., 2021). However the pressure to meet food demands for the 9 billion inhabitants predicted by 2050 (Finger, 2021; Popp et al., 2013) will mean that pesticide could continue to increase. Changes in consumption will lead to changes in emissions, exposure and risks to the natural environment. For instance, the risk posed by antibiotic ciprofloxacin to aquatic species has increased by 10–20 fold worldwide in twenty years because of increasing exposure (Oldenkamp et al., 2019). Future societal changes will therefore affect the number, the quantity and the diversity of chemicals and subsequently chemical risks in different ways.

Few societal changes have been studied to determine their impact on chemical emissions. Advanced technologies for wastewater treatment can decrease the load of chemicals released in water bodies (Fairbairn et al., 2018; Yaman et al., 2017); legislation and regulation can limit the number of compounds available on the market (van Dijk et al., 2020); chemical engineering can create genetically modified crops (GMO) that reduce the number and volume of fertilisers and pesticides used by farmers (Klümper and Qaim, 2014). At the same time, new chemicals designed to satisfy specific needs can also be more persistent and more dangerous for the environment (e.g. perfluorooctanoic acid); GMO crops can promote resistant pests that will require stronger and potentially more toxic pesticides (Van Acker et al., 2017). The societal changes (including socio-economic factors such as human development, urbanization, demographics change, inequalities, international agreements, economic growth, diets, etc) have not been studied altogether to estimate their potentials effects on chemical emissions for the future. Potentially important trends in future environmental emissions may be missed if all aspects of societal changes are not considered. This also means that mitigation and adaptation strategies to deal with future chemical pollution are based on incomplete evidence.

One approach to inform the research and management of chemical emissions in the future under global change is to use scenarios. Scenarios explore multiple alternative futures with the aim of evaluating strategies to respond to any potential adverse changes (Jones et al., 2015). A very influential set of recent scenarios are the representative concentration pathways -RCPs- (van Vuuren et al., 2011) and the shared socio-economic pathways -SSPs- (O'Neill et al., 2017), developed by the global climate change research community. The SSPs describe five contrasting socio-economics pathways with their abilities to adapt and mitigate to global change challenges. They are based on six categories: demographics, human development, economy and lifestyle, policies and institutions, technology and environment and natural resources. Each category is further detailed with SSP elements like, among others, population growth, fertility and urbanisation for demographics or education, health investment and equity for human development. For each SSP storyline, a socio-economic situation is described with variation of SSP elements (e.g. health investment is high under SSP1 and low under SSP3). They are meant to be used as baselines for climate change and sustainable development research. SSPs are made to serve the global climate change community, but they are also designed to be extended to multiple sectors and scales and improve consistency with all global change-related research. Different sectors and geographic scales, including land-use management in central Asia, European agriculture or more recently the United Kingdom, have downscaled scenarios based on the SSPs to explore the impacts of future climate conditions (Mitter et al., 2020; Nunez et al., 2020; Pedde et al., 2021). Scenario development and scenario extensions are a relatively recent area of research, but the number of scenario studies has increased rapidly in recent years. An article looking at achievements of the climate change scenario framework reported 1400 articles that used and/or developed scenarios based on SSPs since 2010 (O'Neill et al., 2020). Nevertheless, such scenarios have not yet been developed for emissions to the environment from the chemical sector.

Ideally, global SSP scenarios would be extended to all the chemicals within the chemical sector. The research community focusing on chemical emissions in the future could then work under the same storylines and extend those scenarios to more specific research questions if needed. To do so, key drivers and relevant scale for all chemicals must be defined. This is not possible as key drivers and relevant scale vary between and among groups of chemicals. A single set of narratives cannot adequately cover all chemicals because of the diversity of chemicals' physical and chemical properties, environmental behaviour, human usage and future needs for society.

To be able to study chemicals in the future, here, we present a framework, based on the socio-economic and climate scenarios (combined SSP-RCPs), for the development of scenarios for emissions of single chemicals or groups of similar chemicals to the natural environment in the future. 'Chemicals', being a heterogeneous group, do not have the same drivers of emissions and relevant study scales for all classes. A 'simple' extension of SSPs cannot, therefore be made, the thematic focus of scenarios developed must be for single chemicals or groups of similar chemicals. We therefore illustrate the approach for antidepressant and insecticide emissions in Europe in the 2050 s

Antidepressants and insecticides were chosen for multiple reasons. Their usage is reported to come from different drivers in the literature. On one hand, antidepressant usage is driven by sociodemographic drivers like education, social cohesion, inequalities and/or culture (Gomez-Lumbreras et al., 2019; Henriksson & Isacsson, 2006; Hiilamo, 2014; Lewer et al., 2015; Park et al., 2018). On the other hand, usage of insecticides can be driven by cultural practices (e.g. type of crops, crops rotation, conventional vs. non-conventional practices), regulations, technology development but also by consequences of climate change like increase temperature or increase rainfall (Bloomfield et al., 2006; Brookes & Barfoot, 2018; Meissle et al., 2010; Rhodes & McCarl, 2020; Wan et al., 2018). Consumption has consistently increased in the last 50 years and is expected to continue. However, looking at SSPs storylines, the changes in antidepressants and insecticides' emissions in the future are uncertain. Global changes that are projected to occur over the next 30 years could have an effect on antidepressant and insecticide consumption and, therefore, on emissions into the environment. These future emissions must be understood in order to assess future risk and mitigate their impacts.

Here we propose a four-step framework, inspired by the approach developed by Mitter et al. (2019) for the European agricultural sector, and apply it to antidepressants and pesticides to demonstrate the framework's utility as a tool to gain a better understanding of future chemical emissions and the way that societal change influences this future.

2. Methods

a group of eight scientists with expertise in scenario developments, in environmental sciences, in chemistry and in toxicology gathered to develop the following four-step framework to characterise chemical emissions in the future under the SSPs. The framework proposed is inspired by the methodology developed by Mitter et al. (2019) to European SSPs to Agricultural European SSPs and follow standard methodologies for scenario development (O'Brien, 2004; Priess & Hauck, 2014; Rose & Star, 2013; Rounsevell & Metzger, 2010).

2.1. Step 1: Define key characteristics of scenarios

The first step focuses on the determination of key characteristics of the scenarios required. This is an essential step to have a clear understanding of the specifications and boundaries of the scenarios, as well as to answer "why", "for whom" and "how" are those scenarios being developed. The following questions should be addressed:

- **What is the goal and purpose of the scenario**? the goal and purpose of the scenarios must be determined: Why are the scenarios needed? What are the questions we want to answer with the output from the scenarios?
- **Which chemical or group of chemicals is being investigated?** The chemical or group of chemicals for which the scenarios are to be applied should be defined. Multiple chemicals/molecules could be considered as one group of chemicals for scenario development if molecules have the same dynamics in the society, environmental behaviours and fates within the temporal and spatial scale chosen further in step 1. If a group of chemicals is to be considered, similarities in production, usage, consumption and environmental behaviours are mandatory. Here, we want to avoid selecting multiple chemicals that would be impacted by socioeconomic drivers in different ways, making the development of a scenario storyline for all chemicals included impossible.
- **Which environmental matrices are being considered?** Do the scenarios focus on air, water, or soil compartments? We recommend to only select one matrix as chemicals can behave differently in different environmental compartments.
- **What temporal scale is required?** Are the scenarios focusing on future of chemicals in 2030, 2050, 2100 etc?
- **What geographical scale is required?** Are the scenarios focusing on a city, a country or a continent? Urban environments? Urban environments in developed countries? A small geographical scale involves an easier understanding of the dynamics of the system, but literature can be limited on the system in question. Moreover large scale SSPs might be more difficult to extend because they are not specific enough for smaller scale systems. A large geographic scale has more chances to have available SSPs (e.g. Europe, United Kingdom), but the system might be more difficult to understand and to apply to a chemical or group of chemicals. Determination of temporal and spatial scale are necessary to define the system boundary in which scenario will be develop and should be primary determined by the goal and purposes of the scenarios.
- **How many and which SSPs need to be explored?** There are multiple SSPs that are available in the literature: global SSPs, European SSPs, water-sector SSPs, drought characteristics in China SSPs to cite a few (Graham et al., 2018; Kok et al., 2019; Riahi et al., 2017; Su et al., 2021). Depending on the characteristics of the scenarios wanted, the most relevant and logical SSPs should be selected for use. The number of scenarios can range from a minimum of two scenarios to five (all SSP scenarios). A single scenario should not be developed by itself, as it should be comparable to another.
- **Which climate projections should be explored?** The use of many chemicals will be affected by weather conditions such as temperature, moisture content and flood events. For the system of interest, therefore, projections of future weather patterns associated with the selected SSPs should be obtained to provide a foundation for identifying any climate-driven changes in chemical use during Step 2.
- **Who is the target audience**? The targeted audience can be climate change scientists, social scientists, regulators, industries, public, etc. The format of the scenarios and the level of detail should be relevant to the knowledge and needs of the targeted audience.

- **What will be the form of the scenario**? How will the scenario look: an infographic? a set of storylines? a table with increasing and decreasing chemicals trends? Output scenarios can have any format, but must be relevant to the scenario's goal, purpose and targeted audience.

2.2. Step 2: Review and prioritisation of the potential impacts of changes in socio-economic and climate on chemical emissions

In step 2, a combination of literature searching and expert elicitation is used to develop an evidence-base on how chemical emissions could change in the future. This analysis considers: a) the socio-economic changes expected for the selected SSPs from Step 1; and b) the effects of projected changes in weather patterns on chemical use. The findings from the systematic review are then used in an expert consultation exercise to select the most important future changes for chemical emissions which are then used as a basis for the emission scenario development in Step 3.

These drivers can be related to socio-economics elements (similar as SSP elements in O'Neil et al., 2017) or climate change elements (e.g. natural disasters, temperature). The idea here is to understand how the thematic focus is influenced in a society and to develop a list of drivers by conducting a systematic review. We recommend using the elements of the SSPs to extend chosen to extend in step 1.

To do the systematic review, we recommend using the elements of the SSPs initially chosen in step 1 to extend as specific search terms. The driver(s) and findings should be extracted from the articles. We found that the search terms "association", "impact", "influence", "effect" and "connection" might extend search results to a large number of relevant articles when looking for dynamic/ interactions between drivers and the thematic focus. Direct (e.g. leakage from production site; release from road runoff) and indirect drivers (e.g. consumption; outbreaks of diseases) should be considered in the systematic review.

For some chemicals, climate change driven effects will need to be considered alongside socio-economic driven effects. For example, use of UV-filter molecules in sunscreens might be expected to increase due to projected increases in hot and dry weather. Increased pest disease pressures resulting from changes in climate could alter the use of insecticides, herbicides and fungicides. As climate change has multiple possible future outlooks, selection of climate change scenario is needed. Representative Concentration Pathways (RCPs) provide estimations of plausible future changes in greenhouse gas emissions, that translate into a different range of temperature and precipitation outputs. We recommend using RCPs for climate change integration as SSPs and RCPs can be combined in a scenario matrix architecture (van Vuuren et al., 2017). These 'integrated scenarios' help to understand the combined effect of socio-economic change and climate change. Relevant RCPs and related climate change impacts should be chosen and integrated in the same way as SSPs in the scenarios.

Because not all aspects of a society have been researched with respect to chemicals, relevant literature is limited. To enrich the comprehension of the thematic focus dynamic in a society and the list of drivers of the SSPs to extend and the thematic focus should be analysed one by one. The elicitation of experts' judgement is encouraged. This allows the inclusion of multiple perspectives and opinions on the thematic focus in a society. Expert judgements can be solicitated in multiple ways (e.g. personal interview, group interviews, development of fuzzy cognitive map, survey) depending on cost and logistical limitations. If an SSP element is considered relevant to the thematic focus by scenario developers and/or experts, then it should be added to the list of drivers.

When the systematic review is done, prioritisation or determination of key drivers is recommended. Drivers (direct and indirect) do not have the same importance to the thematic focus. Two methodologies are recommended here:

- Scenario developers can conduct a qualitative synthesis based on literature review and, if applicable, experts' input to determine which drivers are key drivers for scenario development. A criterion could be 'a driver that influences the consumption of chemical "x" is more relevant than a driver influencing the production of "x"'.
- Experts' judgements can also be solicitated to define key drivers using the same methodologies as mentioned before. A survey to experts with specific questions (e.g. Do you consider this driver to have a high, medium or low influence on the thematic focus?) could be used to identify key drivers. Experts' time involvement is then limited, and experts are free to complete the survey on their own time.

2.3. Step 3: develop chemicals emissions scenarios

This step of the framework is focused on the development of scenarios. We recommend doing it in two parts. The first part is to focus on each key driver and each scenario at a time. The second part is to gather all the effects of drivers, consider the drivers' direct and indirect impacts on the thematic focus and propose an overall effect on the thematic focus.

For the first part, each key driver is studied individually. For each key driver, an impact on the thematic focus must be defined following 3 steps:

A. Gather outputs from the literature review and experts' judgements from step 2 for the chosen driver
B. Identify how the driver is said to change/be in the SSP to extend in step 1 (e.g. in SSP1, the world population increases until 2100)
C. Propose an impact of the driver on the chemical or group of chemicals. The impact could be qualitative (e.g. increase/decrease) or semi-quantitative (e.g. small/medium/high increase). The proposed-impact should be consistent with the findings from literature review and with how the driver is said to change/be in the SSPs. The reasoning should be rational. The following statements should be verified:
    1. The driver's proposed-impact is consistent with the findings on how the driver impacts the thematic focus in the literature review

2. The driver's proposed-impact is consistent with the literature review and with how the driver is said to change in the SSPs to extend
3. The proposed-impact can be explicate by rational thinking

For the second part, drivers direct or indirect impact on the thematic focus must be explained. For example: "*Changing population size does not have a direct impact on the emissions of chemical X in the environment, however changing population size impact consumption of chemical of X. Increase consumption of X is found to be positively correlated to emissions of X in the environment. Therefore for the development of our scenario we consider population size to be an indirect driver positively correlated to emissions of chemical X in the environment*" When all driver's impacts on the thematic focus are explicit, an overall effect can be proposed and presented in the format chosen on step 1.

2.4. Step 4: consistency checks

This last step aims to check consistency and to assure quality control of the developed scenarios. For this step, the scenario products developed are checked for consistency with the systematic review and with the SSPs. Consistency with the systematic review consists of verifying that a driver's dynamic in the environment and in the society are the same across the literature and scenario developed. For consistency with the SSPs, driver's evolution must be similar across SSPs chosen to extend in step 1 and in scenario developed (e.g. if population side increase in SSP1 chosen to extend, population side must decrease in the scenario developed). Conducting these consistency checks multiple times is essential for quality control of the scenario development process (Priess & Hauck, 2014). When time and financial resources permit, we recommend to conduct consistency checks with experts (Ernst et al., 2018; Mitter et al., 2019). Consistency checks can also be done by scenario developers by repeating and verifying step 3 multiple times.

2.5. Uncertainties

There are uncertainties when scenarios are developed. Uncertainties can arise around lack of system understanding of the thematic focus, on the thematic focus within a society and on the study of the future that is fully unknown.

In step 2, uncertainties can arise around lack of understanding on how chemicals behave in the environment or a society. This could be due to lack of data availability or literature on the chemical in question but also on the dynamics of a society. or general.

In step 3 of our framework, the SSPs' storyline and other products must be interpretated for the development of chemical emissions scenarios (e.g. population growth increases strongly). Vagueness and ambiguity of scenario terminologies make interpretations of SSPs different between researchers. Techniques to address these uncertainties can be to increase the number of scenarios to develop, to perform sensitivity analysis or to solicit experts (Gao et al., 2016; Rounsevell et al., 2021). The advantage of involving experts is to build consensus on uncertainties, but also to discuss and obtain diverse expertise on the chemical focus, allowing an improved understanding. Uncertainties should not deter the development of scenarios but should be considered in output scenario interpretations. (Fig. 1).

3. Results

The framework is illustrated for two case studies: antidepressants and insecticides emissions in European freshwater systems in 2050. The methodology followed is the same as the one presented previously except that exploratory reviews were conducted instead of systematic reviews. Moreover uncertainties on scenario developed were not investigated. The reasons are that fully developed scenarios for antidepressants or insecticides would require individual articles with more extensive reviews and engagement with experts. This does not impact the aim of this section which is to illustrate how the proposed framework can be applied.

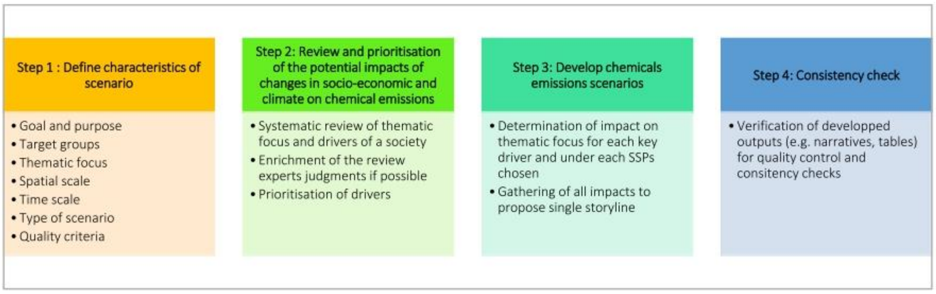

Fig. 1. Framework proposal to extend SSPs storylines to single chemicals emissions or group of chemical sharing similar features.

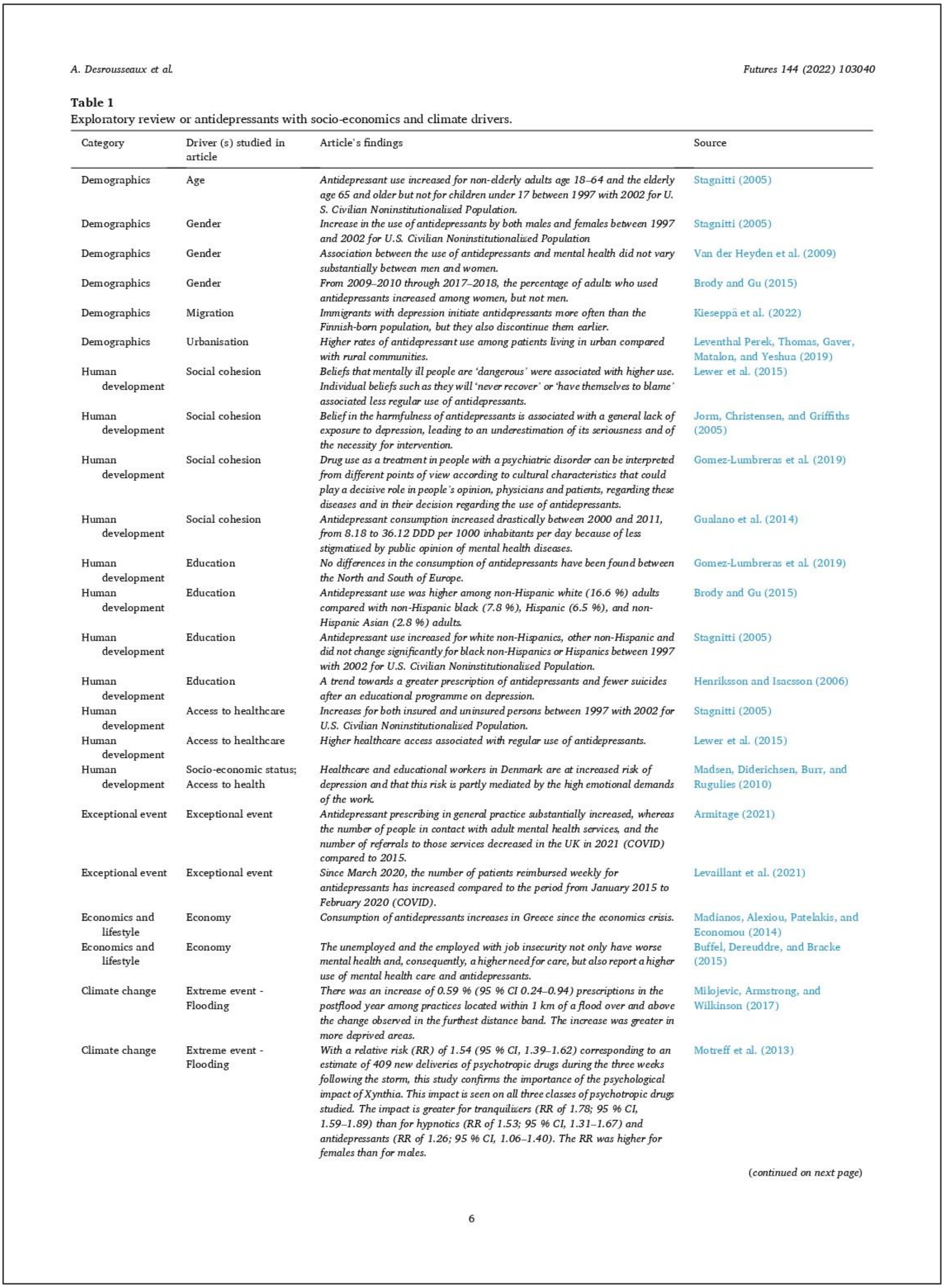

Table 1
Exploratory review or antidepressants with socio-economics and climate drivers.

Category	Driver (s) studied in article	Article's findings	Source
Demographics	Age	*Antidepressant use increased for non-elderly adults age 18–64 and the elderly age 65 and older but not for children under 17 between 1997 with 2002 for U. S. Civilian Noninstitutionalized Population.*	Stagnitti (2005)
Demographics	Gender	*Increase in the use of antidepressants by both males and females between 1997 and 2002 for U.S. Civilian Noninstitutionalized Population*	Stagnitti (2005)
Demographics	Gender	*Association between the use of antidepressants and mental health did not vary substantially between men and women.*	Van der Heyden et al. (2009)
Demographics	Gender	*From 2009–2010 through 2017–2018, the percentage of adults who used antidepressants increased among women, but not men.*	Brody and Gu (2015)
Demographics	Migration	*Immigrants with depression initiate antidepressants more often than the Finnish-born population, but they also discontinue them earlier.*	Kieseppä et al. (2022)
Demographics	Urbanisation	*Higher rates of antidepressant use among patients living in urban compared with rural communities.*	Leventhal Perek, Thomas, Gaver, Matalon, and Yeshua (2019)
Human development	Social cohesion	*Beliefs that mentally ill people are 'dangerous' were associated with higher use. Individual beliefs such as they will 'never recover' or 'have themselves to blame' associated less regular use of antidepressants.*	Lewer et al. (2015)
Human development	Social cohesion	*Belief in the harmfulness of antidepressants is associated with a general lack of exposure to depression, leading to an underestimation of its seriousness and of the necessity for intervention.*	Jorm, Christensen, and Griffiths (2005)
Human development	Social cohesion	*Drug use as a treatment in people with a psychiatric disorder can be interpreted from different points of view according to cultural characteristics that could play a decisive role in people's opinion, physicians and patients, regarding these diseases and in their decision regarding the use of antidepressants.*	Gomez-Lumbreras et al. (2019)
Human development	Social cohesion	*Antidepressant consumption increased drastically between 2000 and 2011, from 8.18 to 36.12 DDD per 1000 inhabitants per day because of less stigmatized by public opinion of mental health diseases.*	Gualano et al. (2014)
Human development	Education	*No differences in the consumption of antidepressants have been found between the North and South of Europe.*	Gomez-Lumbreras et al. (2019)
Human development	Education	*Antidepressant use was higher among non-Hispanic white (16.6 %) adults compared with non-Hispanic black (7.8 %), Hispanic (6.5 %), and non-Hispanic Asian (2.8 %) adults.*	Brody and Gu (2015)
Human development	Education	*Antidepressant use increased for white non-Hispanics, other non-Hispanic and did not change significantly for black non-Hispanics or Hispanics between 1997 with 2002 for U.S. Civilian Noninstitutionalized Population.*	Stagnitti (2005)
Human development	Education	*A trend towards a greater prescription of antidepressants and fewer suicides after an educational programme on depression.*	Henriksson and Isacsson (2006)
Human development	Access to healthcare	*Increases for both insured and uninsured persons between 1997 with 2002 for U.S. Civilian Noninstitutionalized Population.*	Stagnitti (2005)
Human development	Access to healthcare	*Higher healthcare access associated with regular use of antidepressants.*	Lewer et al. (2015)
Human development	Socio-economic status; Access to health	*Healthcare and educational workers in Denmark are at increased risk of depression and that this risk is partly mediated by the high emotional demands of the work.*	Madsen, Diderichsen, Burr, and Rugulies (2010)
Exceptional event	Exceptional event	*Antidepressant prescribing in general practice substantially increased, whereas the number of people in contact with adult mental health services, and the number of referrals to those services decreased in the UK in 2021 (COVID) compared to 2015.*	Armitage (2021)
Exceptional event	Exceptional event	*Since March 2020, the number of patients reimbursed weekly for antidepressants has increased compared to the period from January 2015 to February 2020 (COVID).*	Levaillant et al. (2021)
Economics and lifestyle	Economy	*Consumption of antidepressants increases in Greece since the economics crisis.*	Madianos, Alexiou, Patelakis, and Economou (2014)
Economics and lifestyle	Economy	*The unemployed and the employed with job insecurity not only have worse mental health and, consequently, a higher need for care, but also report a higher use of mental health care and antidepressants.*	Buffel, Dereuddre, and Bracke (2015)
Climate change	Extreme event - Flooding	*There was an increase of 0.59 % (95 % CI 0.24–0.94) prescriptions in the postflood year among practices located within 1 km of a flood over and above the change observed in the furthest distance band. The increase was greater in more deprived areas.*	Milojevic, Armstrong, and Wilkinson (2017)
Climate change	Extreme event - Flooding	*With a relative risk (RR) of 1.54 (95 % CI, 1.39–1.62) corresponding to an estimate of 409 new deliveries of psychotropic drugs during the three weeks following the storm, this study confirms the importance of the psychological impact of Xynthia. This impact is seen on all three classes of psychotropic drugs studied. The impact is greater for tranquilizers (RR of 1.78; 95 % CI, 1.59–1.89) than for hypnotics (RR of 1.53; 95 % CI, 1.31–1.67) and antidepressants (RR of 1.26; 95 % CI, 1.06–1.40). The RR was higher for females than for males.*	Motreff et al. (2013)

(continued on next page)

Table 1 (*continued*)

Category	Driver (s) studied in article	Article's findings	Source
Climate change	Extreme event - Heatwaves	*While only incremental increases in morbidity and mortality above previous findings occurred in 2008, health impacts of the 2009 heatwave stand out. These findings send a signal that the intense and long 2009 heatwave may have exceeded the capacity of the population to cope.*	Nitschke et al. (2011)
Climate change	Extreme event - Wildfires	*The results show an increased rate of PTSD, depression, and generalized anxiety at several times of follow-up post-wildfire, from the subacute phase, to years after. An increased rate of mental health disorders post-wildfire has been found in both the adult and pediatric population, with a number of associated risk factors, the most significant being characteristics of the wildfire trauma itself.*	To et al. (2021)
Climate change	Global change	*Mental health impacts represent both direct (i.e. heat stress, exposure to extreme weather events) and indirect (i.e. economic loss, threats to health and well-being, displacement and forced migration, collective violence and civil conflict, and alienation from a degraded and potentially uninhabitable environment) consequences of acute, subacute and long lasting climate-related events.*	Palinkas and Wong (2020)
Multiples	Age; Gender	*Antidepressants use is higher in women than in men, and increases progressively with age in both sexes.*	Gomez-Lumbreras et al. (2019)
Multiples	Age; Gender	*Antidepressant use increased with age, overall and in both sexes—use was highest among women aged 60 and over (24.3 %). During 2015–2018, 13.2 % of adults aged 18 and over used antidepressant medications in the past 30 days. Use was higher among women than men.*	Brody and Gu (2015)
Multiples	Age; Education	*Disbelief in the medical model of depression and family shame reduced willingness to use mental health counseling and antidepressants in older population in Korea.*	Park et al. (2018)
Multiples	Urbanisation; Environment	*Antidepressant medication has strong associations with neighborhood conditions including socioeconomic satisfaction and the seasonality of particulate matter under 2.5 μm in the air.*	Lee, Kim, and Ham (2022)
Multiples	Urbanisation; Education	*Lower rate of antidepressant use was found in urban and rural Arab-majority communities.*	Leventhal Perek et al. (2019)
Multiples	Urbanisation; Age	*Associations of neighbourhood socioeconomic and physical characteristics with older people's antidepressant use were small and inconsistent.*	Tarkiainen et al. (2021)
Multiples	Age; Socio-economics status	*Antidepressant medication use was higher for adults with at least some college education compared with those with a high school education or less.*	Brody and Gu (2015)
Multiples	Gender; Education	*In men, antidepressant treatment was less common among low educational groups than among high educational groups'. 'In women, socio-economic position was not associated with antidepressant use.*	Kivimäki et al. (2007)
Multiples	Gender; Socio-Economics Status	*Use of antidepressants was significantly associated with female gender, higher socioeconomic status, and unemployment in Rio Grande do Sul State in Brazil in 2006.*	Garcias et al. (2008)
Multiples	Socio-economic status; access to health	*Socioeconomically disadvantaged respondents reported greater antidepressant use than those who were not classified as disadvantaged. These findings suggest Australia's universal health-care system does promote equitable health care across the population.*	Butterworth, Olesen, and Leach (2013)
Multiples	Age; Gender; Inequalities	*More young adult females used antidepressants in municipalities where relative poverty had increased. Fewer elderly females used antidepressants in municipalities where the Gini index (calculating distance between the richest and the poorest) increased. More young adults used antidepressants in municipalities where the number of those not being educated or trained had increased.*	Hiilamo (2014)
Multiples	Age; Gender; Social cohesion	*An increase in the number of persons over 65 years of age living alone was positively associated with an increase in the use of antidepressants among elderly females.*	Hiilamo (2014)
Multiples	Age; Gender; Education	*In this elder sample, taking into account depressive symptom severity and other confounds, antidepressant use is nearly half as likely among men and African Americans.*	Grunebaum, Oquendo, and Manly (2008)

3.1. Antidepressants emissions at European scale for 2050 (Eur-Ant-SSPs)

Antidepressants are regularly detected in European fresh water monitoring campaigns, mostly in urban environments where consumption is high and waste water treatment does not effectively remove this type of molecule (Metcalfe et al., 2016; Wilkinson et al., 2022). Traces of antidepressants in the aquatic environments threaten aquatic ecosystems by altering swimming and cryptic behaviours of invertebrates and behaviour and the development and reproduction of aquatic vertebrates (Sehonova et al., 2018). Global changes that are projected to occur in the next 30 years will likely affect antidepressant consumption and therefore, emissions into the environment. These future emissions must be understood in order to assess future risk and mitigate their impacts. Here, we develop antidepressant emissions scenarios under global change.

3.2. Step 1: Define characteristics of scenarios of Eur-Ant-SSPS

The characteristics of the chemical emissions scenario wanted were developed:

- **What is the goal and purpose of the scenario?** Extend European SSPs (Kok et al., 2019) to antidepressant emissions to envision multiple scenarios of antidepressant emissions in 2050
- **Which chemical or group of chemicals is being investigated?** Within the EU market, antidepressants currently available, antidepressants currently developed but not registered yet and future antidepressants molecules developed under the green chemistry framework by Ganesh et al. (2021)
- **Which environmental matrices are being considered?** European freshwater aquatic systems
- **What spatial scale is required?** Europe
- **What temporal scale is required?** 2050
- **How many and which SSPs needs to be explored?** European SSP1 (Eur-SSP1), SSP4 and SSP5 (Kok et al., 2019). Eur-SSP1 is selected to study antidepressant emissions in a sustainable society with less resource-intensive lifestyles, high human investment and high social cohesion. Eur-SSP4 and Eur-SSP5 are selected to study antidepressant emissions in nuanced societies with high inequalities in human development and some environmental considerations in Eur-SSP4, and intensive lifestyle with high human investment and high environmental considerations for Eur-SSP5.
- **Which climate projections should be explored?** Climate change impacts human mental health in multiple ways in the literature. Increased temperature could lead to more aggressive behaviour and extreme events to stress-related psychiatric disorders (Padhy et al., 2015). The consumption of antidepressants among practices located within 1 km of a flood areas increased compared to further distance lands (Milojevic et al., 2017). Climate change-related declining/changing societies affect mental health with more psychiatric disorders (e.g. ecoanxiety, post-traumatic events stress, depression, survivor guilt) (Cianconi et al., 2020; Hayes et al., 2018; Palinkas & Wong, 2020). The impacts of climate change is therefore considered for antidepressants emissions scenarios. Climate change is considered and integrated with RCP 4.5, 6 and 8.5 combined with Eur-SSP1, Eur-SSP4 and Eur-SSP5 respectively.
- **Who is the targeted audience?** Scientists from the climate change research community like eco-toxicologists, chemists and social scientists working at European scales.
- **What will be the form of the scenario?** Tables with antidepressants trends for each key driver and qualitative storylines assessing the overall effects of the set of drivers for each scenario.

Table 2

Eur-Ant-SSP1, Eur-Ant-SSP4 and Eur-Ant-SSP5 antidepressant emissions scenarios for Europe for the year 2050 for each key drivers defined.

SSPs drivers	SSPs sub-drivers	Eur-SSP1[1] and other SSPs	Eur-Ant-SSP1	Eur-SSP4[1] and other SSPs	Eur-Ant-SSP4	Eur-SSP5[1] and other SSPs	Eur-Ant-SSP5
Demographics	*Population Growth*	Relatively low growth [2]	↗	Low growth [2]	↗	Relatively low growth [2]	↗
Economy and lifestyle	*Inequalities*	Reduced across and within countries [2]	↘	High, especially within countries [2]	↗	Strongly reduced, especially across countries [2]	↘
Environment and natural ressources	*Urbanization*	High and well-managed [2]	↘	Medium with mixed urbanisation type across and within cities [2]	↗	High with a better management over time [2]	↗
Human development	*Economy*	Gradual (with hiccups at the beginning) [1]	↘	High [1]	↗	High [1]	↗
	Social participation	High for rich OECD countries [2]	↘	Low for rich OECD countries [2]	↗	High for rich OECD countries [1]	↘
	Social cohesion	High [1]	↘	Low [1]	↗	High [3]	↘
	Healthcare investment	High [3]	↗	High for elites, medium for lower class [3]	↗	High [3]	↗
	Healthcare access	High [2]	↗	Medium [2]	↗	High [2]	↗
	Education	High [1]	↘	High for elites, medium for lower class [1]	↗	High [1]	↘
Technology	*Development*	High, but no pervasive [1]	↘	High in some areas; low in labour intensive areas [1]	↘	Strong and crucial [1]	↘
Climate Change	Extreme events	RCP-4.5–6: droughts and floods increase [3]	↗	RCP6: droughts and floods increase [3]	↗	RCP-8.5: droughts and floods increase [3]	↗

1 Kok, K., Pedde, S., Gramberger, M. et al., (2019) New European socio-economic scenarios for climate change research: operationalising concepts to extend the shared socio-economic pathways. Reg Environ Change 19, 643–65.

[2] Brian C. O'Neill, Elmar Kriegler, Kristie L. Ebi, et al., (2017) The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century, Global Environmental Change, Volume 42, 169–180.

[3] Tabari, H., Hosseinzadehtalaei, P., Thiery, W., & Willems, P. (2021). Amplified Drought and Flood Risk Under Future Socioeconomic and Climatic Change. Earth's Future, *9(10), e2021EF002295*

3.3. Step 2: Review and prioritisation of the potential impacts of changes in socio-economic and climate on chemical emissions

An exploratory review was conducting using the Scopus search engine. The search terms “antidepressant” in combination with Eur-SSPs drivers’ elements. 51 articles were identified. Further targeted searching was conducted when cited literature yielded relevant peer-reviewed articles. Articles were kept if they confirmed the following statements: 1) the article focuses on change in trends in antidepressants use/consumption; 2) the change in antidepressants trends is related to a socio-economics, technological or climate change; 3) the article does not focus on people with medical pre-conditions; and 4) the article focused on Europe, a country in Europe or a society similar in socio-economic development as Europe. In total, 23 relevant articles were kept. Articles covered primally drivers related to demographics and human development change. The driver(s) studied and their impacts on antidepressant were extracted from each article and presented in Table 1.

To prioritise drivers, nine experts on chemical emissions from academia were solicited. Based on the exploratory review provided and their expertise, experts were asked to assign a priority (high, low or uncertain) for all SSPs elements of Kok et al. (2019) and climate change drivers. If 70 % of experts defined a driver as “high” priority, the driver was considered key and selected for scenario development. For antidepressants emissions, 11 key drivers were identified: population growth, inequalities, urbanization, economy, social participation, social cohesion, healthcare access, healthcare investment, education, technology development and extreme droughts and floodings events (see Table S1). Those drivers were studied exclusively in step 3 to develop emissions scenarios.

3.3.1. Step 3: Develop chemicals emissions scenarios

Prioritised drivers of antidepressants emissions in European aquatic freshwater systems selected in step 2 were studied individually. An emissions trend (increasing, decreasing or both) was proposed for each prioritized driver. Each driver’s individual future trend is presented in section 3.1 and in Table 2, and output scenario storylines are presented in the section 3.2. Note that because of time and financial restrictions and because these scenarios storylines were mostly developed to illustrate the framework, step 3 was developed using desk-based research conducted by the authors.

3.3.2. Step 3.1 Antidepressants emissions trends by priority drivers in Eur-Ant-SSPs

The 11 prioritised drivers were studied one at a time based on results from the exploratory review, historical data and storylines from Eur-SSPs (Kok et al., 2019). If a key driver has no specific indication in Eur-SSPs (e.g. “Inequalities”), storylines provided in global SSPs for Rich-OECD countries (high-income countries – GNI per capita above $13 205 – according to the World Bank) was used (O’Neill et al., 2017; WBD, 2022). When considered relevant and useful for the general understanding of antidepressant emissions in a society, effects of key drivers were extended to mental health or depression by desk-based research.

3.4. Population growth

The total European population was 738 million in 2010. European population growth is estimated to increase in SSP1 (up to 769 million) and SSP5 (847 million) and to decrease in SSP4 (716 million). Based on historical data, we concluded that antidepressants emissions is positively correlated to population growth, therefore antidepressants emissions increase in Eur-Ant-SSP1 and Eur-Ant-SSP5 and decreases in Eur-Ant-SSP4.

3.5. Inequalities

In Global SSPs, inequalities were found to be “reduced across and within countries” in SSP1, “high, especially within countries” in SSP4 and “strongly reduced, especially across countries” in SSP5. Correlations between inequalities and antidepressants or mental health can be difficult to interpret as inequalities can cover poverty, unequal career opportunities or unequal access to education among others. The consensus though is that higher inequalities is correlated to low mental health (Murali & Oyebode, 2004; Yu, 2018) and indirectly to antidepressant consumption. We concluded that in Eur-Ant-SSP1 and Eur-Ant-SSP5, because inequalities decrease, antidepressants emissions decrease. In Eur-Ant-SSP4, we concluded that antidepressants increase.

3.6. Urbanisation

Urbanisation is high and well-managed in global SSP1, medium with mixed type of urbanisation across and within cities in SSP4 and high and better managed over time in SSP5. Dynamic between urbanisation and antidepressants or/or mental health is unclear from the literature. Some articles showed that antidepressant use was higher in urban environments (Leventhal Perek et al., 2019). Another study found that rural individuals are at increased risk to suffer from depression than people living in urban environments (Wang et al., 2019). The type and quality of urbanisation also influences mental health (Triguero-Mas et al., 2015; Wheeler et al., 2015). For Eur-Ant-SSP1 and Eur-Ant-SSP5, because urbanisation increases with environmental considerations and desire for better management, we concluded that antidepressants emissions decrease. In Eur-Ant-SSP4, because of the infrastructure inequalities and the lack of consideration for the environment, we concluded that antidepressants emissions increase.

3.7. Economy

Economy development in Eur-SSPs increases gradually in SSP1 and is defined as a “high economy” in SSP4 and SSP5. Exploratory review showed that high economy in terms of high employment and job security is correlated with less antidepressant consumption compared to unemployed or employed with no job security (Buffel et al., 2015). For Eur-Ant-SSP1, we interpreted that gradual economy in a human-based society with high and security employments result in a decrease in antidepressant emissions. For Eur-Ant-SSP4, economic competition and low consideration for human well-being was translated as employment but with insecurity. We concluded antidepressant increases for Eur-Ant-SSP4, but also in Eur-Ant-SSP5 where we concluded that competition surpasses human consideration.

3.8. *Social participation and social cohesion*

Social participation is high in SSP1 and SSP5 and low in SSP4. Similar projections were determined for social cohesion in European SSPs. High social cohesion (e.g. playing sport, social encounters) is associated with lower depressive symptoms and better mental health (Almedom, 2005; Wang et al., 2019). Exploratory review also showed that society divergence and malicious regards to the mental health issue discourage individuals to take antidepressants (Jorm et al., 2005; Lewer et al., 2015; Park et al., 2018). While impacts of social participation was not directly studied with respect to antidepressants, we considered that social participation and social cohesion are positively related. We concluded that antidepressants emissions decrease in Eur-Ant-SSP1 and Eur-Ant-SSP5 and increase in Eur-Ant-SSP4 based on social participation and social cohesion.

3.9. *Healthcare investment and healthcare access*

In Eur-SSPs, human health investment and access is high for SSP1 and SSP5 and high for elites and medium for lower class for SSP4. In the literature, access and investment in healthcare was positively associated with antidepressant use and better mental health outcomes (Chisholm, 2015; McGorry & Purcell, 2007). We therefore concluded that antidepressants emissions increase in all Eur-Ant-SSPs.

3.10. *Education*

In Eur-SSP1 and Eur-SSP5, education is high. In Eur-SSP4, the number of highly educated people decreases. Articles found in the exploratory review showed that antidepressant consumption were less for highly educated groups. Education in terms of culture was also found to be an influencing factor (Brody & Gu, 2015; Kivimäki et al., 2007). “Open-minded” environments with less judgement and more cohesion were found to encourage individuals to seek help and accept antidepressant treatment (Gomez-Lumbreras et al., 2019). High numbers of educated and, indirectly, high support for human development was translated into antidepressant emissions decreasing in Eur-Ant-SSP1 and Eur-Ant-SSP5 and, inversely, increasing in Eur-Ant-SSP4.

3.11. *Technology development*

Technology development is “high, but not persuasive” in Eur-SSP1, “High in some areas; low in labour intensive areas” in Eur-SSP4 and “strong and crucial” in Eur-SSP5. For antidepressants emissions, technology development could cover improved wastewater treatment technology or shift in antidepressants chemistry design (Ganesh et al., 2021). Green chemistry encourages the development of less toxic molecule, for instance less persistent or less bio-accumulative (Kümmerer, 2007). We concluded that because of high investments in technology development in Eur-SSP1, Eur-SSP4 and Eur-SSP5, antidepressants emissions decrease for all Eur-Ant-SSPs.

3.12. *Extreme droughts and floodings events*

Droughts and floodings are increasing in Europe RCP 4.5, RCP6 and RCP 8.5 (Tabari et al., 2021). The exploratory review showed correlations between extreme weather events and mental health (Nitschke et al., 2011; To et al., 2021). Number of antidepressants prescriptions increases after floodings events. (Milojevic et al., 2017; Motreff et al., 2013). We concluded that antidepressants emissions increase under all RCPs considered.

3.13. *Eur-Ant-SSP1, Eur-Ant-SSP4 and Eur-Ant-SSP5 storylines*

Before developing the Eur-Ant-SSPs, the authors considered the interactions between direct and indirect drivers of antidepressants on a society. While scenario development focuses on emissions, the antidepressants exploratory review focussed only on indirect drivers related to consumption and usage. The development of the scenario narratives was conducted in accordance with the following assumptions:

1. Key drivers including population growth, inequalities, economy, social participation, social cohesion, healthcare investment, healthcare access and education are indirect drivers of antidepressants emissions. These drivers are related to related to consumption and usage of antidepressants.
2. Consumption of antidepressants impact antidepressants loads in wastewater and sewage treatment facilities. These wastewater and sewage treatment facilities can remove/decrease antidepressants emissions release in the natural environment.

Table 3
Exploratory review of insecticides and socio-economics drivers.

Category	Driver (s) studied in article	Article's findings	Source
Demography	Urbanisation	*Higher concentrations occurred in the central Pearl River Delta (China) with more urbanization level than that in the Pearl River Delta's surrounding areas. Relatively higher concentrations of legacy organochlorine pesticides and current-use insecticides were found in the residency land than in other land-use types, which may be attributed to land-use change under rapid urbanization.*	Wei et al. (2015)
Demography	Urbanisation	*Wash-off potential of urban use insecticides on concrete surfaces.*	Jiang et al. (2010)
Environment & natural resources	Environment	*Presence of a border crop of soybeans and neighboring crops (maize, eggplant and Chinese cabbage), both without weed control, increased invertebrate predator abundance, decreased the abundance of pests and dependence on insecticides, and increased grain yield and economic profits.*	Wan et al. (2018)
Environment & natural resources	Land-use	*Since the use of pesticides can negatively impact the population of farmland birds via direct poisoning or, indirectly, by affecting food availability (seeds and insects) and habitat for breeding and foraging, practices that support integrated pest management and that minimise pesticide applications can potentially reduce those negative impacts*	Chiron et al. (2014); Stanton et al. (2018)
Environment & natural resources	Land-use	*At the field level, agricultural intensification, reflected by increasing chemical inputs and field areas and decreasing crop diversity, leads to increased yield, whereas at the farm level, the spread of cropped areas results in a loss and fragmentation of natural and semi-natural habitats.*	Doxa et al. (2012); OECD (2019)
Human development	Food Demand	*Pesticides increased by 15–20-fold since the 60 s to increase food production and respond to world food demand.*	Oerke (2006)
Human development	Education	*For underdeveloped countries like Pakistan a comprehensive and well planned program targeting on alternative pest control method and use of biological agents along with insecticides need to be initiated that can reduce the total dependency on chemicals.*	Id and Afsheen (2021)
Human development	Education	*Farmers' inadequate knowledge of pesticides, the influence of pesticide retailers and lack of access to non-synthetic methods of pest control are positively associated with pesticide overuse, while the propensity to overuse decreases with higher levels of education.*	Jallow, Awadh, Albaho, Devi, and Thomas (2017)
Human development	Consumption and Diets	*Vegetarian and vegan diets with an increased amount of organic foods may further improve upon the toxicity potential by removing conventionally-produced products and removing pesticides.*	Martin and Brandão (2017)
Human development	Consumption and Diets	*Assessment suggests that on average the complete life cycle environmental impact of nonvegetarian meals may be roughly a factor 1.5–2 higher than the effect of vegetarian meals in which meat has been replaced by vegetable protein. Although on average vegetarian diets may well have an environmental advantage, exceptions may also occur. Long-distance air transport, deep-freezing, and some horticultural practices may lead to environmental burdens for vegetarian foods exceeding those for locally produced organic meat.*	Reijnders and Soret (2003)
Human development	Consumption and Diets	*Using a quadrant analysis, a recommended diet was identified with a 38 % lower pesticide toxicity footprint. This was achieved mainly through a reduction in the discretionary food intake and by limiting the choice of fresh fruits. As the latter contradicts dietary recommendations to eat a variety of fruits of different types and colors, we concluded that dietary change may not be the best approach to lowering the environmental impacts of pesticides in the food system. Instead, targeted action in the horticultural industry may be more effective.*	Ridoutt, Baird, Navarro, and Hendrie (2021)
Economy	Economic Model	*Our analysis shows that a 1 % increase in crop output per hectare is associated with a 1.8 % increase in pesticide use per hectare but that the growth in intensity of pesticide use levels off as countries reach a higher level of economic development. However, very few high income countries have managed to significantly reduce the level of intensity of their pesticide use, because decreases in insecticide use at higher income levels are largely offset by increases in herbicide and fungicide use*	Schreinemachers & Tipraqsa (2012)
Technology	Technology Development	*While improved seeds increase pesticide, herbicide and fungicide use, mixed cropping and row planting generally reduce these practices. Moreover, mixed cropping moderately increases expected harvest while improved seeds and row planting have the reverse effect*	Onjewu et al. (2022)
Technology	Technology Development	*Adoption of GM insect resistant and herbicide tolerant technology has reduced pesticide spraying by 671.4 million kg (8.2 %) and, as a result, decreased the environmental impact associated with herbicide and insecticide use on these crops.*	Brookes and Barfoot, (2018)
Technology	Technology Development	*We also report increasing applied toxicity to aquatic invertebrates and pollinators in genetically modified (GM) corn and to terrestrial plants in herbicide-tolerant soybeans since approximately 2010.*	Schulz et al. (2021)
Climate change	Flooding event	*There was an increase of 0.59 % (95 % CI 0.24–0.94) prescriptions in the postflood year among practices located within 1 km of a flood over and above*	Milojevic et al. (2017)

(*continued on next page*)

Table 3 (*continued*)

Category	Driver (s) studied in article	Article's findings	Source
		the change observed in the furthest distance band. The increase was greater in more deprived areas.	
Climate change	Flooding event	*With a relative risk (RR) of 1.54 (95 % CI, 1.39–1.62) corresponding to an estimate of 409 new deliveries of psychotropic drugs during the three weeks following the storm, this study confirms the importance of the psychological impact of Xynthia. This impact is seen on all three classes of psychotropic drugs studied. The impact is greater for tranquilizers (RR of 1.78; 95 % CI, 1.59–1.89) than for hypnotics (RR of 1.53; 95 % CI, 1.31–1.67) and antidepressants (RR of 1.26; 95 % CI, 1.06–1.40). The RR was higher for females than for males.*	Motreff et al. (2013)
Climate change	Heatwaves	*While only incremental increases in morbidity and mortality above previous findings occurred in 2008, health impacts of the 2009 heatwave stand out. These findings send a signal that the intense and long 2009 heatwave may have exceeded the capacity of the population to cope.*	Nitschke et al. (2011)
Climate change	Wildfires	*The results show an increased rate of PTSD, depression, and generalized anxiety at several times of follow-up post-wildfire, from the subacute phase, to years after. An increased rate of mental health disorders post-wildfire has been found in both the adult and pediatric population, with a number of associated risk factors, the most significant being characteristics of the wildfire trauma itself.*	To et al. (2021)
Multiples	Land-use; public policy	*Our results indicate that the direct impacts of agricultural land use changes on pesticide use in France have varied depending on the time period considered, reflecting the influence of public regulations, notably the compulsory set-aside policy in force during the 1990 s, and market conditions, particularly the context of high prices for cereal grains at the end of the 2000 s. Over the six years from 2008 to 2013, this index is roughly constant, indicating that the 17 % increase in French pesticide use in 2013 compared to 2008 (as assessed from annual pesticide sales) cannot be even partially attributed to agricultural land use changes*	Urruty et al. (2016)
Multiples	Land-use; Economy	*Our analysis affirms that organic farming has large positive effects on biodiversity compared with conventional farming, but that the effect size varies with the organism group and crop studied, and is greater in landscapes with higher land-use intensity. Decisions about where to site organic farms to maximize biodiversity will, however, depend on the costs as well as the potential benefits.*	Tuck et al. (2014)
Multiples	Land-use; Consumption and diets	*This investigation showed that compliance with healthy eating guidelines leads to lower energy demand and a decrease in greenhouse gas emissions, largely due to a decrease in livestock numbers. Furthermore, arable land and grassland no longer needed for animal feed production becomes redundant and can possibly be used for the production of raw materials for renewable energy.*	Fazeni and Steinmüller (2011)
Multiples	Climate change; Economics	*Increases in rainfall increases average per acre pesticide usage costs for corn, cotton, potatoes, soybeans, and wheat. Hotter weather increases pesticide costs for corn, cotton, potatoes, and soybeans but decreases the cost for wheat.*	Chen and McCarl (2001)
Multiples	Climate change; Economics	*Climate factors influence fungicide, herbicide, and insecticide expenditures and that this influence is heterogeneous, varying in nature across crops and pesticide categories.*	Rhodes and McCarl (2020)
Multiples	Climate change; Regulation	*In the absence of green house gases emission and pesticide externality regulations, climate change would not only increase agricultural production in the USbut also raise pesticide use and the external environmental and human health costs.*	Shakhramanyan at al. (2013)
Multiples	Climate change; Land-use	*In the long-term, indirect impacts, such as land-use change driven by changes in climate, may have a more significant effect on pesticides in surface and groundwaters than the direct impacts of climate change on pesticide fate and transport.*	Bloomfield et al. (2006)
Multiples	Regulations; Public opinion; Urbanisation	*Denmark, Sweden, the Netherlands and Germany have, or have had, a strong public and political interest for reducing the use of herbicides to control weeds in urban amenity areas and also have very strict regulations. The UK is currently undergoing a period of increasing awareness and strengthening regulation, while Latvia and Finland do not have specific regulations for weed control in urban amenity areas or on hard surfaces.*	Kristoffersen et al. (2008)

3. Capacities of wastewater and sewage treatment are related to technology development. Cities connectiveness of water systems is related to urbanisation. Technology development and urbanisation are therefore considered direct drivers of emissions.
4. If there is no change in technological development, then an increase in antidepressants consumption would increase antidepressants emissions in the natural environment. Similarly, if there is no change in technological development, an increase in consumption would lead to an increase in emissions.

3.13.1. *Eur-Ant-SSP1*

In 2050 in Europe, social and environmental awareness shift the European societies towards human and environment development and sustainable management of resources like water. Despite easy access to antidepressants due to healthcare investment, consumption of antidepressants is reduced because of a supportive society with high social participation and cohesion, high investment in education, and low inequality between individuals. Urbanisation and technologies increase in line with human and environmental desires for the more sustainable- and human- friendly societies. Because of the decrease in antidepressant consumption and investment in technological development, **antidepressant emissions in freshwater systems decrease.**

3.13.2. *Eur-Ant-SSP4*

In 2050 in Europe, despite a strong economy and high technological development permitting stable economic outcomes and a low unemployment rate, the consumption of antidepressants is high because of generally poor human well-being. Antidepressant usage is triggered by low human consideration in the society. The poorer population are more likely to take antidepressants because of high inequality in the society and low investment in education, making access to higher social status and good quality of life more difficult. Investment in wastewater technology does not counterbalance the high consumption of antidepressants. Consumption of antidepressants is exacerbated by increasing extreme climate weather events. **Emissions of antidepressants increase in freshwater systems** because of low human consideration in the societies.

3.13.3. *Eur-Ant-SSP5*

In 2050 the European societies shift toward economic and human development. Economy is boosted by innovation and technological development ensuring low labour-intensive work and a low unemployment rate. There is high social cohesion and participation between individuals, and education is accessible to all. Healthcare investments make antidepressants widely available but increasing human well-being and economic stability reduce the number of antidepressant consumers. Antidepressant consumption is, however, important for individuals who do not fit to the intensive society lifestyle based on performance and for individuals concerned about natural resources. Technology development is strongly based on fossil-fuel resources, provoking anxiety and stress for the portion of the population concerned about natural resources and extreme climate events. Overall, **antidepressants emissions decreased in freshwater systems** because of high human well-being consideration in societies and innovation in wastewater technologies.

3.13.4. *Step 4. Consistency check*

Eur-Ant-SSPs outputs scenarios narratives as well as the results represented in Table 2 were repeated and verified to ensure consistency with results from the exploratory review and with Eur-SSPs storylines by the authors. When consistency was considered satisfactory, the output narratives scenarios were considered fully developed.

3.14. *Insecticides emissions at European scale for 2050 (Eur-Ins-SSPs)*

Insecticides are used in agricultural production for pest control and for minimizing risk of crop loss. They are regularly detected in surface water through runoff or groundwater contamination, exposing and affecting surrounding non-target organisms (Kreutzweiser et al., 2007). Usage of insecticides is predicted to be correlated to agricultural practices and climate change (Delcour et al., 2015; Kattwinkel et al., 2011; Rhodes & McCarl, 2020). Global changes that are projected to occur over the next 30 years could have an effect on insecticide usage and, therefore, on emissions into the environment. Table 3.

3.14.1. *Step 1: Define characteristics of scenarios*

- **What is the goal and purpose of the scenario?** To extend European Agriculture SSPs (Mitter et al., 2020) to insecticide emissions coming from agricultural fields in order to envision multiple scenarios of insecticide emissions in European freshwater systems in 2050.
- **Which chemical or group of chemicals is being investigated?** Within the EU market, insecticides currently available, insecticides currently developed but not registered yet and future insecticides molecules developed under the green chemistry framework by Ganesh et al. (2021)
- **Which environmental matrices are being considered?** European freshwater aquatic systems in rural areas
- **Spatial scale:** Europe
- **Temporal scale:** 2050
- **How many and which SSPs need to be explored?** European Agriculture SSP1 (Eur-Agri-SSP1), SSP4 and SSP5 will be extended to insecticide emissions (Mitter et al., 2020). Eur-Agro-SSP1 was selected to study insecticide emissions in a sustainable society with rapid technological development. Eur-Agri-SSP4 was chosen because of inequalities between urban and rural populations and because policies supporting economic development that predominantly benefit the largest industrial companies. Last, Eur-Agri-SSP5 was selected to represent a liberal society with high investment in technology by private actors. Public environmental awareness is low and public financial support for farmers is low.
- **Which climate projections should be explored?** Climatic events such as increase rainfall, temperature or pest pressure were found to be correlated to incesctices usage in the literature (Chen & McCarl, 2001; Grünig et al., 2020; Rhodes & McCarl, 2020). Climate change is considered and integrated with RCP 4.5, 6 and 8.5 combined with Eur-Agri-SSP1, Eur-Agri-SSP4 and Eur-Agri-SSP5 respectively.

- **Targeted audience:** scientists from the climate change research community with eco-toxicologists, chemists and social scientists working at European scales
- **Type of scenarios:** tables with emissions trends for each key driver with qualitative storylines assessing the overall effects of the set of drivers for each scenario.

3.14.2. Step 2: Review and prioritisation of the potential impacts of changes in socio-economic and climate on chemical emissions

An exploratory review was conducted in order to define dynamic between SSP drivers listed in Mitter et al. (2020) and insecticides. Articles were kept if they confirmed the following statements: 1) the article focuses on change in trends in insecticides use/-consumption; 2) the change in insecticides usage trends is related to a socio-economic, technological or climate change; 3) the article focused on Europe, a country in Europe or a society similar in socio-economic development as Europe. Twenty-five articles were reviewed and major findings are in Table 4.

Using the same methodology applied for the determination of key drivers for antidepressant emissions, ten experts on chemical emissions in academia were solicited to determine key drivers of insecticide emissions. Ten key drivers were considered as high priority by at least 70 % of our expert panel: population growth, education, consumption and diet, land-use, policy orientation, technology development (including agricultural practices) and temperature, rainfall, extreme events and pest pressure regarding climate change (see Table S2). These drivers were studied exclusively in step 3 to develop insecticides emissions scenarios.

3.14.3. Step 3: Develop chemical emissions scenarios

An emissions trend (increasing, decreasing or both) was proposed for each prioritized driver. Each driver's individual future trend is presented in section 3.1 and Table 4, and output scenario storylines are presented section 3.2. As mentioned for Eur-Ant-SSPs, step 3 was developed by desk-based research conducted by the authors.

3.14.3.1. Step 3.1. Insecticides emissions trends by priority drivers in Eur-Ins-SSPs. Prioritised drivers of insecticide emissions selected in step 2 were studied individually using Eur-Agri-SSPs (Mitter et al., 2020).

Table 4
Eur-Ins-SSP1, Eur-Ins-SSP4 and Eur-Ins-SSP5 insecticides emissions scenarios for Europe for the year 2050 for each key drivers defined.

SSPs drivers	SSPs sub-drivers	Eur-SSP1[1] or Global SSP1[2]	Ins-Eur-SSP1	Eur-SSP4[1] or Global SSP4[2]	Ins-Eur-SSP4	Eur-SSP5[1] or Global SSP5[2]	Ins-Eur-SSP5
Demographics	*Population Growth*	Relatively low growth [2]	↗	Low growth [2]	↗	Relatively low growth [2]	↗
Human Devlopment	Education	High [1]	↘	High for elites, medium for lower class [1]	↗	High [1]	↘
Economy and Lifestyle	Consumption and diet	Low growth in material consumption, low-meat diets, first in high income countries [2]	↘	Elites: High consumption life, Rest: low consumption, low mobility [2]	↗	Materialism, status consumption, meat-rich diets [2]	↘
Environment and Natural Resources	Land-use	Strong regulations to avoid environmental trade-offs [2]	↘	Highgly regulated in High income countries[2]	↗	Medium regulations lead to slow decline in rate of deforestation [2]	↗
Policies and Institutions	Policy orientation	Towards sustainable development [2]	↘	Toward the benefit of political and business elite [2]	↗	Toward development, free market, human capital [2]	↗
Technology	Technology development and agricultural practices	Improvement in agriculture productivity; rapid diffusion of best practices [2]	↘	Ag productivity high for large scale industries, low for small scale industries [2]	↗	Highly managed, resource-intensive; rapid increase in ag productivity [2]	↗
Climate Change	Temperature	RCP-4.5–6: Temperature increases [3]	↗	RCP- 6: Temperature increases [3]	↗	RCP-8.5: Temperature increases [3]	↗
	Rainfall	RCP-4.5–6: Rainfalls increase [3]	↗	RCP- 6: Rainfalls increase [3]	↗	RCP-8.5: Rainfalls increase [3]	↗
	Extreme events	RCP-4.5–6: Droughts and floods increase [3]	↗	RCP- 6: Droughts and floods increase [3]	↗	RCP-8.5: Droughts and floods increase [3]	↗
	Pest pressure	RCP-4.5–6: Rising pest pressure[4]	↗	RCP-6: Rising pest pressure[4]	↗	RCP-8.5: Rising pest pressure[4]	↗

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3.15. *Population growth*

European population size is stable in Eur-Agri-SSP1 and Eur-Agr-SSP4 but increase in Eur-Agri-SSP5. Insecticides usage since the 60 s increase to increase food production and answer to the food demand (Oerke, 2006). We considered that increase population is positively correlated with food demand. Therefore, we concluded that insecticides emissions are stable in Eur-Ins-SSP1 and Eur-Ins-SSP4 and increase in Eur-Ins-SSP5.

3.16. *Education*

In Eur-Agri-SSP1 and Eur-Agri-SSP5, education investment increases. For Eur-Agri-SSP4, education investment stays stable. Despite being conducted in countries outside Europe, the exploratory review showed low education for farmers and food producers was associated with over-consumption of pesticides (Jallow et al., 2017). We considered that similar effects would occur in European countries. We concluded that insecticides emissions decrease in Eur-Ins-SSP1 and Eur-Ins-SSP5 and stays stable in Eur-Ins-SSP4.

3.17. *Consumption and diet*

In Eur-Agri-SSP1, demand for meat and feed decrease. For Eur-Agri-SSP4 and Eur-Agri-SSP5, demand for meat and feed stay stable. One article in the exploratory review showed vegan or vegetarian diets decreases pesticides usage (Fazeni & Steinmüller, 2011; Martin & Brandão, 2017; Reijnders & Soret, 2003). There are many uncertainties between diet consumption and insecticide usage though. A decrease in meat demand means a shift towards vegetable and fruit crops. Meat production is usually associated with high antibiotic treatments while vegetables and food crops are associated with high pesticide treatment including insecticides (Ridoutt et al., 2021). Our interpretations of European Agriculture SSPs and the exploratory review was that in Eur-Ins-SSP1 less demand for food and feed led to less insecticide usages and emissions. For Eur-Ins-SSP4 and Eur-Ins-SSP5, insecticides emissions stay stable because the food demand stay stable.

3.18. *Policy orientation*

Relative importance of agri-food policy increases in Eur-Agri-SSP1, stabilises in Eur-Agri-SSP4 and decreases in Eur-Agri-SSP5. Regarding these policies, the socio-environmental focus increased in Eur-SSP1 and stabilizes in Eur-Agri-SSP4 and Eur-Agri-SSP5. For Eur-Ins-SSP1, we concluded that utilisation of insecticides is regulated and limited, therefore emissions decreases. In Eur-Ins-SSP4, the stabilise agri-food policies and socio-environmental focus was translated as no or limited actions are taken for the regulations of insecticides probably due to a lack of interest in environmental topics in the society. Therefore emissions increase in Eur-Ins-SSP4. Similarly, in Eur-Ins-SSP5, the decrease of agri-food policies means a free-market with no chemical regulations. Insecticide emissions increase.

3.19. *Land-use*

Multiple aspects of land-use are covered in Eur-Agri-SSPs: land productivity, resources depletion and resources use efficiency. In all scenarios considered here, land productivity increases. In Eur-Agri-SSP1, resources use efficiency increase and resources depletion decrease. In Eur-Agri-SSP4, resources use efficiency and resources depletion increase. In Eur-SSP5, resources use efficiency stabilize and resource depletion increase. In our exploratory review, land use and pest management can reduce pesticides usage but is usually correlated to public policies and economic investments (Tuck et al., 2014; Urruty et al., 2016). We interpreted that in Eur-Ins-SSP1, insecticides emissions decrease because of conscious and well managed land and water resources, leading to increase food productivity. Reversely, in Eur-Ins-SSP4 and Eur-Ins-SSP5, insecticides emissions increase to increase food productivity while resources are mismanaged and resources depletion increase.

3.20. *Technology Development and agricultural practices*

In Eur-Agri-SSP1 and SSP5, speed of agricultural technology development increases alongside an increase technology uptake in agriculture and an increase technology acceptance by producers and consumers. In Eur-Agr-SSP4, the difference is that technology acceptance by producers and consumers stabilizes. Technology development like GMO was said to reduces pesticides and insecticides utilisation in one while another article stated the opposite in the exploratory review (Brookes & Barfoot, 2018; Schulz et al., 2021). For Eur-Ins-SSP1, the general interest in social and environmental topics in the society makes that the increasing technology development aims at the reducing chemicals emissions. For Eur-Ins-SSP5, increasing investments in technical infrastructures for technology developments and technological innovations brings agricultural practices that do not require insecticides usage (e.g. indoors farming; connected farms). Therefore insecticides emissions decreases. For Eur-Ins-SSP4, we concluded that insecticides emissions increase because technology development benefits large, industrialized farms that do not have an interest in chemicals usage, but mostly focuses on low-emissions technology and nitrogen efficiency (Mitter et al., 2020).

3.21. *Rainfall, temperature, extreme events and pest pressure*

In the RCPs 4.5, 6 and 8.5, the climate events of temperature, rainfall, *pest pressure* and extreme events are increasing (Tabari et al., 2021). Articles found in the exploratory review showed climatic events have a significant effects on pesticides expenses dependent to type of crops. Increase temperature, rainfall and extreme events led increase pesticides costs for most of the crops (Chen & McCarl, 2001). The magnitude will depend on the type of crops, the sub-category of the pesticides and, for few cases, are location-specific (Rhodes & McCarl, 2020). Therefore we concluded that for most crops, increase temperature, rainfall, pest pressure and extreme climatic events led to increase insecticides emissions. Insecticides emissions increase in all Eur-Ins-SSPs.

3.21.1. *Step 3.2. Eur-Ins-SSPs storylines*

Before developing the Eur-Ins-SSPs, the authors considered the interactions between direct and indirect drivers of insecticides on a society. While scenario development focuses on emissions, the exploratory review focused mostly on indirect drivers related to consumption and usage. The development of the scenario narratives was conducted in accordance with the following assumptions:

- Socio-economics drivers (population growth, education, consumption and diet, land-use, policy orientation and technology development) are indirect drivers of insecticides emissions as they impact consumption and usage. Climate drivers (temperature, rainfall, extreme events and pest pressure) can have direct and indirect impacts on insecticides emissions.
- Because agriculture fields are open-systems and because there is no treatment of agriculture effluent, we consider that an increase in insecticides consumption/usage causes an increase of insecticides emissions in the surrounding environment.

3.21.2. *Eur-Ins-SSP1*

In Europe in 2050, social and environmental awareness encourages the usage of insecticides to be largely reduced. Consumers are educated on environmental problems and prefer buying products that do not require pesticides or insecticides. Farmers are encouraged financially and by new technologies to shift towards no or low pesticides and insecticides farming. Climate change does increase pest pressure but adaptation strategies are developed to avoid insecticide usage. **Insecticide emissions in freshwater systems decrease**.

3.21.3. *Eur-Ins-SSP4*

In Europe in 2050, agricultural policies are developed by the wealthy upper class. The larger portion of the population is not represented in public institutions. Policies and regulations are developed for the advantage of large, industrialized companies. Environmental issues like insecticide usage are considered low importance topics compared to social inequalities happening in the society. The large majority of individuals in the society is unaware of environmental problems related to insecticides. Climate change increases pest pressure and usage of insecticides is the only adaptation strategy available. **Insecticide emissions in freshwater systems increase.**

3.21.4. *Eur-Ins-SSP5*

In Europe in 2050, individuals are educated on environmental issues but technology is believed to be the solution to these issues. Investments in innovation and technology development in agriculture is high and towards new technology farming like connected or indoors farms. The free market makes that there is no environmental policy, regulation or financial support to agriculture and food systems. A part of innovation and technology development reduces insecticides usage, but the pressure of climate change and the absence of regulations results in insecticides being the chosen adaptation solution to secure food production for the increasing population. Public awareness for the impact of insecticides in the environment is limited. **Insecticide emissions in freshwater systems increase.**

3.21.5. *Step 4. Consistency check*

Similar as for the development of Eur-Ant-SSPs, Eur-Ins-SSPs output narratives scenarios as well as the results represented in Table 5 were repeated and verified to ensure consistency with results from the exploratory review and with Eur-SSPs storylines. When consistency was considered satisfactory, the output narratives scenarios were considered fully developed.

4. Discussion

Comparison of our results with the literature was difficult because, to our knowledges, this represents the first attempt at developing future chemical emission scenarios. Nevertheless, possible change in antidepressants and insecticides emissions in the future have been studied in the literature. Articles usually focus on a single future situation. There is, to be best of our knowledge, no consideration of multiple alternative futures.

Human health or diseases was studied under the influence of climate change (Barrett et al., 2015; Epstein, 2009; McMichael et al., 2006; Mills et al., 2010). More specifically to antidepressants, similar dynamics between key drivers and antidepressant consumption or emissions were found in the literature. Antidepressant consumption was found to increase in the future because of climate change, and more specifically because of increase in floods and naturals disasters (Redshaw et al., 2013). Projections of population size and gender was found to increase consumption by 61 % by 2090 in a study conducted in the Netherlands (Van Der Aa et al., 2011). Schlüsener et al., 2015 found an increase of antidepressant consumption in the future due to climate change but concluded that demographic development and change in lifestyle was probably more important. In our scenarios, demographic change was considered to have a bigger impact on antidepressant emissions in the environment as well, but a lesser impact compared to human developmental drivers.

Regarding insecticides, usage and costs were found to increase under extreme weather events (Rhodes & McCarl, 2020), precipitation and rainfall (Chen & McCarl, 2001), pesticide efficacy (Matzrafi, 2019) and climate change and land-management (Kattwinkel et al., 2011) in the future. The influence of technological change was debated in a study looking at pesticide efficiency: authors found that increased pesticide consumption could be related to pesticide decreases in efficiency. Consistent with our findings, change in molecule design could therefore play an important role in reducing pesticide consumption and, consequently, pesticide emission in the future (Matzrafi, 2019).

These studies are relevant to understand the influence of a single or few key drivers on a thematic focus. They are, however, less informative of future conditions as they do not consider a society as a complex system where socio-economics, technological and climate change interact and influence each over. They, by default, disregard current societal debates (e.g economics degrowth), actions (e.g. Fridays for Futures and Extinction Rebellion movements) on global change and their impacts on the society. Despite being uncertain, those societal dynamics should be included in future research. In our framework the society is considered as a whole. Socio-economics, technological and climate change drivers interact with each other and can be weighed against each other. In Eur-Ant-SSPs, human development drivers were considered to have the greatest impact on antidepressants emissions. For Eur-Ins-SSPs, land-use, policy and climate drivers had the greatest impacts on insecticides. This framework adapted from the methodology of Mitter et al. (2019) permits for the first time the study of chemical emissions in the future under the shared socio-economics pathways scenarios and in dynamic complex socio-economics societies. The framework is applicable to single molecules or groups of chemicals sharing similar features with an easily applicable methodology.

The two sets of scenarios developed demonstrates the ability of the framework to fit different chemicals. We studied antidepressants with an exploratory review of 23 relevant articles and insecticides, with 25 articles. Antidepressants and insecticides had 10 and 9 key drivers defined respectively. Population growth, technological development and education were key drivers in common for both examples. Our final scenario showed that antidepressants and insecticide emissions both decreased in SSP1 and increased in SSP4. SSP5 had opposite future trends: antidepressant emissions decreased while insecticide emissions increased. The reason is that human development and wellbeing are highly emphasised in SSP5 (which decrease consumption of antidepressants), but environmental regulations and financial investment in the agricultural sector are low due to a desired-liberal society (which increase insecticide usage). Moreover, the impact of climate change is more relevant to insecticide usage and socio-economic trends do not permit an overall reversal of insecticide emissions trends. For Eur-Ins-SSP1, climate change makes the reduction of insecticide usage difficult but is compensated by socio-economic trends.

Scenario development, whether it is for the development of single future trends for each key driver or for the development of storylines, involves uncertainties. There are more uncertainties when literature is limited and when there are multiple sources of chemicals in the environment. For future chemical scenarios, we recommend involving experts and shareholders to discuss the thematic focus and to develop scenarios. Involvement of shareholders from academia, regulatory agencies, and industry is highly encouraged in all steps of the framework. Depending on scenario developers' financial and time resources, experts' judgement can be collected by various methods from surveys sent online to individual interviews where the thematic focus can be discussed in detail. Note that involvement of experts and shareholders also introduces other challenges, for instance, motivate shareholders' participation or maintain this motivation (Alcamo & Henrichs, 2008; Mcbride et al., 2017).

To evaluate our output scenarios, we used the six quality criteria (plausibility, consistency, salience, legitimacy, richness and creativity) proposed by Mitter et al. (2019). These quality criteria were developed to enhance plausibility and consistency with other scenarios. Plausibility of our scenarios is established by the systematic review. Incorporation of the systematic review ensures the storyline is consistent with evidence-based results. Consistency with global SSPs or other scenarios is ensured by the inclusion of these scenarios' outputs within the scenario development. European SSPs or Global SSPs outputs were directly considered on the future of the thematic focus, ensuring consistency with their storylines. Salience, defined as social and/or political relevance of the output scenarios is possible with the characteristics of scenarios wanted in step 1. A scenario's characteristics should focus the framework on a defined goal to ensure salience. Output scenarios should then relate to a specific context within the chemical sector, which would ensure their utility to the targeted audience. Richness of the scenario is emphasized by the consideration of all global SSP drivers in the systematic review covering socio-economic, technological and climate drivers. Inclusion of expert's judgements largely increase richness of the output scenarios with the inclusion of expertise and opinions on the thematic focus. Legitimacy, defined as the inclusion of multiple stakeholders and multiple visions, will depend on scenarios developers' resources and time. In the scenarios we developed, we solicited academic experts for the determination of key drivers, but, as mentioned before, involvement is encouraged in all steps of our framework. The final quality criteria is creativity. Creativity is limited in our framework. The structural approach of linking already defined SSPs drivers to a thematic focus and including results from previous studies restricts out-of-the-box thinking. As mentioned in Mitter et al. (2019), trade-off between quality criteria can happen. In our framework, plausibility and consistency are prioritised over creativity.

A key step in the process of scenario development is comprehending the current situation. This requires the understanding of the past and current trends in chemical release and occurrence. However, the data needed to assess chemical emissions (e.g. production, consumption and trade) are limited to select regions of the world and are often only available for select groups of chemicals such as pharmaceuticals and pesticides. Where data does exist, this is often commercially sensitive so is not always freely available. There is a need to generate data on chemical usage in regions where these data do not exist and for increased data transparency so that researchers can more easily access existing datasets. Access to improved emissions data will facilitate the development of chemical emissions scenarios and, subsequently, support the development of mitigation and adaptation strategies to avoid the negative impacts of chemicals in the future.

5. Conclusion

In this article, we present a framework to study the future of chemical emissions under climate, socio-economic and technological changes. The framework was tested for antidepressants and insecticide emissions in Europe in 2050. Both chemicals had 10 key drivers: for antidepressants, drivers were mainly related to human development while for insecticides, drivers were also related to climate change. Output scenarios describe multiple future emissions depending on the SSP societies described. For both chemicals, emissions were forecast to decrease under SSP1 and increase under SSP4. SSP5 gave conflicting future trends: antidepressant emissions decreased while insecticides increased. The high impact of climate change is compensated by socio-economic trends in SSP1 for insecticides emissions but not in SSP5.

This framework adapted from the methodology of Mitter et al. (2019) permits for the first time the study of chemical emissions in the future under the shared socio-economics pathways scenarios and in dynamic complex socio-economics societies. The framework proved to be adaptable to different chemical uses and allowed the development of detailed scenarios but could also be adapted to other research fields. The more chemical emission scenarios that are developed using this framework, the more researchers, regulators, politicians, governments, or private sector representatives will be able to envision and anticipate the future of chemical emissions to the environment. The knowledge generated will be essential to focus and develop mitigation and adaptation strategies in support of national and international policy initiatives such as the EUs vision to move towards a non-toxic environment.

Declaration of Competing Interest

The Authors declare no conflict of interest.

Acknowledgements

This work is part of the Innovative Training Network ECORISK2050 and was supported by the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No [813124].

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.futures.2022.103040.

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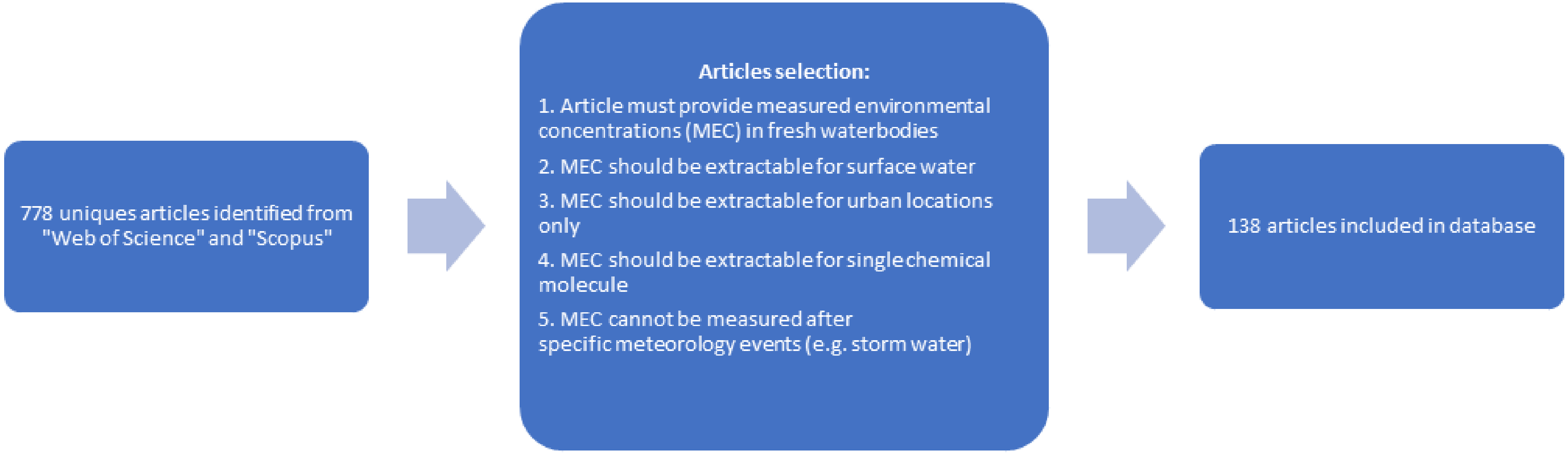
Annexe 1.1: Diagram of articles selection systematic review chapter (chapter 2)



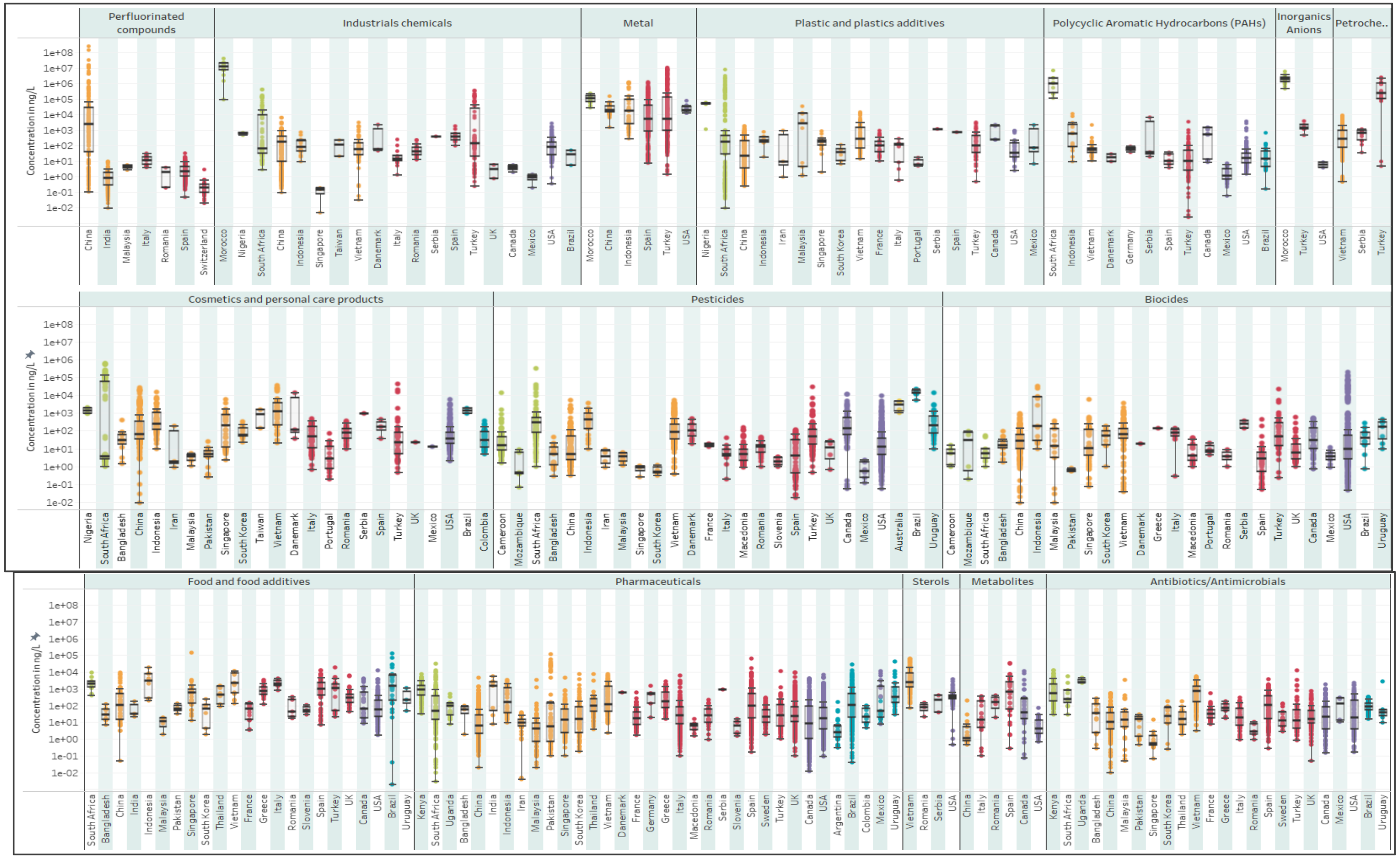
778 uniques articles identified from "Web of Science" and "Scopus"

Articles selection:

1. Article must provide measured environmental concentrations (MEC) in fresh waterbodies
2. MEC should be extractable for surface water
3. MEC should be extractable for urban locations only
4. MEC should be extractable for single chemical molecule
5. MEC cannot be measured after specific meteorology events (e.g. storm water)

138 articles included in database

Annexe 1.2: Environmental concentrations of chemicals in ng/L extracted across chapter 2 systematic review. Chemicals are presented by class categories and by country. Every dot represents a concentration detected at 1 site in 1 of the monitoring studies. The lowest data on the panel represent "<LOQ", "<LOQ" or ND.



Annexe 2.1: List of chemicals with no CAS number determined

Nereistoxin oxalate deg.	4,5-Methylene-phenanthrene	Elaidic acid methyl ester
Phenmedipham deg.	5-Chloro-2-methyl aniline	EPN oxon
Thiamethoxam deg.	7-Nitrobenz(a)anthracene	Erucic acid methyl ester
1-Acetoxy-2-methoxyethane	Adenochrome semicarbazone/Carbazochrome	Esfenvalerate 1
1-chloro-2-[2,2,2-trichloro-1-(4-chlorophenyl)ethyl]	Aldoxycarb (deg)	Esfenvalerate 2
1,2,3,5,8-&1,2,3,6,8-Pentachloronaphthalene	Allethrin 1	Etoxazole metabolite
1,2,4,5,6,8-&1,2,4,5,7,8-Hexachloronaphthalene	Allethrin 2 & Bioallethrin 1	Etridiazole (Echlomezol)
1,2,5,7-&1,2,4,6-&1,2,4,7-Tetrachloronaphthalene	Amitraz (deg)	Fenbuconazole lactone A
1,2,5,8-&1,2,6,8-Tetrachloronaphthalene	Arachidonic acid methyl ester	Fenbuconazole lactone B
1,3,7-&1,4,6-Trichloronaphthalene	b-HCH	Fenitrothion (MEP)
1,4-&1,6-Dichloronaphthalene	Behenic acid methyl ester	Ferimzone(E)
1,4-&2,3-Dimethylnaphthalene	Benzo(c)phenenthrene	Ferimzone(Z)
2-(Di-n-butylamino)ethanol	Benzo(e)pylene	Flucythrinate 1
2-Hydroxy-4-methoxy-4'-methyl-benzophenone	Benzo(j&b)fluoranthene	Flucythrinate 2
2-Phenylphenol (OPP)	Benzobicyclon metabolite	Flufenoxuron dec2
2,2'-Dibromobiphenyl (BB-4)	Bromuconazole-1	Flufenoxuron dec3
2,2',4,4'-Tetrabromodiphenyl ether (BDE-47)	Chlorfenvinphos E	Flusilazole metabolite
2,2',4,4',5,5'-Hexabromobiphenyl (BB-153)	Chlorfenvinphos Z	Fluvalinate 1
2,2',4,4',5,5'-Hexabromodiphenyl ether (BDE-153)	Chlornitrofen (CNP)	Fluvalinate 2
2,2',5,5'-Tetrabromobiphenyl (BB-52)	Chlorothalonil (TPN)	Fosthiazate 2
2,3-&3,4-Dimethylaniline	Chrysene & Triphenylene	Furametpyr metabolite
2,3,4,5,6-Pentachloro-p-terphenyl	cis-4,7,10,13,16,19-Docosahexaenoic acid methyl este	g-HCH
2,3,5,6-&2,3,4,5-Tetrachlorophenol	cis-5,8,11,14,17-Eicosapentaenoic acid, methyl ester	gamma-Linolenic acid methyl ester
2,3,5,6-Tetrachloro-p-terphenyl	cis-8,11,14-Eicosatrienoic acid methyl ester	Heneicosanoic acid methyl ester
2,3,6,7-&1,2,4,8-Tetrachloronaphthalene	cis-10-Heptadecenoic acid methyl ester	Heptachlor epoxide (B)

Annexe 2.1: List of chemicals with no CAS number determined

2,4-&2,5-Dichloro-p-terphenyl
2,4-Dibromodiphenyl ether (BDE-7)
2,4,4',6-Tetrachloro-p-terphenyl
2,4,6-Trichloro-p-terphenyl
2,5-Dichloro-o-terphenyl
2,6-&1,7-Dichloronaphthalene
2,6-Di-t-butyl-4-ethylphenol
2,6-Di-tert-butyl-4-benzoquinone
2,6-Dichlorobenzamid
3- & 4-tert-Butylphenol
3-&4-Chlorophenol
3-&4-Nitroanisole
3-Hydroxycarbofuran 1
3-Hydroxycarbofuran 2
3-Methoxy-1-butyl acetate
3,3-Dimethoxybenzidine
4-Bromophenylphenyl ether
4-Chloro-o-terphenyl
4-Chloro-p-terphenyl
4-Chlorophenylphenyl ether
4,4'-Diaminodiphenyl-methane
4,4'-Oxybis-benzenamine
4,5-Methylene-phenanthrene
5-Chloro-2-methyl aniline
7-Nitrobenz(a)anthracene
Adenochrome semicarbazone/Carbazochrome
Aldoxycarb (deg)
Allethrin 1
Allethrin 2 & Bioallethrin 1
Amitraz (deg)
Arachidonic acid methyl ester
b-HCH
Propargite 2
Propiconazole 1

cis-11-Eicosenoic acid methyl ester
cis-11,14-Eicosadienoic acid methyl ester
cis-11,14,17-Eicosatrienoic acid methyl ester
cis-13,16-Docosadienoic acid methyl ester
coprostanol/cholesterol
Cyanophos, CYAP
Cyfluthrin 1
Cyfluthrin 2
Cyfluthrin 3
Cyfluthrin 4
Cyhalothrin 1
Cyhalothrin 2
Cypermethrin 1
Cypermethrin 2
Cypermethrin 3
Cypermethrin 4
d-HCH
Dichlofenthion, ECP
Dichlofluanid metabolite
Diclocymet 1
Diclocymet 2
Dicofol-deg
Dimethomorph(E)
Dimethomorph(Z)
Dimethylterephthalate
Dimetylvinphos 1
Dimetylvinphos 2
Diofenolan 1
Diofenolan 2
Dioxabenzofos(Salithion)
Diphenyldisulfide
e-Caprolactam
Pyriminobac-methyl(E)
Pyriminobac-methyl(Z)

Iprobenfos (IBP)
Iprodione metabolite
Lignoceric acid, methyl ester
Linolelaidic acid methyl ester
Linolenic acid methyl ester
MCPA-thioethyl (Phenothiol)
Mepanipyrim metabolite
Methomyl oxime
Methyl dymron
Metominostrobin Z
Metominostrobin(E)
Metribuzin DK
Mevinphos 1
Mevinphos 2
n-Butylacrylate
N-Nitroquinoline-N-oxide
Nervonic acid methyl ester
Nitrofen (NIP)
Novaluron-deg
Oleic acid methyl ester
Oxpoconazole-formyl
Oxpoconazole-fumalate
p,p'-DDD +o,p'-DDT
PCB 4&10
PCB 138&158
PCB 153&168
Pentachloronitrobenzene (Quintozene)
Permethrin 1
Permethrin 2
Phenothrin 1
Phenothrin 2
Propargite 1
Tolylfluanid metabolite
Tralkoxydim-1

Annexe 2.2 : List of chemicals with no PNEC determined.

CAS Number	Chemical name
100-00-5	4-Chloronitrobenzene
100-01-6	4-Nitroaniline
10004-44-1	Hymexazol
100-25-4	1,4-Dinitrobenzene
100-44-7	Benzyl chloride
100-54-9	Nicotinonitrile
100-61-8	N-Methylaniline
100-74-3	N-Ethylmorpholine
100-75-4	N-Nitrosopiperidine
10075-50-0	5-Bromoindole
100784-20-1	Halosulfuron-methyl
101007-06-1	Acrinathrin
101-14-4	4,4'-Methylene-bis(2-chloroaniline)
101200-48-0	Tribenuron-methyl
101-21-3	Chlorpropham
1014-70-6	Simetryn
101-81-5	Diphenylmethane
102608-53-7	3,7,11,15-tetramethyl-2-hexa- decen-1-ol
10265-92-6	Methamidophos
10311-84-9	Dialifos
103361-09-7	Flumioxazin
103426-93-3	1,2,3,4,5,8-Hexachloronaphthalene
103426-94-4	1,2,3,5,7,8-Hexachloronaphthalene
103426-96-6	1,2,3,4,6,7-Hexachloronaphthalene
103-50-4	Dibenzylether
103577-45-3	Lansoprazole
103-69-5	N-Ethylaniline
103-84-4	Acetamide, N-phenyl-
10443-70-6	MCPB-ethyl
104-94-9	4-Anisidine
105024-66-6	Silafluofen
10543-57-4	N,N,N’,N’-tetraacetylethylenediamine
10552-74-6	Nitrothal-isopropyl
105779-78-0	Pyrimidifen
106-41-2	4-Bromophenol
106-50-3	p-Phenylenediamine
106-70-7	Methyl hexanoate
106917-52-6	Flusulfamide
107-41-5	2-Methyl-2,4-pentandiol
108050-54-0	Tilmicosin
108-37-2	3-Bromochlorobenzene
108427-53-8	Perfluorohexanesulfonate
108-44-1	3-Toluidine
108-45-2	m-Phenylenediamine
1404-90-6	Vancomycin
1404-93-9	Vancomycin hydrochloride
140-57-8	Aramite
14086-35-2	Fenthion oxon sulfone
140923-17-7	Iprovalicarb
141112-29-0	Isoxaflutole
141-66-2	Dicrotophos
14206-58-7	4-epi-Oxytetracycline
142-91-6	Isopropyl palmitate
14297-93-9	4-Epichlortetracycline
143-07-7	Dodecanoic acid
143-08-8	1-Nonanol
143807-66-3	Chromafenozide
143-98-6	Dextrorphan tartrate
144457-28-3	Clopidogrel carboxylic acid
144550-36-7	Iodosulfuron-methyl-sodium
145701-21-9	Diclosulam
145701-23-1	Florasulam
14698-29-4	Oxolinic acid
14769-73-4	Levamisole
147-82-0	2,4,6-Tribromoaniline
14816-18-3	Phoxim
148477-71-8	Spirodiclofen
14933-08-5	3-(N,N-dimethyllaurylammo- nio)propanesulfonate
14938-35-3	4-n-Pentylphenol
149508-90-7	Simeconazole
149877-41-8	Bifenazate
150224-20-7	1,2,4,5,6-Pentachloronaphthalene
150224-21-8	1,2,4,7,8-Pentachloronaphthalene
150224-22-9	1,2,4,6,8-Pentachloronaphthalene
150224-25-2	1,2,4,5,8-Pentachloronaphthalene
150824-47-8	Nitenpyram
150-86-7	Phytol
15299-99-7	Napropamide
15318-45-3	Thiamphenicol
153197-14-9	Oxaziclomefone
153233-91-1	Etoxazole
156052-68-5	Zoxamide
1560-84-5	Eicosane, 2-methyl-
156963-66-5	Benzobicyclon
1577-52-2	9,12-octadecadien-1-ol
158237-07-1	Fentrazamide
158474-72-7	Prohydrojasmon
15950-66-0	2,3,4-Trichlorophenol

1085-98-9	Dichlofluanid
108-60-1	DCIP
108-69-0	3,5-Dimethylaniline
108-93-0	Cyclohexanol
108-99-6	3-Methylpyridine
109-21-7	Butanoic acid, butyl ester
110235-47-7	Mepanipyrim
110-27-0	Tetradecanoic acid, 1-methyl- ethyl ester
110-34-9	Hexadecanoic acid, 2-methyl- propyl ester
11039-68-2	2-{Carboxy[(1-hydroxy-2-phenylethylidene)amino]methyl}-5,5-dimethyl-1,3-thiazolidine-4-carboxylic acid
110-42-9	Methyl decanoate
110956-75-7	Pentoxazone
111-01-3	Squalane
111-06-8	Hexadecanoic acid, butyl ester
111-11-5	Methyl octanoate
111-44-4	Bis(2-chloroethyl)ether
1114-71-2	Pebulate
111479-05-1	Propaquizafop
111-76-2	2-Butoxyethanol
111-82-0	Methyl dodecanoate
1118-46-3	Butyltin trichloride
111872-58-3	Halfenprox
111-87-5	Octanol
111-91-1	Bis(2-chloroethoxy)methane
111-92-2	Dibutylamine
111991-09-4	Nicosulfuron
1120-25-8	Methyl palmitoleate
1120-28-1	Arachidic acid methyl ester
1120-36-1	1-tetradecene
1120-72-5	Cyclopentanone, 2-methyl-
112-39-0	Hexadecanoic acid, methyl ester
112398-08-0	Danofloxacin
112410-23-8	Tebufenozide
112-61-8	Stearic acid methyl ester
112-63-0	Linoleic acid methyl ester
112-80-1	9-octadecenoic acid
112-88-9	Octadecene
1134-23-2	Cycloate
113-92-8	Chlorpheniramine maleate
114420-56-3	Clodinafop
115852-48-7	Fenoxanil
115-90-2	Fensulfothion
1159-82-6	10-Hydroxyamitriptyline
116-06-3	Aldicarb
116255-48-2	Bromuconazole-2

16118-49-3	Carbetamide
161326-34-7	Fenamidone
163520-33-0	Isoxadifen-ethyl
1638-22-8	4-n-Butylphenol
1646-88-4	Aldicarb sulfone
16752-77-5	Methomyl
1698-60-8	Chloridazon
1702-17-6	Clopyralid
17024-19-0	3-Nitrophenanthrene
17040-19-6	Demeton-S-methylsulphon
17109-49-8	Edifenphos
171118-09-5	Metolachlor ESA
173159-57-4	Foramsulfuron
1731-86-8	Methyl undecanoate
1731-88-0	Methyl tridecanoate
1731-92-6	Methyl heptadecanoate
1746-81-2	Monolinuron
175217-20-6	Silthiofam
1763-23-1	Perfluorooctanesulfonic acid
17655-31-1	azanide
1795-18-2	Cyclohexane, tetradecyl-
180409-60-3	Cyflufenamid
1806-26-4	4-n-Octylphenol
181274-15-7	Propoxycarbazone-sodium
1825-30-5	1,5-Dichloronaphthalene
18496-25-8	Sulfide
1861-32-1	Chlorthal-dimethyl
1861-40-1	Benfluralin
18691-97-9	Methabenzthiazuron
18694-40-1	Mepirizole
18854-01-8	Isoxathion
1888-71-7	Hexachloropropylene
189278-12-4	Proquinazid
1918-16-7	Propachlor
1918-18-9	Swep
19406-51-0	4-Amino-2,6-dinitrotoluene
19466-47-8	Stigmastanol
19780-44-0	3-Hexanol, 4-ethyl-
1987-50-4	4-n-Heptylphenol
199119-58-9	Trifloxysulfuron-sodium
2008-41-5	Butylate
201341-05-1	Tenofovir disoproxil
2027-17-0	2-Isopropylnaphthalene
2032-65-7	Methiocarb
2042-14-0	4-Methyl-3-nitrophenol

116-29-0	Tetradifon
117337-19-6	Fluthiacet-methyl
117-80-6	Dichlone
117-96-4	Diatrizoic acid
118-96-7	2,4,6-Trinitrotoluene
119-12-0	Pyridaphenthion
1191-85-1	5,8,11,14-eicosatetraynoic acid
119-32-4	4-Amino-2-nitrotoluene
120067-83-6	Fipronil sulfide
120068-36-2	Fipronil sulfone
120116-88-3	Cyazofamid
120162-55-2	Azimsulfuron
120-58-1	Isosafrole
120-75-2	2-Methylbenzothiazole
120868-66-8	Imidacloprid urea
121-14-2	2,4-Dinitrotoluene
121-21-1	Pyrethrin 1
121-29-9	Pyrethrin 2
1214-39-7	N-Benzyladenine
121-69-7	N,N-Dimethylaniline
121-73-3	3-Chloronitrobenzene
121776-33-8	Furilazole
122008-85-9	Cyhalofop Butyl
1220-83-3	Sulfamonomethoxine
122-37-2	Phenol, 4-(phenylamino)-
122453-73-0	Chlorfenapyr
122548-33-8	Imazosulfuron
122-62-3	Bis(2-ethylhexyl) sebacate
123-31-9	1,4-Benzenediol
123572-88-3	Furametpyr
123-79-5	Hexanedioic acid, dioctyl ester
123-95-5	Octadecanoic acid, butyl ester
124-10-7	Methyl myristate
125306-83-4	Cafenstrole
126801-58-9	Ethoxysulfuron
128639-02-1	Carfentrazone-ethyl
129558-76-5	Tolfenpyrad
129630-19-9	Pyraflufen ethyl
130000-40-7	Thifluzamide
13067-93-1	Cyanofenphos
13071-79-9	Terbufos
131-16-8	Dipropyl phthalate
131-18-0	Dipentyl phthalate
131341-86-1	Fludioxonil
13171-21-6	Phosphamidon
131807-57-3	Famoxadone
131860-33-8	Azoxystrobin
131929-60-7	Spinosyn A
131929-63-0	Spinosyn D

204-809-1	2,4,7,9-Tetramethyl-5-decyne-4,7-diol
205650-65-3	Fipronil-desulfinyl
2058-94-8	Perfluoroundecanoic acid
206-793-1	Perfluorobutane sulfonic acid
2104-64-5	EPN
2135-17-3	Flumethasone
214-987-2	Pestanal
21564-17-0	TCMTB
21609-90-5	Leptophos
219714-96-2	Penoxsulam
22224-92-6	Fenamiphos
22248-79-9	Tetrachlorvinphos
2234-13-1	Octachloronaphthalene
223580-51-6	Tiadinil
2255-17-6	Fenitrothion oxon
2275-23-2	Vamidothion
22781-23-3	Bendiocarb
229977-93-9	Fluacrypyrim
2303-17-5	Tri-allate
2310-17-0	Phosalone
23135-22-0	Oxamyl
2387-23-7	1,3-Dicyclohexylurea
23893-13-2	Anhydroerythromycin A
24017-47-8	Triazophos
24151-93-7	Piperophos
2416-20-8	Hexadecenoic acid, (11)-
24221-86-1	2-(Methylamino)-1-phenylpropan-1-ol--hydrogen chloride (1/1)
24307-26-4	1,1-Dimethylpiperidinium chloride
243-17-4	2,3-Benzofluorene
24353-61-5	Isocarbophos
2437-55-0	1,4,5-Trichloronaphthalene
2437-56-1	1-tridecene
24390-14-5	Doxycycline hyclate
2446-69-7	4-n-Hexylphenol
24602-86-6	Tridemorph
24934-91-6	Chlormephos
25117-37-7	Heneicosane, 5-methyl-
25311-71-1	Isofenphos
2531-84-2	2-Methylphenanthrene
25606-41-1	Propamocarb hydrochloride
25637-99-4	Hexabromocyclododecane
2595-54-2	Mecarbam
26140-60-3	Terphenyl
262-20-4	Phenoxathiin
26225-79-6	Ethofumesate
26306-61-6	Amino-chlornitrofen
26523-78-4	Nonylphenolphosphite(3:1)
26545-51-7	Diethyltoluamide
2655-14-3	XMC

13194-48-4	Ethoprophos
131983-72-7	Triticonazole
132539-06-1	Olanzapine
132-64-9	Dibenzofuran
132-65-0	Dibenzothiophene
132-66-1	Naptalam
133-06-2	Captan
133-07-3	Folpet
1330-78-5	Tricresyl phosphate
133220-30-1	Indanofan
13356-08-6	Fenbutatin oxide
134098-61-6	Fenpyroximate
134-32-7	1-Naphthylamine
134523-00-5	Atorvastatin
134605-64-4	Butafenacil
13481-95-3	10-octadecenoic acid, methyl ester
134-96-3	Benzaldehyde, 4-hydroxy-3,5-dimethoxy-
135186-78-6	Pyriftalid
135-19-3	2-Naphthol
135590-91-9	Mefenpyr-diethyl
135-67-1	Phenoxazine
1356927-15-5	4-Nonylphenoldiethoxylate
135821-03-3	syn-Dechlorane Plus
135821-74-8	anti-Dechlorane Plus
135-88-6	N-Phenyl-2-naphthylamine
13593-03-8	Quinalphos
136426-54-5	Fluquinconazole
13679-74-8	2-Acetyl-5-methylthiophene
13684-56-5	Desmedipham
137-41-7	Potassium N-methyldithiocarbamate
137641-05-5	Picolinafen
137862-53-4	Valsartan
138402-11-6	Irbesartan
139481-59-7	Candesartan
139528-85-1	Metosulam
140-08-9	Tris(2-chloroethyl)phosphite
14042-01-4	Peroxynitrite

2655-15-4	2,3,5-Trimethacarb
2675-77-6	Chloroneb
272451-65-7	Flubendiamide
27304-13-8	Oxychlordane
27314-13-2	Norflurazon
27355-22-2	Fthalide
27400-77-7	Nonadecene
27512-72-7	Ethychlozate
27554-26-3	1,2-benzenedicarboxylic acid, diisooctyl ester
27575-78-6	Tris(4-chlorophenyl)methane
27605-76-1	Probenazole
2797-51-5	Quinoclamine
28249-77-6	Thiobencarb
28434-01-7	Bioresmethrin
28556-81-2	2,6-dimethylphenyl isocyanate
29331-92-8	10-hydroxycarbazepine
298-02-2	Phorate
298-04-4	Disulfoton
29973-13-5	Ethiofencarb
299-84-3	Fenchlorphos
299-85-4	Zytron
300-76-5	Naled
3010-80-8	Tris(4-chlorophenyl)methanol
3055-94-5	Triethylene glycol monodo- decyl ether
3055-95-6	Pentaethylene glycol monodo- decyl ether
3055-97-8	Heptaethylene glycol mono- dodecyl ether
3055-98-9	Octaethylene glycol monodo- decyl ether
307-55-1	Perfluorododecanoic acid
311-45-5	Diethyl-p-nitrophenyl phosphate
31218-83-4	Propetamphos
31895-21-3	Thiocyclam
3208-26-2	9-phenyl-1-nonanol
3209-22-1	2,3-Dichloronitrobenzene
32306-29-9	Isoxathion oxon
32492-61-8	Poly(oxy-1,2-ethanediyl), .alpha.,.alpha.'-[(1-methylethylidene)di-4,1-phenylene]bis[.omega.-hydroxy-
3337-71-1	Asulam
334-48-5	Decanoic acid

Annexe 2.3: List of chemicals with associated CAS number and PNEC used

Class category	CAS Number	Chemical Name	PNEC used (ng/L)
Antibiotics/Antimicrobials	551-92-8	1,2-Dimethyl-5-nitroimidazole	28,787.40
Antibiotics/Antimicrobials	26787-78-0	Amoxicillin	570
Antibiotics/Antimicrobials	69-53-4	Ampicillin	600
Antibiotics/Antimicrobials	83905-01-5	Azithromycin	30
Antibiotics/Antimicrobials	94-09-7	Benzocaine	6,990
Antibiotics/Antimicrobials	05/07/6804	Carbadox	49,436.93
Antibiotics/Antimicrobials	63527-52-6	Cefotaxime	120
Antibiotics/Antimicrobials	15686-71-2	Cephalexin	210
Antibiotics/Antimicrobials	56-75-7	Chloramphenicol	21,713.90
Antibiotics/Antimicrobials	85721-33-1	Ciprofloxacin	450
Antibiotics/Antimicrobials	81103-11-9	Clarithromycin	250
Antibiotics/Antimicrobials	105956-97-6	Clinafloxacin	4,174,080.66
Antibiotics/Antimicrobials	18323-44-9	Clindamycin	100
Antibiotics/Antimicrobials	61-72-3	Cloxacillin	20,000
Antibiotics/Antimicrobials	127-33-3	Demeclocycline	48,620
Antibiotics/Antimicrobials	564-25-0	Doxycycline	25,100
Antibiotics/Antimicrobials	74011-58-8	Enoxacin	10,280,476.38
Antibiotics/Antimicrobials	93106-60-6	Enrofloxacin	1,910
Antibiotics/Antimicrobials	114-07-8	Erythromycin	500
Antibiotics/Antimicrobials	86386-73-4	Fluconazole	265,473.79
Antibiotics/Antimicrobials	42835-25-6	Flumequine	1,744,705.51
Antibiotics/Antimicrobials	100-97-0	Hexamethylenetetramine	60,380
Antibiotics/Antimicrobials	65277-42-1	Ketoconazole	10,000
Antibiotics/Antimicrobials	100986-85-4	Levofloxacin	1,520
Antibiotics/Antimicrobials	154-21-2	Lincomycin	810
Antibiotics/Antimicrobials	165800-03-3	Linezolid	3,500
Antibiotics/Antimicrobials	98079-51-7	Lomefloxacin	5,768,173.22
Antibiotics/Antimicrobials	56392-14-4	Metoprolol acid	23,750
Antibiotics/Antimicrobials	443-48-1	Metronidazole	94,916.92
Antibiotics/Antimicrobials	10118-90-8	Minocycline	1,100
Antibiotics/Antimicrobials	151096-09-2	Moxifloxacin	2,898,900.22
Antibiotics/Antimicrobials	70458-96-7	Norfloxacin	12,000.00
Antibiotics/Antimicrobials	82419-36-1	Ofloxacin	10,000
Antibiotics/Antimicrobials	66-79-5	Oxacillin	67,191.00
Antibiotics/Antimicrobials	79-57-2	Oxytetracycline	33,756.81
Antibiotics/Antimicrobials	61-33-6	Penicillin G	1,498,750.21
Antibiotics/Antimicrobials	87-08-1	Penicillin V	305,260.70
Antibiotics/Antimicrobials	80214-83-1	Roxithromycin	6,800
Antibiotics/Antimicrobials	110871-86-8	Sparfloxacin	8,265,650.94
Antibiotics/Antimicrobials	8025-81-8	Spiramycin	1,090
Antibiotics/Antimicrobials	144-80-9	Sulfacetamide	101,500
Antibiotics/Antimicrobials	68-35-9	Sulfadiazine	11,210
Antibiotics/Antimicrobials	122-11-2	Sulfadimethoxine	347,298.60
Antibiotics/Antimicrobials	144-82-1	Sulfamethizole	851,866.44
Antibiotics/Antimicrobials	723-46-6	Sulfamethoxazole	600
Antibiotics/Antimicrobials	60-54-8	Tetracycline	1,000
Antibiotics/Antimicrobials	55297-95-5	Tiamulin	4,752
Antibiotics/Antimicrobials	738-70-5	Trimethoprim	1,614.86
Antibiotics/Antimicrobials	1401-69-0	Tylosin	980
Biocides	67564-91-4	(2R,6S)-Fenpropimorph	5,530
Biocides	90-43-7	[1,1’-biphenyl]-2-ol	899.9999613

Biocides	608-73-1	1,2,3,4,5,6-Hexachlorocyclohexane	20
Biocides	149-30-4	2-Mercaptobenzothiazole	1,960
Biocides	122-99-6	2-Phenoxyethanol	314,000
Biocides	90-43-7	2-Phenylphenol	899.9999613
Biocides	64359-81-5	4,5-Dichloro-2-octyl-3(2H)-isothiazolone	5,487.01
Biocides	26172-55-4	5-Chloro-2-methyl-3(2H)-isothiazolone	20,388.56
Biocides	135410-20-7	Acetamiprid	20,763.11
Biocides	67375-30-8	alpha-Cypermethrin	1,879
Biocides	82657-04-3	Bifenthrin	0.02775447
Biocides	1897-45-6	Chlorothalonil	2,580
Biocides	15545-48-9	Chlorotoluron	6,548.14
Biocides	5598-13-0	Chlorpyrifos-methyl	1.480612409
Biocides	210880-92-5	Clothianidin	267,402.22
Biocides	28159-98-0	Cybutryne	5,838
Biocides	68359-37-5	Cyfluthrin	1,051
Biocides	52315-07-8	Cypermethrin	2.00E-05
Biocides	66215-27-8	Cyromazine	18,200
Biocides	62-73-7	DDVP	1,587.94
Biocides	134-62-3	DEET	34,700
Biocides	319-86-8	delta-Hexachlorocyclohexane	2,280
Biocides	333-41-5	Diazinon	1.59827774
Biocides	333-41-5	Diazinone	1.59827774
Biocides	1918-00-9	Dicamba	19,590
Biocides	62-73-7	Dichlorvos	1,587.94
Biocides	60-51-5	Dimethoate	4,967.10
Biocides	165252-70-0	Dinotefuran	628,732.78
Biocides	330-54-1	Diuron	200
Biocides	5989-27-5	D-Limonene	4,298.97
Biocides	1031-07-8	Endosulfan sulfate	2,383.61
Biocides	122-99-6	Ethanol, 2-phenoxy-	314,000
Biocides	72490-01-8	Fenoxycarb	0.25
Biocides	67564-91-4	Fenpropimorph	5,530
Biocides	120068-37-3	Fipronil	80.58155654
Biocides	35554-44-0	Imazalil	1,830.54
Biocides	138261-41-3	Imidacloprid	307,226.66
Biocides	173584-44-6	Indoxacarb	740.7084107
Biocides	67-63-0	Isopropanol	204,000
Biocides	34123-59-6	Isoproturon	300
Biocides	121-75-5	Malathion	3,468.99
Biocides	22916-47-8	Miconazole	26.13842953
Biocides	72-55-9	p,p'-DDE	8.228021907
Biocides	59-50-7	p-Chlorocresol	13,210
Biocides	52645-53-1	Permethrin	0.959340286
Biocides	51-03-6	Piperonyl butoxide	3,000
Biocides	29232-93-7	Pirimiphos-methyl	1.493763411
Biocides	7287-19-6	Prometryn	19,354.77
Biocides	60207-90-1	Propiconazole	1,367.06
Biocides	95737-68-1	Pyriproxyfen	0.502
Biocides	107534-96-3	Tebuconazole	1,712.54
Biocides	148-79-8	Thiabendazole	14,284.14
Biocides	111988-49-9	Thiacloprid	30,949.22
Biocides	153719-23-4	Thiamethoxam	256,985.59

Biocides	101-20-2	Triclocarban	1,342.47
Biocides	55335-06-3	Triclopyr	33,352.24
Biocides	3380-34-5	Triclosan	3,350
Biocides	81-81-2	Warfarin	19,070
Biocides	91465-08-6	λ-Cyhalothrin	0.730359752
Cosmetics and personal care products	6790-58-5	(-)-Ambroxide	8,572.73
Cosmetics and personal care products	947-19-3	(1-Hydroxycyclohexyl)(phenyl)methanone	28,660
Cosmetics and personal care products	14739-11-8	(2,2-Dimethyl-1,3-dioxolan-4-yl)methyl acetate	90,600
Cosmetics and personal care products	85-19-8	(5-Chloro-2-hydroxyphenyl)phenylmethanone	5,100
Cosmetics and personal care products	95-14-7	1,2,3-Benzotriazole	97,000.00
Cosmetics and personal care products	95-63-6	1,2,4-Trimethylbenzene	34,970
Cosmetics and personal care products	4273-98-7	2-(Phenylsulfonyl)aniline	7,998
Cosmetics and personal care products	131-55-5	2,2',4,4'-Tetrahydroxybenzophenone	11,550
Cosmetics and personal care products	6846-50-0	2,2,4-Trimethyl-1,3-pentanediol diisobutyrate	3,119.55
Cosmetics and personal care products	131-53-3	2,2'-Dihydroxy-4-methoxybenzophenone	13,030
Cosmetics and personal care products	81-15-2	2,4,6-Trinitro-1,3-dimethyl-5-tert-butylbenzene	5,310
Cosmetics and personal care products	126-86-3	2,4,7,9-Tetramethyl-5-decyne-4,7-diol	21,500
Cosmetics and personal care products	105-67-9	2,4-Dimethylphenol	42,920
Cosmetics and personal care products	1125-21-9	2,6,6-Trimethyl-2-cyclohexene-1,4-dione	300
Cosmetics and personal care products	576-26-1	2,6-Dimethylphenol	54,000.00
Cosmetics and personal care products	88-26-6	2,6-Di-tert-butyl-4-(hydroxymethyl)phenol	8,620
Cosmetics and personal care products	93-08-3	2'-Acetonaphthone	18,480
Cosmetics and personal care products	95-85-2	2-Amino-4-chlorophenol	3,660
Cosmetics and personal care products	104-76-7	2-Ethyl-1-hexanol	28,810
Cosmetics and personal care products	6197-30-4	2-Ethylhexyl-2-cyano-3,3-diphenylacrylate	183.8673837
Cosmetics and personal care products	131-57-7	2-Hydroxy-4-methoxybenzophenone	8,570
Cosmetics and personal care products	95-48-7	2-Methylphenol	65,964.04
Cosmetics and personal care products	88-75-5	2-Nitrophenol	92,000.00

Cosmetics and personal care products	121-00-6	2-tert-Butyl-4-methoxyphenol	26,243.01
Cosmetics and personal care products	106-44-5	3-&4-Methylphenol	49,470
Cosmetics and personal care products	18127-01-0	3-(4-tert-Butylphenyl)propanal	1,689.18
Cosmetics and personal care products	61792-11-8	3,7-Dimethylnona-2,6-dienenitrile	9,032.04
Cosmetics and personal care products	77439-76-0	3-Chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone	10,887.15
Cosmetics and personal care products	83-34-1	3-Methylindole	5,009.18
Cosmetics and personal care products	37677-14-8	4-(4-Methyl-3-pentenyl)cyclohex-3-ene-1-carbaldehyde	772.3313291
Cosmetics and personal care products	101-61-1	4,4'-Methylenebis(N,N-dimethylaniline)	1,382
Cosmetics and personal care products	59-50-7	4-Chloro-3-methylphenol	13,210
Cosmetics and personal care products	104-40-5	4-n-Nonylphenol	300
Cosmetics and personal care products	104-40-5	4-Nonylphenol	300
Cosmetics and personal care products	21145-77-7	7-Acetyl-1,1,3,4,4,6-hexamethyltetraline	417.0553759
Cosmetics and personal care products	88-29-9	7-acetyl-6-ethyl-1,1,4,4-tetramethyl tetralin	361.1268941
Cosmetics and personal care products	88-29-9	7-Acetyl-6-ethyl-1,1,4,4-tetramethyltetralin	361.1268941
Cosmetics and personal care products	3115-49-9	Acetic acid, 2-(4-nonylphenoxy)-	2,320
Cosmetics and personal care products	98-86-2	Acetophenone	209,000
Cosmetics and personal care products	77-90-7	Acetyl tributyl citrate	8,490
Cosmetics and personal care products	42615-29-2	Alkylbenzenesulfonate, linear	11,400
Cosmetics and personal care products	22839-47-0	Aspartame	25,670
Cosmetics and personal care products	119-61-9	Benzophenone	50,170
Cosmetics and personal care products	95-16-9	Benzothiazole	64,330
Cosmetics and personal care products	94-18-8	Benzyl 4-hydroxybenzoate	11,610
Cosmetics and personal care products	100-51-6	Benzyl alcohol	246,000
Cosmetics and personal care products	120-51-4	Benzyl benzoate	17,390
Cosmetics and personal care products	118-58-1	Benzyl salicylate	6,311.80
Cosmetics and personal care products	103-23-1	Bis(2-ethylhexyl)hexanedioate	27.67969854

Cosmetics and personal care products	106-97-8	Butane	12,850
Cosmetics and personal care products	25013-16-5	Butylated hydroxyanisole	26,243.01
Cosmetics and personal care products	128-37-0	Butylated hydroxytoluene	3,345.84
Cosmetics and personal care products	94-26-8	Butylparaben	19,869.08
Cosmetics and personal care products	123-72-8	Butyraldehyde	14,755.61
Cosmetics and personal care products	76-22-2	Camphor	3,200.00
Cosmetics and personal care products	75-45-6	Chlorodifluoromethane	2,630,145.65
Cosmetics and personal care products	38083-17-9	Climbazole	2,879.37
Cosmetics and personal care products	91-64-5	Coumarin	37,790
Cosmetics and personal care products	1222-05-5	Cyclopenta[g]-2-benzopyran, 1,3,4,6,7,8-hexahydro-4,6,6,7,8,8-hexamethyl-	492.3298489
Cosmetics and personal care products	84-74-2	Dibutyl phthalate	4,838.62
Cosmetics and personal care products	84-66-2	Diethyl phthalate	34,300
Cosmetics and personal care products	112-36-7	Diethylene glycol diethyl ether	115,000
Cosmetics and personal care products	17092-92-1	Dihydroactinidiolide	1,990.07
Cosmetics and personal care products	141-04-8	Diisobutyl adipate	8,674.31
Cosmetics and personal care products	67-71-0	Dimethyl sulfone	179,000
Cosmetics and personal care products	27503-81-7	Ensulizole	51,170
Cosmetics and personal care products	27986-36-3	Ethylene glycol nonylphenyl ether	1,924.26
Cosmetics and personal care products	120-47-8	Ethylparaben	67,312.44
Cosmetics and personal care products	507442-49-1	Galaxolidone	4,480
Cosmetics and personal care products	6259-76-3	Hexyl salicylate	1,922.25
Cosmetics and personal care products	78-59-1	Isophorone	166,000
Cosmetics and personal care products	1490-04-6	Menthol	43,260
Cosmetics and personal care products	2128-93-0	Methanone, [1,1'-biphenyl]-4-ylphenyl-	3,810
Cosmetics and personal care products	1235-74-1	methyl dehydroabietate	179.2329364
Cosmetics and personal care products	99-76-3	Methylparaben	20,000.00

Cosmetics and personal care products	81-14-1	Musk ketone	707.8607567
Cosmetics and personal care products	120-40-1	N,N-Bis(2-hydroxyethyl)dodecanamide	22,800
Cosmetics and personal care products	80-39-7	N-Ethyl-4-methylbenzenesulfonamide	86,179.04
Cosmetics and personal care products	1077-56-1	N-Ethyltoluene-2-sulphonamide	86,179.04
Cosmetics and personal care products	25154-52-3	n-Nonylphenol	807.1800694
Cosmetics and personal care products	84852-15-3	Nonylphenol	130.0000027
Cosmetics and personal care products	104-40-5	Nonylphenol	300
Cosmetics and personal care products	9016-45-9	Nonylphenoxypolyethoxyethanol	5,507.09
Cosmetics and personal care products	95-48-7	o-Cresol	65,964.04
Cosmetics and personal care products	5466-77-3	Octinoxate	791.0933346
Cosmetics and personal care products	27193-28-8	Octylphenol	1,564.51
Cosmetics and personal care products	59-50-7	p-Chlorocresol	13,210
Cosmetics and personal care products	106-44-5	p-Cresol	49,470
Cosmetics and personal care products	110-62-3	Pentanal	10,766.72
Cosmetics and personal care products	109-66-0	Pentane	17,790
Cosmetics and personal care products	2050-08-0	Pentyl 2-hydroxybenzoate	3,864.48
Cosmetics and personal care products	62-44-2	Phenacetin	102,098.44
Cosmetics and personal care products	108-95-2	Phenol	96,935.60
Cosmetics and personal care products	103-82-2	Phenylacetic acid	317,000
Cosmetics and personal care products	60-12-8	Phenylethyl alcohol	170,000
Cosmetics and personal care products	94-62-2	Piperine	3,175.02
Cosmetics and personal care products	94-13-3	Propylparaben	25,000
Cosmetics and personal care products	4065-45-6	Sulisobenzone	146,000
Cosmetics and personal care products	108-88-3	Toluene	51,630
Cosmetics and personal care products	620-40-6	Tribenzylamine	877.0680986
Cosmetics and personal care products	77-93-0	Triethyl citrate	28,920

Cosmetics and personal care products	2315-61-9	Triton X-100.2	7,030
Earth Elements	7429-90-5	Aluminum	4.059999883
Earth Elements	7440-36-0	Antimony	17,400.00
Earth Elements	7440-38-2	Arsenic	235,300
Earth Elements	7440-39-3	Barium	23,000.00
Earth Elements	24959-67-9	Bromide	1,000
Earth Elements	7440-43-9	Cadmium	80
Earth Elements	7440-44-0	Carbon	597,802.93
Earth Elements	7440-47-3	Chromium	6,500
Earth Elements	7440-48-4	Cobalt	106
Earth Elements	7440-50-8	Copper	200
Earth Elements	7439-89-6	Iron	16,000
Earth Elements	7439-92-1	Lead	121.9999981
Earth Elements	7439-96-5	Manganese	34,000,000
Earth Elements	7439-97-6	Mercury	50
Earth Elements	7440-02-0	Nickel	800
Earth Elements	7727-37-9	Nitrogen	8,440
Earth Elements	14265-44-2	Phosphate	297,100
Earth Elements	7723-14-0	Phosphorus	4,000.00
Earth Elements	7440-22-4	Silver	5.700000003
Earth Elements	7440-31-5	Tin	192.0000076
Earth Elements	7440-32-6	Titanium	730
Earth Elements	7440-62-2	Vanadium	2,200.00
Earth Elements	7440-66-6	Zinc	490.0000095
Flame retardants	134237-51-7	(+/-)-beta-Hexabromocyclododecane	1,030
Flame retardants	134237-52-8	(+/-)-gamma-Hexabromocyclododecane	1,030
Flame retardants	134237-50-6	(+/-)-α-Hexabromocyclododecane	1,030
Flame retardants	3194-55-6	1,2,5,6,9,10-Hexabromocyclododecane	1,030
Flame retardants	37853-59-1	1,2-Bis(2,4,6-tribromophenoxy)ethane	4.590986282
Flame retardants	3322-93-8	1,2-Dibromo-4-(1,2-dibromoethyl)cyclohexane	1,208.51
Flame retardants	79-94-7	3,3',5,5'-Tetrabromobisphenol A	320.00002
Flame retardants	76025-08-6	Bis(2-chloro-1-methylethyl) 2-chloropropyl phosphate	1,192.06
Flame retardants	2104-96-3	Bromofos	330
Flame retardants	2104-96-3	Bromophos	330
Flame retardants	4824-78-6	Bromophos-ethyl	190
Flame retardants	85535-84-8	C10-13 chloro alkanes	50
Flame retardants	56-23-5	Carbon tetrachloride	7,170.00
Flame retardants	57-74-9	Chlordane	5.096748355
Flame retardants	75-09-2	Dichloromethane	20,000
Flame retardants	60-57-1	Dieldrin	10
Flame retardants	101-84-8	Diphenyl ether	15,830
Flame retardants	101-84-8	Diphenyl oxide	15,830
Flame retardants	959-98-8	Endosulfan I	1,274.36
Flame retardants	87-82-1	Hexabromobenzene	1.59999996
Flame retardants	2385-85-5	Mirex	239.1102724
Flame retardants	1836-75-5	Nitrofen	4,540
Flame retardants	32534-81-9	Pentabromodiphenyl ether	0.5
Flame retardants	87-83-2	Pentabromotoluene	146.0000034
Flame retardants	1336-36-3	Polychlorinated biphenyls	480.6787241

Flame retardants	127-18-4	Tetrachloroethylene	7,751.79
Flame retardants	126-73-8	Tributyl phosphate	734.2040539
Flame retardants	126-71-6	Triisobutyl phosphate	784.0608247
Flame retardants	115-86-6	Triphenyl phosphate	691.5885955
Flame retardants	115-86-6	Triphenylphosphate	691.5885955
Flame retardants	13674-87-8	Tris(1,3-dichloro-2-propyl) phosphate	1,249.60
Flame retardants	78-51-3	Tris(2-butoxyethyl) phosphate	1,403.92
Flame retardants	115-96-8	Tris(2-chloroethyl) phosphate	1,509.02
Flame retardants	13674-84-5	Tris(2-chloroisopropyl)phosphate	1,192.06
Flame retardants	78-42-2	Tris(2-ethylhexyl) phosphate	3.824829764
Food and food additives	25013-16-5	Butylated hydroxyanisole	26,243.01
Food and food additives	58-08-2	Caffeine	397.0228601
Food and food additives	60-01-5	Glycerol tributyrate	16,640
Food and food additives	2216-51-5	L-Menthol	43,260
Food and food additives	108-67-8	Mesitylene	39,060
Food and food additives	56038-13-2	Sucralose	233,817,651.37
Industrials chemicals	156-59-2	(Z)-1,2-Dichloroethylene	9,519.36
Industrials chemicals	1506-02-1	1-(5,6,7,8-Tetrahydro-3,5,5,6,8,8-hexamethyl-2-naphthalenyl)ethanone	417.0553759
Industrials chemicals	75-35-4	1,1-Dichloroethylene	8,599.52
Industrials chemicals	634-66-2	1,2,3,4-Tetrachlorobenzene	2,020
Industrials chemicals	87-61-6	1,2,3-Trichlorobenzene	3,000
Industrials chemicals	95-94-3	1,2,4,5-Tetrachlorobenzene	2,060
Industrials chemicals	120-82-1	1,2,4-Trichlorobenzene	2,370
Industrials chemicals	541-73-1	1,3-Dichlorobenzene	10,000.00
Industrials chemicals	777-95-7	1,6-Dioxacyclododecane-7,12-dione	53,920
Industrials chemicals	90-13-1	1-Chloronaphthalene	7,000.00
Industrials chemicals	50-45-3	2,3-Dichlorobenzoic acid	14,540
Industrials chemicals	88-06-2	2,4,6-Trichlorophenol	180
Industrials chemicals	732-26-3	2,4,6-Tris(tert-butyl)phenol	2,150
Industrials chemicals	732-26-3	2,4,6-Tri-tert-butylphenol	2,150
Industrials chemicals	554-00-7	2,4-Dichloroaniline	930
Industrials chemicals	530-55-2	2,6-Dimethoxy-1,4-benzoquinone	4,218,840.03
Industrials chemicals	728-40-5	2,6-Di-tert-butyl-4-nitrophenol	4,779.15
Industrials chemicals	20427-84-3	2-[2-(4-Nonylphenoxy)ethoxy]ethanol	3,490
Industrials chemicals	719-59-5	2-Amino-5-chlorobenzophenone	1,560
Industrials chemicals	615-20-3	2-Chlorobenzothiazole	67,440
Industrials chemicals	91-58-7	2-Chloronaphthalene	13,860
Industrials chemicals	95-57-8	2-Chlorophenol	30,000
Industrials chemicals	10461-98-0	2-Cyclohexyl-2-phenylacetonitrile	3,074
Industrials chemicals	938-73-8	2-Ethoxybenzamide	107,000
Industrials chemicals	95-76-1	3,4-Dichloroaniline	310
Industrials chemicals	102-36-3	3,4-Dichlorophenyl isocyanate	33,679.45
Industrials chemicals	20189-42-8	3-Ethyl-4-methyl-1H-pyrrole-2,5-dione	6,272.76
Industrials chemicals	21494-57-5	3-Methyl-2-vinylmaleimide	6,579.97
Industrials chemicals	80-09-1	4,4'-Sulfonyldiphenol	49,080
Industrials chemicals	60-09-3	4-Aminoazobenzene	142.0000009
Industrials chemicals	106-47-8	4-Chloroaniline	1,880
Industrials chemicals	20665-85-4	4-Formyl-2-methoxyphenyl isobutyrate	10,292.95
Industrials chemicals	1137-42-4	4-Hydroxybenzophenone	32,170
Industrials chemicals	100-02-7	4-Nitrophenol	50,910
Industrials chemicals	140-66-9	4-tert-Octylphenol	100

Industrials chemicals	136-85-6	5-Methyl-1H-benzotriazole	105,386.87
Industrials chemicals	82304-66-3	7,9-di-tert-butyl-1-oxaspi- ro[4.5]deca-6,9-diene-2,8- dione	10,490
Industrials chemicals	82304-66-3	7,9-Di-tert-butyl-1-oxaspiro(4,5)deca-6,9-diene-2,8-dione	10,490
Industrials chemicals	71-43-2	Benzene	10,000
Industrials chemicals	3112-85-4	Benzene, (methylsulfonyl)-	83,260
Industrials chemicals	778-28-9	Benzenesulfonic acid, 4-methyl-, butyl ester	53,297.46
Industrials chemicals	941-57-1	Benzothiazole-2-sulfonic acid	41,930
Industrials chemicals	613-62-7	Benzyl 2-naphthyl ether	159.999996
Industrials chemicals	6422-86-2	Bis(2-ethylhexyl) terephthalate	15.19999981
Industrials chemicals	24038-68-4	BisOPP-A	4,590
Industrials chemicals	620-92-8	Bisphenol F	21,540
Industrials chemicals	75-27-4	Bromodichloromethane	78,000.00
Industrials chemicals	75-25-2	Bromoform	86,670
Industrials chemicals	05/11/3896	Bumetrizole	1,034.98
Industrials chemicals	124-48-1	Chlorodibromomethane	114,000
Industrials chemicals	67-66-3	Chloroform	2,500
Industrials chemicals	98-82-8	Cumene	20,500
Industrials chemicals	100-88-9	Cyclamic acid	244,268,750
Industrials chemicals	101-83-7	Cyclohexanamine, N-cyclohexyl-	1,635.73
Industrials chemicals	298-07-7	DEHPa	890.803989
Industrials chemicals	101-83-7	Dicyclohexylamine	1,635.73
Industrials chemicals	28553-12-0	Diisononyl phthalate	4.41873417
Industrials chemicals	64532-94-1	Diphenyl o-isopropylphenylphenyl phosphate	101.1936367
Industrials chemicals	127-63-9	Diphenylsulfone	8,740
Industrials chemicals	938-73-8	Ethenzamide	107,000
Industrials chemicals	7782-41-4	Fluorine	29,600
Industrials chemicals	3089-11-0	Hexa(methoxymethyl)melamine	31,830
Industrials chemicals	87-68-3	Hexachloro-1,3-butadiene	100
Industrials chemicals	118-74-1	Hexachlorobenzene	10
Industrials chemicals	13849-08-6	Marmesin	311,454.56
Industrials chemicals	1634-04-4	Methyl tert-butyl ether	204,000
Industrials chemicals	793-24-8	N-(1,3-Dimethylbutyl)-N'-phenyl-p-phenylenediamine	370.0000001
Industrials chemicals	1122-58-3	N,N-dimethylpyridin-4-amine	230,000
Industrials chemicals	98-95-3	Nitrobenzene	38,720
Industrials chemicals	08/10/4292	N-Laurylamidopropyl-N,N-dimethylbetaine	492,921.50
Industrials chemicals	2082-79-3	Octadecyl 3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate	92
Industrials chemicals	95-47-6	o-Xylene	29,450
Industrials chemicals	608-93-5	Pentachlorobenzene	7
Industrials chemicals	65796-87-4	Phenol, 2,6-bis(1,1-dimethylethyl)-4-(1,1,3,3-tetramethylbutyl)-	41.27607099
Industrials chemicals	59778-96-0	Phenol, 2,6-bis(1,1-dimethylethyl)-4-[(2,4,6-trimethylphenyl)methyl]-	1,066
Industrials chemicals	103-65-1	Propylbenzene	13,260
Industrials chemicals	438-67-5	Sodium estrone sulfate	9,766,367.34
Industrials chemicals	29385-43-1	Tolyltriazole	105,386.87
Industrials chemicals	36643-28-4	Tributylstannylium	0.2
Industrials chemicals	76-03-9	Trichloroacetic acid	932.0455603

Industrials chemicals	12002-48-1	Trichlorobenzene	400
Industrials chemicals	78-40-0	Triethyl phosphate	1,208.23
Industrials chemicals	108-38-3	Xylene (m)	55,890
Inorganics Anions	57-12-5	Cyanide	29,400
Inorganics Anions	14797-55-8	Nitrate	63,000
Metabolites	1438-62-6	13-Epimanool	27.14277478
Metabolites	83-33-0	1H-Inden-1-one, 2,3-dihydro-	108,000
Metabolites	127-54-8	2,2-Bis(4-hydroxy-3-isopropylphenyl)propane	1,410
Metabolites	603-79-2	2,3-Dimethylbenzoic acid	35,290
Metabolites	96-76-4	2,4-Di-tert-butylphenol	2,000.71
Metabolites	51146-55-5	2-Hydroxyibuprofen	18,540
Metabolites	1672-58-8	4-Formylaminoantipyrine	18,466.76
Metabolites	98-73-7	4-tert-Butylbenzoic acid	44,070
Metabolites	566-88-1	5alpha-Cholestan-3-One	13.22395838
Metabolites	529-38-4	Cocaethylene	19,440
Metabolites	67035-22-7	Dimethyl 2,6-dimethyl-4-(2-nitrophenyl)-3,5-pyridinedicarboxylate	17,520
Metabolites	03/11/2599	Hydroxysimazine	161,694.51
Metabolites	611-59-6	Paraxantine	366.6314064
Metabolites	34834-67-8	trans-3'-Hydroxycotinine	47,400
No class category defined	36557-05-8	11-Hydroxytetrahydrocannabinol	2,870
No class category defined	56354-06-4	11-Nor-9-carboxy-delta-9-tetrahydrocannabinol	2,110
No class category defined	615-22-5	2-(Methylthio)-benzothiazol	5,100
No class category defined	615-22-5	2-(Methylthio)benzothiazole	5,100
No class category defined	877-11-2	2,3,4,5,6-Pentachlorotoluene	870
No class category defined	501-34-8	2-{[(1-Hydroxy-2-phenylethylidene)amino]methyl}-5,5-dimethyl-1,3-thiazolidine-4-carboxylic acid	1,498,750.21
No class category defined	16584-00-2	2H-Benzotriazole, 2-methyl-	989,861.97
No class category defined	41889-45-6	3-(Benzoyloxy)-8-azabicyclo[3.2.1]octane-2-carboxylic acid	24,260
No class category defined	108-68-9	3,5-Dimethylphenol	44,132.88
No class category defined	1620-98-0	3,5-di-tert-Butyl-4-hydroxybenzaldehyde	1,608.07
No class category defined	1576-67-6	3,6-Dimethylphenanthrene	2,680
No class category defined	1844-01-5	4,4'-Dihydroxytetraphenylmethane	450
No class category defined	33665-90-6	Acesulfame	151,701,232.91
No class category defined	15234-85-2	Acetic acid, (4-octylphenoxy)-	3,090
No class category defined	1665-56-1	Anhydrotetracycline	30,041.07
No class category defined	4221-80-1	Benzoic acid, 3,5-bis(1,1-dimethylethyl)-4-hydroxy-, 2,4-bis(1,1-dimethylethyl)phenyl ester	1.745738336
No class category defined	25122-57-0	Clobetasone butyrate	7,224.52
No class category defined	126605-22-9	Dechlorometolachlor	4,756
No class category defined	60831-46-1	Di-O-demethylcurcumin	27,300
No class category defined	484-93-5	Ecgonidine	85,290
No class category defined	23313-80-6	Epitetracycline hydrochloride	174,572.97
No class category defined	514-36-3	Fludrocortisone acetate	6,500
No class category defined	18418-21-8	Hexadecanoic acid, (2,2-dimethyl-1,3-dioxolan-4-yl)methyl ester	1,714
No class category defined	514-53-4	Isochlortetracycline	17,785.24

No class category defined	4253-89-8	Isopropyl disulfide	37,403.86
No class category defined	3562-63-8	Megestrol	14,630
No class category defined	21312-10-7	N-Acetyl sulfamethoxazole	315,925.12
No class category defined	83-15-8	N-Acetylaminoantipyrine	26,112.57
No class category defined	58817-05-3	Octyl dimethyl 4-aminobenzoic acid	1,540
No class category defined	879-65-2	Quinoxaline-2-carboxylic acid	41,400
No class category defined	1605-73-8	tert-Butyl radical	2,570
Perfluorinated compounds	3330-15-2	Perfluoro-3-(1H-perfluoroethoxy)propane	109,169.36
Perfluorinated compounds	375-73-5	Perfluorobutanesulfonic acid	1,868,649.60
Perfluorinated compounds	375-22-4	Perfluorobutanoic acid	7,684,498.60
Perfluorinated compounds	307-24-4	Perfluorohexanoic acid	226,112.86
Perfluorinated compounds	375-95-1	Perfluorononanoic acid	80
Perfluorinated compounds	335-67-1	Perfluorooctanoic acid	26,826.82
Perfluorinated compounds	2706-90-3	Perfluoropentanoic acid	3,001,837.73
Perfluorinated compounds	423-41-6	Perfluoropropanesulfonic acid	49,178,683.47
Perfluorinated compounds	422-64-0	Perfluoropropanoic acid	18,597,979.74
Pesticides	75-34-3	1,1-Dichloroethane	53,000.00
Pesticides	107-06-2	1,2-Dichloroethane	10,000
Pesticides	106-46-7	1,4-Dichlorobenzene	5,520
Pesticides	123-91-1	1,4-Dioxane	394,000
Pesticides	288-88-0	1H-1,2,4-Triazole	245,280.62
Pesticides	90-12-0	1-Methylnaphthalene	11,320
Pesticides	117-18-0	2,3,5,6-Tetrachloronitrobenzene	3,960
Pesticides	93-76-5	2,4,5-Trichlorophenoxyacetic acid	13,060
Pesticides	25168-26-7	2,4-D isooctyl ester	202.9312775
Pesticides	120-83-2	2,4-Dichlorophenol	10,020
Pesticides	2008-58-4	2,6-Dichlorobenzamide	29,560
Pesticides	24157-81-1	2,6-Diisopropylnaphthalene	574.925635
Pesticides	41814-78-2	2,7,8,9-Tricyclazole	374,667.62
Pesticides	2163-68-0	2-Hydroxyatrazine	110,069.88
Pesticides	2814-20-2	2-Isopropyl-6-methyl-4-pyrimidone	80,175.02
Pesticides	534-52-1	2-Methyl-4,6-dinitrophenol	1,000
Pesticides	55701-05-8	3-(2,2-Dichlorovinyl)-2,2-dimethylcyclopropanecarboxylic acid	24,170
Pesticides	08/02/2327	3,4-Dichlorophenylurea	10,339.77
Pesticides	3337-62-0	3,5-Dibromo-4-hydroxybenzoic acid	37,410
Pesticides	3739-38-6	3-Phenoxybenzoic acid	12,620
Pesticides	80-46-6	4-(2-Methylbutan-2-yl)phenol	10,000.00
Pesticides	28343-61-5	4-Hydroxy-2,5,6-trichloroisophthalonitrile	16,360
Pesticides	3397-62-4	6-Chloro-1,3,5-triazine-2,4-diamine	5,415.07
Pesticides	30560-19-1	Acephate	2,061.21
Pesticides	34256-82-1	Acetochlor	40.41998473
Pesticides	74070-46-5	Aclonifen	1,650
Pesticides	58-89-9	a-HCH	2,280
Pesticides	15972-60-8	Alachlor	40.41998473
Pesticides	309-00-2	Aldrin	1.170956748
Pesticides	319-84-6	alpha-1,2,3,4,5,6-Hexachlorocyclohexane	2,280
Pesticides	834-12-8	Ametryn	109.9999994
Pesticides	120923-37-7	Amidosulfuron	3,726.84
Pesticides	1066-51-9	Aminomethylphosphonic acid	64,664,862.06
Pesticides	33089-61-1	Amitraz	433.8983446
Pesticides	1610-17-9	Atraton	33,770.19

Pesticides	1912-24-9	Atrazine	600
Pesticides	2642-71-9	Azinphos-ethyl	2,059.89
Pesticides	86-50-0	Azinphos-methyl	2,977.72
Pesticides	82560-54-1	Benfuracarb	145.1614546
Pesticides	83055-99-6	Bensulfuron-methyl	2,855.95
Pesticides	25057-89-0	Bentazone	137,272.99
Pesticides	1224510-29-5	beta-Cypermethrin	1,879
Pesticides	319-85-7	beta-Hexachlorocyclohexane	2,280
Pesticides	42576-02-3	Bifenox	5,530
Pesticides	92-52-4	Biphenyl	700.0000216
Pesticides	55179-31-2	Bitertanol	1,453.06
Pesticides	188425-85-6	Boscalid	680
Pesticides	314-40-9	Bromacil	540.8451427
Pesticides	18181-80-1	Bromopropylate	342
Pesticides	1689-84-5	Bromoxynil	23,540
Pesticides	69327-76-0	Buprofezin	5,366.31
Pesticides	23184-66-9	Butachlor	1.191317733
Pesticides	33629-47-9	Butralin	4,770
Pesticides	95465-99-9	Cadusafos	711.3075815
Pesticides	63-25-2	Carbaryl	20
Pesticides	10605-21-7	Carbendazim	21,451.77
Pesticides	1563-66-2	Carbofuran	1,600.14
Pesticides	55285-14-8	Carbosulfan	9.955091809
Pesticides	5234-68-4	Carboxin	11,051.27
Pesticides	133-90-4	Chloramben	1,560
Pesticides	500008-45-7	Chlorantraniliprole	28.6
Pesticides	470-90-6	Chlorfenvinphos	100
Pesticides	510-15-6	Chlorobenzilate	5,840
Pesticides	1982-47-4	Chloroxuron	2,479.34
Pesticides	1321-23-9	Chloroxylenol	30,529.09
Pesticides	2921-88-2	Chlorpyrifos	0.972585331
Pesticides	5103-71-9	cis-Chlordane	5.096748355
Pesticides	74115-24-5	Clofentezine	966
Pesticides	882-09-7	Clofibric acid	36,420
Pesticides	81777-89-1	Clomazone	27,148.07
Pesticides	56-72-4	Coumaphos	6.970755203
Pesticides	21725-46-2	Cyanazine	82,258.78
Pesticides	113136-77-9	Cyclanilide	24,110
Pesticides	2163-69-1	Cycluron	4,876.98
Pesticides	61676-87-7	Cymiazole	20,931.48
Pesticides	121552-61-2	Cyprodinil	9,930
Pesticides	75-99-0	Dalapon	788.0839519
Pesticides	6190-65-4	Deethylatrazine	95,040
Pesticides	1007-28-9	Deisopropylatrazine	192,000
Pesticides	1918-00-9	Dicamba	19,590
Pesticides	1194-65-6	Dichlobenil	23,120
Pesticides	97-17-6	Dichlofenthion	0.833146769
Pesticides	50-29-3	Dichlorodiphenyltrichloroethane	10
Pesticides	120-36-5	Dichlorprop	34,340
Pesticides	115-32-2	Dicofol	186
Pesticides	20256-56-8	Didecyldimethylammonium	5,520
Pesticides	87130-20-9	Diethofencarb	16,440

Pesticides	119446-68-3	Difenoconazole	365.0826402
Pesticides	22936-75-0	Dimethametryn	11,460.18
Pesticides	87674-68-8	Dimethenamid	305.0587839
Pesticides	110488-70-5	Dimethomorph	12,083.54
Pesticides	83657-24-3	Diniconazole	1,735.54
Pesticides	973-21-7	Dinobuton	1,710
Pesticides	6988-21-2	Dioxacarb	54,991.46
Pesticides	122-39-4	Diphenylamine	7,600
Pesticides	330-54-1	Diuron	200
Pesticides	115-29-7	Endosulfan	5
Pesticides	33213-65-9	Endosulfan II	1,274.36
Pesticides	72-20-8	Endrin	10
Pesticides	133855-98-8	Epoxiconazole	727.7812809
Pesticides	55283-68-6	Ethalfluralin	3,368
Pesticides	563-12-2	Ethion	115.7322247
Pesticides	91-53-2	Ethoxyquin	3,200.00
Pesticides	96-45-7	Ethylene thiourea	34,400
Pesticides	60168-88-9	Fenarimol	6,093.81
Pesticides	120928-09-8	Fenazaquin	1,554.73
Pesticides	114369-43-6	Fenbuconazole	233.2923375
Pesticides	126833-17-8	Fenhexamid	3,660
Pesticides	122-14-5	Fenitrothion	6,510
Pesticides	3766-81-2	Fenobucarb	30.00000143
Pesticides	39515-41-8	Fenpropathrin	8.23475857
Pesticides	55-38-9	Fenthion	2.5
Pesticides	3761-41-9	Fenthion sulfoxide	4.197745002
Pesticides	69335-91-7	Fluazifop	990,881.35
Pesticides	79241-46-6	Fluazifop-P-butyl	2,154.85
Pesticides	142459-58-3	Flufenacet	77,516.07
Pesticides	66332-96-5	Flutolanil	7,320
Pesticides	68157-60-8	Forchlorfenuron	8,672.06
Pesticides	1071-83-6	Glyphosate	378,732,656.25
Pesticides	76-44-8	Heptachlor	13.89336423
Pesticides	1024-57-3	Heptachlor epoxide B	533.0716446
Pesticides	79983-71-4	Hexaconazole	2,394.70
Pesticides	51235-04-2	Hexazinone	39,010.24
Pesticides	78587-05-0	Hexythiazox	310.591748
Pesticides	81334-34-1	Imazapyr	1,941,999.97
Pesticides	81335-37-7	Imazaquin	332,750.70
Pesticides	138261-41-3	Imidacloprid	307,226.66
Pesticides	87-51-4	Indole-3-acetic acid	190,000
Pesticides	125225-28-7	Ipconazole	646.0000761
Pesticides	465-73-6	Isodrin	10
Pesticides	2631-40-5	Isoprocarb	1,241.07
Pesticides	50512-35-1	Isoprothiolane	13,660
Pesticides	143390-89-0	Kresoxim methyl	250.421348
Pesticides	143390-89-0	Kresoxim-methyl	250.421348
Pesticides	58-89-9	Lindane	2,280
Pesticides	330-55-2	Linuron	5,780.14
Pesticides	374726-62-2	Mandipropamid	2,063
Pesticides	94-74-6	MCPA	25,190
Pesticides	93-65-2	Mecoprop	45,480

Pesticides	73250-68-7	Mefenacet	36,769.92
Pesticides	104206-82-8	Mesotrione	6,304
Pesticides	3761-41-9	Mesulfenfos	4.197745002
Pesticides	57837-19-1	Metalaxyl	62,700
Pesticides	41394-05-2	Metamitron	10,454.99
Pesticides	72-43-5	Methoxychlor	100
Pesticides	161050-58-4	Methoxyfenozide	2,793
Pesticides	298-00-0	Methyl parathion	7,322
Pesticides	119-36-8	Methyl salicylate	55,164.34
Pesticides	51218-45-2	Metolachlor	59.04245772
Pesticides	1129-41-5	Metolcarb	3,242.71
Pesticides	220899-03-6	Metrafenone	4,220
Pesticides	21087-64-9	Metribuzin	2,130
Pesticides	35045-02-4	Metribuzin DA	6,315.85
Pesticides	35045-02-4	Metribuzin-DA	6,315.85
Pesticides	7786-34-7	Mevinphos	1,535.99
Pesticides	2212-67-1	Molinate	16,058
Pesticides	6923-22-4	Monocrotophos	74,000
Pesticides	88671-89-0	Myclobutanil	2,739.79
Pesticides	3567-62-2	N-(3,4-Dichlorophenyl)-N'-methylurea	7,431.88
Pesticides	52570-16-8	Naproanilide	3,961.54
Pesticides	555-37-3	Neburon	2,226.93
Pesticides	55283-68-6	N-Ethyl-N-(2-methyl-2-propenyl)-2,6-dinitro-4-(trifluoromethyl)benzenamine	3,368
Pesticides	120738-89-8	Nitenpyram	399,426.60
Pesticides	1113-02-6	Omethoate	49,800
Pesticides	19044-88-3	Oryzalin	3,994.63
Pesticides	19666-30-9	Oxadiazon	2,651.29
Pesticides	77732-09-3	Oxadixyl	14,653.84
Pesticides	72-54-8	p,p'-DDD	562
Pesticides	50-29-3	p,p'-DDT	10
Pesticides	76738-62-0	Paclobutrazol	3,398.39
Pesticides	66246-88-6	Penconazole	531.6355266
Pesticides	66063-05-6	Pencycuron	493.4413824
Pesticides	40487-42-1	Pendimethalin	409.4123375
Pesticides	87-86-5	Pentachlorophenol	5.33
Pesticides	87-41-2	Phthalide	214,000
Pesticides	01/02/1918	Picloram	98,325.74
Pesticides	23103-98-2	Pirimicarb	8,111.41
Pesticides	67747-09-5	Prochloraz	1,393.63
Pesticides	32809-16-8	Procymidone	6,476
Pesticides	2631-37-0	Promecarb	333.199231
Pesticides	1610-18-0	Prometon	21,981.40
Pesticides	24579-73-5	Propamocarb	108,703.16
Pesticides	709-98-8	Propanil	1,300
Pesticides	139-40-2	Propazine	14,270
Pesticides	122-42-9	Propham	45,990
Pesticides	114-26-1	Propoxur	2,995.45
Pesticides	23950-58-5	Propyzamide	2,274
Pesticides	52888-80-9	Prosulfocarb	2,284.98
Pesticides	34643-46-4	Prothiofos	44
Pesticides	123312-89-0	Pymetrozin	14,467.00

Pesticides	123312-89-0	Pymetrozine	14,467.00
Pesticides	175013-18-0	Pyraclostrobin	369.1574791
Pesticides	13457-18-6	Pyrazophos	10.13906294
Pesticides	96489-71-3	Pyridaben	1.8
Pesticides	53112-28-0	Pyrimethanil	1,500
Pesticides	84087-01-4	Quinclorac	3,098
Pesticides	124495-18-7	Quinoxyfen	306
Pesticides	100646-51-3	Quizalofop-P-ethyl	1,758
Pesticides	81-07-2	Saccharin	16,888.95
Pesticides	1982-49-6	Siduron	2,398.72
Pesticides	122-34-9	Simazine	1,000
Pesticides	673-04-1	Simetone	51,652.69
Pesticides	118134-30-8	Spiroxamine	477.4065223
Pesticides	100-42-5	Styrene	25,520
Pesticides	63-74-1	Sulfanilamide	220,000.00
Pesticides	59-40-5	Sulfaquinoxaline	53,061.47
Pesticides	122836-35-5	Sulfentrazone	11,516.28
Pesticides	74222-97-2	Sulfometuron-methyl	2,430.17
Pesticides	141776-32-1	Sulfosulfuron	3,469.16
Pesticides	119168-77-3	Tebufenpyrad	207.0647664
Pesticides	34014-18-1	Tebuthiuron	13,841.79
Pesticides	117-18-0	Tecnazene	3,960
Pesticides	149979-41-9	Tepraloxydim	12,903.20
Pesticides	886-50-0	Terbutryn	18,550.55
Pesticides	5915-41-3	Terbutylazine	31,802.18
Pesticides	112281-77-3	Tetraconazole	1,254.01
Pesticides	640-15-3	Thiometon	50
Pesticides	23564-05-8	Thiophanate-methyl	1,352
Pesticides	57018-04-9	Tolclofos-methyl	660
Pesticides	87820-88-0	Tralkoxydim	1,550.57
Pesticides	5103-74-2	trans-Chlordane	5.096748355
Pesticides	55335-06-3	Triclopyr	33,352.24
Pesticides	41814-78-2	Tricyclazole	374,667.62
Pesticides	141517-21-7	Trifloxystrobin	82.59546012
Pesticides	1582-09-8	Trifluralin	30
Pesticides	95266-40-3	Trinexapac-ethyl	13,400
Pesticides	50471-44-8	Vinclozolin	6,206
Pesticides	1315501-18-8	zeta-Cypermethrin	1,879
Petrochemicals	124-18-5	Decane	390.6188533
Petrochemicals	629-97-0	Docosane	72
Petrochemicals	112-40-3	Dodecane	341.3673723
Petrochemicals	544-85-4	Dotriacontane	14
Petrochemicals	112-95-8	Eicosane	0.257269107
Petrochemicals	629-94-7	Heneicosane	88
Petrochemicals	629-78-7	Heptadecane	3.924961129
Petrochemicals	630-01-3	Hexacosane	0.001039077
Petrochemicals	544-76-3	Hexadecane	9.673018212
Petrochemicals	629-92-5	Nonadecane	0.639884229
Petrochemicals	111-84-2	Nonane	921.5246886
Petrochemicals	630-02-4	Octacosane	26
Petrochemicals	593-45-3	Octadecane	1.587192128
Petrochemicals	629-99-2	Pentacosane	44

Petrochemicals	629-62-9	Pentadecane	1,140
Petrochemicals	629-59-4	Tetradecane	58.0467924
Petrochemicals	638-67-5	Tricosane	0.016489115
Petrochemicals	629-50-5	Tridecane	141.1760109
Petrochemicals	1120-21-4	Undecane	1,720
Pharmaceuticals	52-53-9	(+/-)-Verapamil	2,361.36
Pharmaceuticals	53-19-0	1-(2-Chlorophenyl)-1-(4-chlorophenyl)-2,2-dichloroethane	1,301.44
Pharmaceuticals	6640-24-0	1-(3-Chlorophenyl)piperazine	29,039.01
Pharmaceuticals	53-86-1	1-(p-Chlorobenzoyl)-5-methoxy-2-methyl-Indole-3-acetic acid	3,701.02
Pharmaceuticals	95-50-1	1,2-Dichlorobenzene	10,000.00
Pharmaceuticals	108-70-3	1,3,5-Trichlorobenzene	8,150
Pharmaceuticals	68-96-2	17alpha-Hydroxyprogesterone	14,290
Pharmaceuticals	50-28-2	17beta-Estradiol	8.3
Pharmaceuticals	10161-33-8	17beta-Trenbolone	10,360
Pharmaceuticals	57-63-6	17α-ethinylestradiol	1,000
Pharmaceuticals	97-00-7	1-Chloro-2,4-dinitrobenzene	600.0000052
Pharmaceuticals	51-28-5	2,4-Dinitrophenol	45,080
Pharmaceuticals	486-56-6	2-pyrrolidinone, 1-methyl-5- (3-pyridinyl)-	299,000
Pharmaceuticals	561-27-3	3,6-Diacetylmorphine	26,100
Pharmaceuticals	30516-87-1	3'-Azido-3'-deoxythymidine	546.7108451
Pharmaceuticals	599-64-4	4-Cumylphenol	11,020
Pharmaceuticals	57-41-0	5,5-Diphenylhydantoin	524.6512126
Pharmaceuticals	521-18-6	5alpha-Dihydrotestosterone	10,220
Pharmaceuticals	2784-73-8	6-O-Monoacetylmorphine	28,910
Pharmaceuticals	486-66-8	7,4'-Dihydroxyisoflavone	6,828
Pharmaceuticals	34084-50-9	7-Aminoflunitrazepam	1,415
Pharmaceuticals	136470-78-5	Abacavir	29,956.90
Pharmaceuticals	103-90-2	Acetaminophen	18,898.88
Pharmaceuticals	5234-26-4	Acetanilide, 2'-acetyl-	84,780
Pharmaceuticals	968-81-0	Acetohexamide	1,959.00
Pharmaceuticals	498-02-2	Acetovanillone	48,580
Pharmaceuticals	59277-89-3	Acyclovir	711,732.29
Pharmaceuticals	18559-94-9	Albuterol	24,806.23
Pharmaceuticals	52-39-1	Aldosterone	36,620
Pharmaceuticals	28981-97-7	Alprazolam	1,763.01
Pharmaceuticals	768-94-5	Amantadine	16,417.84
Pharmaceuticals	71675-85-9	Amisulpride	115,000
Pharmaceuticals	50-48-6	Amitriptyline	1,185.55
Pharmaceuticals	88150-42-9	Amlodipine	49,110
Pharmaceuticals	300-62-9	Amphetamine	34,813.76
Pharmaceuticals	51264-14-3	Amsacrine	1,097.52
Pharmaceuticals	60-80-0	Antipyrine	14,381.57
Pharmaceuticals	50-78-2	Aspirin	67,230
Pharmaceuticals	29122-68-7	Atenolol	24,260
Pharmaceuticals	51-55-8	Atropine	52,300
Pharmaceuticals	446-86-6	Azathioprine	168,183.49
Pharmaceuticals	4419-39-0	Beclomethasone	27,790
Pharmaceuticals	519-09-5	Benzoylecgonine	31,820
Pharmaceuticals	86-13-5	Benztropine	3,086.37
Pharmaceuticals	378-44-9	Betamethasone	7,986

Pharmaceuticals	41859-67-0	Bezafibrate	3,150
Pharmaceuticals	66722-44-9	Bisoprolol	27,160
Pharmaceuticals	1812-30-2	Bromazepam	7,900
Pharmaceuticals	51333-22-3	Budesonide	11,748
Pharmaceuticals	34911-55-2	Bupropion	4,173.61
Pharmaceuticals	55-98-1	Busulfan	15,854,429.63
Pharmaceuticals	298-46-4	Carbamazepin	9,608.03
Pharmaceuticals	298-46-4	Carbamazepine	9,608.03
Pharmaceuticals	78-44-4	Carisoprodol	19,450
Pharmaceuticals	83881-51-0	Cetirizine	5,000
Pharmaceuticals	79-11-8	Chloroacetic acid	579.9999926
Pharmaceuticals	132-22-9	Chlorpheniramine	5,006.74
Pharmaceuticals	57-62-5	Chlortetracycline	5,000
Pharmaceuticals	51481-61-9	Cimetidine	60,870
Pharmaceuticals	59729-33-8	Citalopram	6,522.83
Pharmaceuticals	37148-27-9	Clenbuterol	1,660
Pharmaceuticals	25122-46-7	Clobetasol propionate	10,201.24
Pharmaceuticals	911-45-5	Clomiphene	6.700240192
Pharmaceuticals	303-49-1	Clomipramine	1,660
Pharmaceuticals	2971-90-6	Clopidol	14,260
Pharmaceuticals	23593-75-1	Clotrimazole	21.33044647
Pharmaceuticals	50-36-2	Cocaine	28,260
Pharmaceuticals	76-57-3	Codeine	25,520
Pharmaceuticals	64-86-8	Colchicine	63,730
Pharmaceuticals	50-22-6	Corticosterone	29,610
Pharmaceuticals	53-06-5	Cortisone	35,720
Pharmaceuticals	486-56-6	Cotinine	299,000
Pharmaceuticals	483-63-6	Crotamiton	5,322.39
Pharmaceuticals	50-18-0	Cyclophosphamide	1,679.99
Pharmaceuticals	20830-81-3	Daunorubicin	24,832.48
Pharmaceuticals	541-02-6	Decamethylcyclopentasiloxane	173.9999962
Pharmaceuticals	14484-47-0	Deflazacort	8,180
Pharmaceuticals	56-47-3	Deoxycorticosterone acetate	12,080
Pharmaceuticals	1088-11-5	Desmethyldiazepam	7,140
Pharmaceuticals	50-02-2	Dexamethasone	7,986
Pharmaceuticals	125-71-3	Dextromethorphan	4,070
Pharmaceuticals	125-73-5	Dextrorphan	7,140
Pharmaceuticals	439-14-5	Diazepam	7,820
Pharmaceuticals	15307-86-5	Diclofenac	6,010
Pharmaceuticals	56-53-1	Diethylstilbestrol	2,630
Pharmaceuticals	98106-17-3	Difloxacin	1,886,872.67
Pharmaceuticals	1672-46-4	Digoxigenin	8,051.63
Pharmaceuticals	20830-75-5	Digoxin	29,580
Pharmaceuticals	509-60-4	Dihydromorphine	20,260
Pharmaceuticals	519-65-3	Dioxypyramidon	37,425.93
Pharmaceuticals	58-73-1	Diphenhydramine	11,611.97
Pharmaceuticals	630-93-3	Diphenylhydantoin sodium	524.6512126
Pharmaceuticals	58-32-2	Dipyridamole	4,742
Pharmaceuticals	63-84-3	dl-Dopa	50,840
Pharmaceuticals	1668-19-5	Doxepin	4,080.46
Pharmaceuticals	23214-92-8	Doxorubicin	30,348.08
Pharmaceuticals	67392-87-4	Drospirenone	10,950

Pharmaceuticals	154598-52-4	Efavirenz	13,045.69
Pharmaceuticals	143491-57-0	Emtricitabine	16,274,276.73
Pharmaceuticals	75847-73-3	Enalapril	31,820
Pharmaceuticals	36861-47-9	Enzacamene	1,496.78
Pharmaceuticals	79-85-6	Epitetracycline	78,900.96
Pharmaceuticals	474-86-2	Equilin	9,250
Pharmaceuticals	29975-16-4	Estazolam	3,599.10
Pharmaceuticals	50-27-1	Estriol	10,580
Pharmaceuticals	53-16-7	Estrone	4,790
Pharmaceuticals	434-03-7	Ethisterone	1,590
Pharmaceuticals	60-00-4	Ethylenediaminetetraacetic acid	10,000.00
Pharmaceuticals	33419-42-0	Etoposide	182,578.18
Pharmaceuticals	76824-35-6	Famotidine	1,914,927.67
Pharmaceuticals	25451-15-4	Felbamate	19,910
Pharmaceuticals	49562-28-9	Fenofibrate	6,370
Pharmaceuticals	29679-58-1	Fenoprofen	9,440
Pharmaceuticals	83799-24-0	Fexofenadine	33,260.72
Pharmaceuticals	54143-55-4	Flecainide	6,357.36
Pharmaceuticals	530-78-9	Flufenamic acid	4,240
Pharmaceuticals	03/03/3385	Flunisolide	80,836.75
Pharmaceuticals	426-13-1	Fluorometholone	7,442
Pharmaceuticals	54910-89-3	Fluoxetine	1,943.86
Pharmaceuticals	54-31-9	Furosemide	157,281.16
Pharmaceuticals	60142-96-3	Gabapentin	90,970
Pharmaceuticals	25812-30-0	Gemfibrozil	5,920
Pharmaceuticals	446-72-0	Genistein	44,459.27
Pharmaceuticals	29094-61-9	Glipizide	2,373.80
Pharmaceuticals	10238-21-8	Glybenclamide	2,157.16
Pharmaceuticals	126-07-8	Griseofulvin	10,100
Pharmaceuticals	58-93-5	Hydrochlorothiazide	1,872,663.69
Pharmaceuticals	125-29-1	Hydrocodone	22,430
Pharmaceuticals	50-23-7	Hydrocortisone	29,930
Pharmaceuticals	15687-27-1	Ibuprofen	26,650
Pharmaceuticals	23210-56-2	Ifenprodil	3,994
Pharmaceuticals	60166-93-0	Iopamidol	27,766,439.82
Pharmaceuticals	6740-88-1	Ketamine	10,572.84
Pharmaceuticals	22071-15-4	Ketoprofen	9,500
Pharmaceuticals	134678-17-4	Lamivudine	3,236,686.71
Pharmaceuticals	84057-84-1	Lamotrigine	1,181.77
Pharmaceuticals	77-07-6	Levorphanol	6,245.12
Pharmaceuticals	137-58-6	Lidocaine	12,870
Pharmaceuticals	79794-75-5	Loratadine	862.5879884
Pharmaceuticals	846-49-1	Lorazepam	67,311.51
Pharmaceuticals	114798-26-4	Losartan	2,934.58
Pharmaceuticals	50-37-3	Lysergide	2,394
Pharmaceuticals	42542-10-9	MDMA	16,854
Pharmaceuticals	71-58-9	Medroxyprogesterone acetate	15,148.85
Pharmaceuticals	61-68-7	Mefenamic acid	3,330
Pharmaceuticals	148-82-3	Melphalan	36,290
Pharmaceuticals	1189805-46-6	Mephedrone	70,700
Pharmaceuticals	96-88-8	Mepivacaine	11,940
Pharmaceuticals	57-53-4	Meprobamate	124,000

Pharmaceuticals	1665-48-1	Metaxalone	16,530
Pharmaceuticals	657-24-9	Metformin	1,319,000
Pharmaceuticals	76-99-3	Methadone	3,609.03
Pharmaceuticals	537-46-2	Methamphetamine	21,131.30
Pharmaceuticals	532-03-6	Methocarbamol	24,750
Pharmaceuticals	552-79-4	Methylephedrine	139,401.16
Pharmaceuticals	83-43-2	Methylprednisolone	28,190
Pharmaceuticals	53-36-1	Methylprednisolone acetate	32,260
Pharmaceuticals	51384-51-1	Metoprolol	17,950
Pharmaceuticals	56392-14-4	Metoprolol acid	23,750
Pharmaceuticals	24219-97-4	Mianserin	8,813.15
Pharmaceuticals	17090-79-8	Monensin	14,500
Pharmaceuticals	57-27-2	Morphine	24,730
Pharmaceuticals	465-65-6	Naloxone	27,940
Pharmaceuticals	22204-53-1	Naproxen	9,150
Pharmaceuticals	3622-84-2	N-Butylbenzenesulfonamide	51,102.33
Pharmaceuticals	129618-40-2	Nevirapine	7,427.25
Pharmaceuticals	2591-86-8	N-Formylpiperidine	349,408.13
Pharmaceuticals	54-11-5	Nicotine	110,409.67
Pharmaceuticals	21829-25-4	Nifedipine	4,844
Pharmaceuticals	18717-72-1	Norcocaine	32,230
Pharmaceuticals	467-15-2	Norcodeine	32,550
Pharmaceuticals	68-22-4	Norethindrone	1,694
Pharmaceuticals	83891-03-6	Norfluoxetine	3,868
Pharmaceuticals	35189-28-7	Norgestimate	1,509.57
Pharmaceuticals	72-69-5	Nortriptyline	364
Pharmaceuticals	67018-85-3	Norverapamil	10,480
Pharmaceuticals	53-19-0	o,p'-DDD	1,301.44
Pharmaceuticals	93413-62-8	O-Desmethyl Venlafaxine	9,444.14
Pharmaceuticals	3922-90-5	Oleandomycin	5,519.07
Pharmaceuticals	73590-58-6	Omeprazole	5,630.00
Pharmaceuticals	6981-18-6	Ormetoprim	936.1796081
Pharmaceuticals	16773-42-5	Ornidazole	61,099.55
Pharmaceuticals	196618-13-0	Oseltamivir	34,570
Pharmaceuticals	604-75-1	Oxazepam	67,481.99
Pharmaceuticals	28721-07-5	Oxcarbazepine	21,450
Pharmaceuticals	959-14-8	Oxolamine	29,188.31
Pharmaceuticals	76-42-6	Oxycodone	30,650
Pharmaceuticals	61869-08-7	Paroxetine	5,047.74
Pharmaceuticals	60-80-0	Phenazone	14,381.57
Pharmaceuticals	630-93-3	Phenytoin	524.6512126
Pharmaceuticals	28797-61-7	Pirenzepine	99,062.19
Pharmaceuticals	50-24-8	Prednisolone	25,800
Pharmaceuticals	53-03-2	Prednisone	31,480
Pharmaceuticals	148553-50-8	Pregabalin	89,970
Pharmaceuticals	125-33-7	Primidone	344,000
Pharmaceuticals	57-83-0	Progesterone	7,380
Pharmaceuticals	60-87-7	Promethazine	2,198.70
Pharmaceuticals	469-62-5	Propoxyphene	853.6118083
Pharmaceuticals	525-66-6	Propranolol	13,630
Pharmaceuticals	479-92-5	Propyphenazone	9,017.91
Pharmaceuticals	90-82-4	Pseudoephedrine	168,501.31

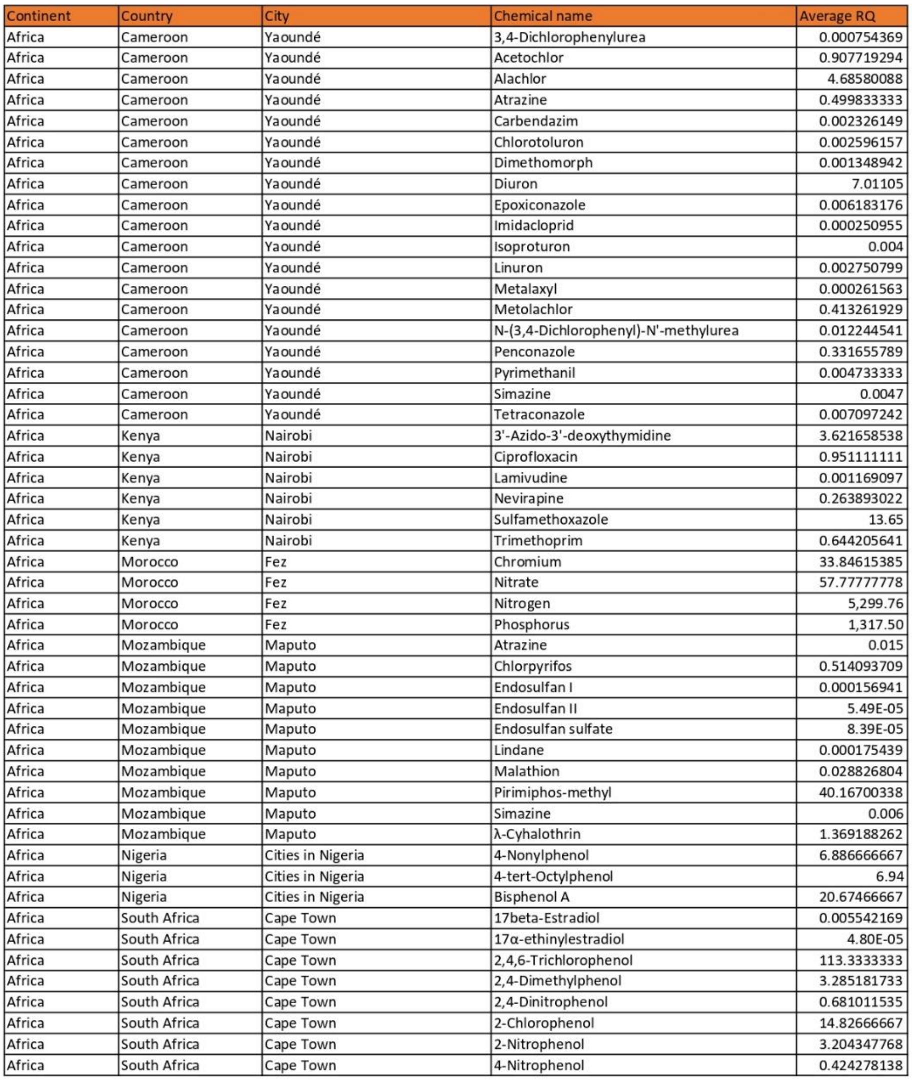
Pharmaceuticals	58-14-0	Pyrimethamine	414.5288095
Pharmaceuticals	84449-90-1	Raloxifene	899
Pharmaceuticals	66357-35-5	Ranitidine	528,354.74
Pharmaceuticals	106266-06-2	Risperidone	11,423.40
Pharmaceuticals	287714-41-4	Rosuvastatin	139,444.91
Pharmaceuticals	18559-94-9	Salbutamol	24,806.23
Pharmaceuticals	69-72-7	Salicylic acid	100,000
Pharmaceuticals	98105-99-8	Sarafloxacin	2,387,472.92
Pharmaceuticals	79617-96-2	Sertraline	740.9658283
Pharmaceuticals	139755-83-2	Sildenafil	20,707.06
Pharmaceuticals	79902-63-9	Simvastatin	2,942.17
Pharmaceuticals	486460-32-6	Sitagliptin	72,839.65
Pharmaceuticals	3930-20-9	Sotalol	415,435.03
Pharmaceuticals	80-32-0	Sulfachloropyridazine	1,035,308.55
Pharmaceuticals	127-79-7	Sulfamerazine	1,096,683.03
Pharmaceuticals	651-06-9	Sulfameter	94,990
Pharmaceuticals	57-68-1	Sulfamethazine	156,300.00
Pharmaceuticals	144-83-2	Sulfapyridine	672,534.32
Pharmaceuticals	72-14-0	Sulfathiazole	533,216.00
Pharmaceuticals	15676-16-1	Sulpiride	87,120
Pharmaceuticals	10540-29-1	Tamoxifen	134.8010846
Pharmaceuticals	846-50-4	Temazepam	89,529.74
Pharmaceuticals	29767-20-2	Teniposide	42,011.84
Pharmaceuticals	23031-25-6	Terbutaline	22,987.44
Pharmaceuticals	58-22-0	Testosterone	10,000
Pharmaceuticals	03/08/1972	Tetrahydrocannabinol	106.2483643
Pharmaceuticals	58-55-9	Theophylline	366.6314064
Pharmaceuticals	51012-32-9	Tiapride	112,000
Pharmaceuticals	27203-92-5	Tramadol	13,515.85
Pharmaceuticals	10161-34-9	Trenbolone acetate	9,180
Pharmaceuticals	124-94-7	Triamcinolone	10,936
Pharmaceuticals	76-25-5	Triamcinolone acetonide	77,255.23
Pharmaceuticals	396-01-0	Triamterene	669.8894501
Pharmaceuticals	79-01-6	Trichloroethylene	8,901.57
Pharmaceuticals	93413-69-5	Venlafaxine	10,085.92
Pharmaceuticals	99300-78-4	Venlafaxine hydrochloride	1,463,521.86
Pharmaceuticals	52-53-9	Verapamil	2,361.36
Pharmaceuticals	21411-53-0	Virginiamycin M1	24,341.43
Plastic and plastics additives	84-74-2	1,2-benzenedicarboxylic acid, dibutyl ester	4,838.62
Plastic and plastics additives	131812-67-4	1,3-Dioxolane, 2,4-dimethyl-2-(5,6,7,8-tetrahydro-5,5,8,8-tetramethyl-2-naphthalenyl)-	419.7048023
Plastic and plastics additives	581-42-0	2,6-Dimethylnaphthalene	2,000.00
Plastic and plastics additives	128-39-2	2,6-Di-tert-butylphenol	10,590
Plastic and plastics additives	91-57-6	2-Methylnaphthalene	9,640
Plastic and plastics additives	79-97-0	3,3'-Dimethylbisphenol A	6,050
Plastic and plastics additives	128-39-2	4-Methyl-2,6-di-t-butylphenol	10,590
Plastic and plastics additives	85-68-7	Benzyl butyl phthalate	3,771.04
Plastic and plastics additives	117-81-7	Bis(2-ethylhexyl)phthalate	18.98248738
Plastic and plastics additives	80-05-7	Bisphenol A	3,000
Plastic and plastics additives	1478-61-1	Bisphenol AF	19,781.47
Plastic and plastics additives	2167-51-3	Bisphenol P	780

Plastic and plastics additives	129188-99-4	bisphenol TMC	2,910
Plastic and plastics additives	843-55-0	Bisphenol Z	3,914.14
Plastic and plastics additives	85-68-7	Butyl benzyl phtalate	3,771.04
Plastic and plastics additives	117-81-7	DEHP	18.98248738
Plastic and plastics additives	103-23-1	Di(2-ethylhexyl)adipate	27.67969854
Plastic and plastics additives	84-74-2	Dibutyl phthalate	4,838.62
Plastic and plastics additives	84-66-2	Diethyl phthalate	34,300
Plastic and plastics additives	598-02-7	Diethyl phthalate	3,230,000
Plastic and plastics additives	131-11-3	Dimethyl phthalate	94,190
Plastic and plastics additives	84-74-2	Di-n-butyl phthalate	4,838.62
Plastic and plastics additives	117-84-0	Di-n-octyl phthalate	384
Polybrominated diphenyl ethers (PBDEs)	2050-47-7	4,4'-Dibromodiphenyl ether	300
Polybrominated diphenyl ethers (PBDEs)	189084-64-8	PBDE 100	922
Polybrominated diphenyl ethers (PBDEs)	5436-43-1	PBDE 47	280
Polybrominated diphenyl ethers (PBDEs)	68631-49-2	PBDE 153	292
Polybrominated diphenyl ethers (PBDEs)	207122-15-4	PBDE 154	1,105
Polybrominated diphenyl ethers (PBDEs)	1163-19-5	PBDE 209	2,409
Polybrominated diphenyl ethers (PBDEs)	41318-75-6	PBDE 28	1,140
Polybrominated diphenyl ethers (PBDEs)	5436-43-1	PBDE 47	280
Polybrominated diphenyl ethers (PBDEs)	60348-60-9	PBDE 99	69.38084844
Polybrominated diphenyl ethers (PBDEs)	101-55-3	PCB 3	6,314.41
Polychlorinated biphenyl (PCB)	35065-28-2	2,2',3,4,4',5'-Hexachlorobiphenyl	47.5518289
Polychlorinated biphenyl (PCB)	35065-27-1	2,2',4,4',5,5'-Hexachlorobiphenyl	47.5518289
Polychlorinated biphenyl (PCB)	35693-99-3	2,2',5,5'-Tetrachlorobiphenyl	480.6787241
Polychlorinated biphenyl (PCB)	32598-14-4	2,3,3',4,4'-Pentachlorobiphenyl	152.0345686
Polychlorinated biphenyl (PCB)	38380-03-9	2,3,3',4',6-Pentachlorobiphenyl	152.0345686
Polychlorinated biphenyl (PCB)	7012-37-5	2,4,4'-Trichlorobiphenyl	1,320
Polychlorinated biphenyl (PCB)	16606-02-3	2,4',5-Trichlorobiphenyl	1,440
Polychlorinated biphenyl (PCB)	32598-13-3	3,3',4,4'-Tetrachlorobiphenyl	1,900
Polychlorinated biphenyl (PCB)	2051-60-7	PCB 1	9,330
Polychlorinated biphenyl (PCB)	37680-73-2	PCB 101	152.0345686
Polychlorinated biphenyl (PCB)	32598-14-4	PCB 105	152.0345686
Polychlorinated biphenyl (PCB)	38380-03-9	PCB 110	152.0345686
Polychlorinated biphenyl (PCB)	31508-00-6	PCB 118	152.0345686
Polychlorinated biphenyl (PCB)	38380-07-3	PCB 128	1,140
Polychlorinated biphenyl (PCB)	35065-28-2	PCB 138	47.5518289
Polychlorinated biphenyl (PCB)	38380-04-0	PCB 149	47.5518289
Polychlorinated biphenyl (PCB)	52663-63-5	PCB 151	47.5518289
Polychlorinated biphenyl (PCB)	35065-27-1	PCB 153	47.5518289
Polychlorinated biphenyl (PCB)	38380-08-4	PCB 156	47.5518289
Polychlorinated biphenyl (PCB)	35065-30-6	PCB 170	14.73728771
Polychlorinated biphenyl (PCB)	52663-70-4	PCB 177	14.73728771

Polychlorinated biphenyl (PCB)	37680-65-2	PCB 18	1,100
Polychlorinated biphenyl (PCB)	35065-29-3	PCB 180	14.73728771
Polychlorinated biphenyl (PCB)	52663-69-1	PCB 183	14.73728771
Polychlorinated biphenyl (PCB)	52663-68-0	PCB 187	14.73728771
Polychlorinated biphenyl (PCB)	38444-73-4	PCB 19	1,330
Polychlorinated biphenyl (PCB)	35694-08-7	PCB 194	4.532718594
Polychlorinated biphenyl (PCB)	52663-75-9	PCB 199	4.532718594
Polychlorinated biphenyl (PCB)	74472-53-0	PCB 205	4.532718594
Polychlorinated biphenyl (PCB)	2051-24-3	PCB 209	0.42096558
Polychlorinated biphenyl (PCB)	38444-85-8	PCB 22	1,498.58
Polychlorinated biphenyl (PCB)	7012-37-5	PCB 28	1,320
Polychlorinated biphenyl (PCB)	38444-86-9	PCB 33	1,498.58
Polychlorinated biphenyl (PCB)	38444-90-5	PCB 37	299.7167222
Polychlorinated biphenyl (PCB)	41464-39-5	PCB 44	480.6787241
Polychlorinated biphenyl (PCB)	35693-99-3	PCB 52	480.6787241
Polychlorinated biphenyl (PCB)	34883-43-7	PCB 8	3,610
Polychlorinated biphenyl (PCB)	38379-99-6	PCB 95	152.0345686
Polychlorinated biphenyl (PCB)	38380-01-7	PCB 99	152.0345686
Polychlorinated biphenyl (PCB)	37680-73-2	PCB101	152.0345686
Polychlorinated biphenyl (PCB)	37680-65-2	PCB18	1,100
Polycyclic Aromatic Hydrocarbons (PAHs)	575-41-7	1,3-Dimethylnaphthalene	7,540
Polycyclic Aromatic Hydrocarbons (PAHs)	238-84-6	11H-Benzo[a]fluorene	1,650
Polycyclic Aromatic Hydrocarbons (PAHs)	120-72-9	1h-indole	7,848.77
Polycyclic Aromatic Hydrocarbons (PAHs)	1746-01-6	2,3,7,8-Tetrachlorodibenzo-p-dioxin	1,010
Polycyclic Aromatic Hydrocarbons (PAHs)	83-32-9	Acenaphthene	7,850
Polycyclic Aromatic Hydrocarbons (PAHs)	208-96-8	Acenaphthylene	7,060
Polycyclic Aromatic Hydrocarbons (PAHs)	260-94-6	Acridine	6,550
Polycyclic Aromatic Hydrocarbons (PAHs)	120-12-7	Anthracene	100
Polycyclic Aromatic Hydrocarbons (PAHs)	84-65-1	Anthraquinone	3,500.00
Polycyclic Aromatic Hydrocarbons (PAHs)	56-55-3	Benz(a)anthracene	670
Polycyclic Aromatic Hydrocarbons (PAHs)	56-55-3	Benzo(a)anthracene	670
Polycyclic Aromatic Hydrocarbons (PAHs)	50-32-8	Benzo(a)pyrene	50
Polycyclic Aromatic Hydrocarbons (PAHs)	205-99-2	Benzo(b)fluoranthene	30
Polycyclic Aromatic Hydrocarbons (PAHs)	192-97-2	Benzo(e)pyrene	80
Polycyclic Aromatic Hydrocarbons (PAHs)	191-24-2	Benzo(g,h,i)perylene	2
Polycyclic Aromatic Hydrocarbons (PAHs)	191-24-2	Benzo(ghi)perylene	2

Polycyclic Aromatic Hydrocarbons (PAHs)	207-08-9	Benzo(k)fluoranthene	30
Polycyclic Aromatic Hydrocarbons (PAHs)	192-97-2	Benzo[e]pyrene	80
Polycyclic Aromatic Hydrocarbons (PAHs)	86-74-8	Carbazole	5,810
Polycyclic Aromatic Hydrocarbons (PAHs)	218-01-9	Chrysene	740
Polycyclic Aromatic Hydrocarbons (PAHs)	53-70-3	Dibenz(a,h)anthracene	33.00000099
Polycyclic Aromatic Hydrocarbons (PAHs)	53-70-3	Dibenzo(a,h)anthracene	33.00000099
Polycyclic Aromatic Hydrocarbons (PAHs)	206-44-0	Fluoranthene	100
Polycyclic Aromatic Hydrocarbons (PAHs)	86-73-7	Fluorene	6,290
Polycyclic Aromatic Hydrocarbons (PAHs)	193-39-5	Indeno(1,2,3-cd)pyrene	2
Polycyclic Aromatic Hydrocarbons (PAHs)	120-72-9	Indole	7,848.77
Polycyclic Aromatic Hydrocarbons (PAHs)	119-65-3	Isoquinoline	153,000
Polycyclic Aromatic Hydrocarbons (PAHs)	91-20-3	Naphthalene	2,400
Polycyclic Aromatic Hydrocarbons (PAHs)	198-55-0	Perylene	230
Polycyclic Aromatic Hydrocarbons (PAHs)	85-01-8	Phenanthrene	3,100.00
Polycyclic Aromatic Hydrocarbons (PAHs)	129-00-0	Pyrene	730
Polycyclic Aromatic Hydrocarbons (PAHs)	91-22-5	Quinoline	80,000
Sterols	83-46-5	beta-Sitosterol	1.037849142
Sterols	57-88-5	Cholesterol	5.738997424
Sterols	360-68-9	Coprostanol	4.88113983
Sterols	360-68-9	Coprosterol	4.88113983
Sterols	83-45-4	Stigmastanol	0.88240231
Sterols	83-48-7	Stigmasterol	742

Annexe 2.4: List of chemicals with associated RQ by urban environment when calculated.



Continent	Country	City	Chemical name	Average RQ
Africa	Cameroon	Yaoundé	3,4-Dichlorophenylurea	0.000754369
Africa	Cameroon	Yaoundé	Acetochlor	0.907719294
Africa	Cameroon	Yaoundé	Alachlor	4.68580088
Africa	Cameroon	Yaoundé	Atrazine	0.499833333
Africa	Cameroon	Yaoundé	Carbendazim	0.002326149
Africa	Cameroon	Yaoundé	Chlorotoluron	0.002596157
Africa	Cameroon	Yaoundé	Dimethomorph	0.001348942
Africa	Cameroon	Yaoundé	Diuron	7.01105
Africa	Cameroon	Yaoundé	Epoxiconazole	0.006183176
Africa	Cameroon	Yaoundé	Imidacloprid	0.000250955
Africa	Cameroon	Yaoundé	Isoproturon	0.004
Africa	Cameroon	Yaoundé	Linuron	0.002750799
Africa	Cameroon	Yaoundé	Metalaxyl	0.000261563
Africa	Cameroon	Yaoundé	Metolachlor	0.413261929
Africa	Cameroon	Yaoundé	N-(3,4-Dichlorophenyl)-N'-methylurea	0.012244541
Africa	Cameroon	Yaoundé	Penconazole	0.331655789
Africa	Cameroon	Yaoundé	Pyrimethanil	0.004733333
Africa	Cameroon	Yaoundé	Simazine	0.0047
Africa	Cameroon	Yaoundé	Tetraconazole	0.007097242
Africa	Kenya	Nairobi	3'-Azido-3'-deoxythymidine	3.621658538
Africa	Kenya	Nairobi	Ciprofloxacin	0.951111111
Africa	Kenya	Nairobi	Lamivudine	0.001169097
Africa	Kenya	Nairobi	Nevirapine	0.263893022
Africa	Kenya	Nairobi	Sulfamethoxazole	13.65
Africa	Kenya	Nairobi	Trimethoprim	0.644205641
Africa	Morocco	Fez	Chromium	33.84615385
Africa	Morocco	Fez	Nitrate	57.77777778
Africa	Morocco	Fez	Nitrogen	5,299.76
Africa	Morocco	Fez	Phosphorus	1,317.50
Africa	Mozambique	Maputo	Atrazine	0.015
Africa	Mozambique	Maputo	Chlorpyrifos	0.514093709
Africa	Mozambique	Maputo	Endosulfan I	0.000156941
Africa	Mozambique	Maputo	Endosulfan II	5.49E-05
Africa	Mozambique	Maputo	Endosulfan sulfate	8.39E-05
Africa	Mozambique	Maputo	Lindane	0.000175439
Africa	Mozambique	Maputo	Malathion	0.028826804
Africa	Mozambique	Maputo	Pirimiphos-methyl	40.16700338
Africa	Mozambique	Maputo	Simazine	0.006
Africa	Mozambique	Maputo	λ-Cyhalothrin	1.369188262
Africa	Nigeria	Cities in Nigeria	4-Nonylphenol	6.886666667
Africa	Nigeria	Cities in Nigeria	4-tert-Octylphenol	6.94
Africa	Nigeria	Cities in Nigeria	Bisphenol A	20.67466667
Africa	South Africa	Cape Town	17beta-Estradiol	0.005542169
Africa	South Africa	Cape Town	17α-ethinylestradiol	4.80E-05
Africa	South Africa	Cape Town	2,4,6-Trichlorophenol	113.3333333
Africa	South Africa	Cape Town	2,4-Dimethylphenol	3.285181733
Africa	South Africa	Cape Town	2,4-Dinitrophenol	0.681011535
Africa	South Africa	Cape Town	2-Chlorophenol	14.82666667
Africa	South Africa	Cape Town	2-Nitrophenol	3.204347768
Africa	South Africa	Cape Town	4-Nitrophenol	0.424278138

Africa	South Africa	Cape Town	Benzyl butyl phthalate	10.55412022
Africa	South Africa	Cape Town	Bis(2-ethylhexyl)hexanedioate	0.152241542
Africa	South Africa	Cape Town	Bisphenol A	0.0011
Africa	South Africa	Cape Town	DEHP	20.09114993
Africa	South Africa	Cape Town	DEHPa	175.7962492
Africa	South Africa	Cape Town	Dibutyl phthalate	119.662187
Africa	South Africa	Cape Town	Diethyl phthalate	0.142600619
Africa	South Africa	Cape Town	Diisononyl phthalate	38.16771806
Africa	South Africa	Cape Town	dl-Dopa	0.238001574
Africa	South Africa	Cape Town	Estrone	0.000866388
Africa	South Africa	Cape Town	p-Chlorocresol	15.14004542
Africa	South Africa	Cape Town	Pentachlorophenol	23,564.73
Africa	South Africa	Cape Town	Phenol	2.762658919
Africa	South Africa	Durban city	Acetaminophen	0.081750874
Africa	South Africa	Durban city	Caffeine	13.92866899
Africa	South Africa	Durban city	Carbamazepine	0.063176296
Africa	South Africa	Durban city	Diclofenac	0.826289517
Africa	South Africa	Durban city	Erythromycin	0.504
Africa	South Africa	Durban city	Ibuprofen	0.374484053
Africa	South Africa	Durban city	Naproxen	0.384699454
Africa	South Africa	Durban city	Sulfamethazine	0.006666667
Africa	South Africa	Durban city	Sulfamethoxazole	8.136666667
Africa	South Africa	Durban city	Trimethoprim	0.535031889
Africa	South Africa	Hartbeespoort Dam	Ametryn	2.614545469
Africa	South Africa	Hartbeespoort Dam	Atraton	0.000805444
Africa	South Africa	Hartbeespoort Dam	Atrazine	1.665666667
Africa	South Africa	Hartbeespoort Dam	Bromacil	0.016640623
Africa	South Africa	Hartbeespoort Dam	Carbamazepine	0.004777252
Africa	South Africa	Hartbeespoort Dam	Efavirenz	0.022122245
Africa	South Africa	Hartbeespoort Dam	Emtricitabine	6.64E-07
Africa	South Africa	Hartbeespoort Dam	Methocarbamol	0.001882828
Africa	South Africa	Hartbeespoort Dam	Nevirapine	0.006058768
Africa	South Africa	Hartbeespoort Dam	Prometon	0.015649591
Africa	South Africa	Hartbeespoort Dam	Prometryn	0.000315168
Africa	South Africa	Hartbeespoort Dam	Propazine	0.039607568
Africa	South Africa	Hartbeespoort Dam	Simazine	0.6414
Africa	South Africa	Hartbeespoort Dam	Terbutylazine	0.018929518
Africa	South Africa	Hartbeespoort Dam	Venlafaxine hydrochloride	4.37E-06
Africa	South Africa	King William’s Town	Aldrin	95.56288069
Africa	South Africa	King William’s Town	alpha-1,2,3,4,5,6-Hexachlorocyclohexane	0.26745614
Africa	South Africa	King William’s Town	beta-Hexachlorocyclohexane	1.437850877
Africa	South Africa	King William’s Town	delta-Hexachlorocyclohexane	0.024122807
Africa	South Africa	King William’s Town	Dichlorodiphenyltrichloroethane	4.4
Africa	South Africa	King William’s Town	Endosulfan I	0.322121354
Africa	South Africa	King William’s Town	Endosulfan II	0.174204484
Africa	South Africa	King William’s Town	Endrin	20.8
Africa	South Africa	King William’s Town	Heptachlor	5.405458229
Africa	South Africa	King William’s Town	Heptachlor epoxide B	0.099798968
Africa	South Africa	King William’s Town	Methoxychlor	1.706
Africa	South Africa	King William’s Town	p,p'-DDD	0.805160142
Africa	South Africa	Ndumo	Dichlorodiphenyltrichloroethane	0.83

Africa	South Africa	Pietermaritzburg	17beta-Estradiol	2.602409639
Africa	South Africa	Pietermaritzburg	17α-ethinylestradiol	0.0028
Africa	South Africa	Pietermaritzburg	Estrone	0.003340292
Africa	South Africa	Pietermaritzburg	Progesterone	0.002140921
Africa	South Africa	Pietermaritzburg	Testosterone	0.00158
Africa	South Africa	Thulamela municipality	Acenaphthene	73.37579618
Africa	South Africa	Thulamela municipality	Acenaphthylene	161.1898017
Africa	South Africa	Thulamela municipality	Anthracene	2,560
Africa	South Africa	Thulamela municipality	Benzo(a)pyrene	24,780
Africa	South Africa	Thulamela municipality	Benzo(b)fluoranthene	250,333.33
Africa	South Africa	Thulamela municipality	Fluoranthene	24,980
Africa	South Africa	Thulamela municipality	Fluorene	394.2766296
Africa	South Africa	Thulamela municipality	Naphthalene	92.5
Africa	South Africa	Thulamela municipality	Phenanthrene	40.64516196
Africa	South Africa	Thulamela municipality	Pyrene	1,558.90
Africa	Uganda	Kampala	Albuterol	0.00079093
Africa	Uganda	Kampala	Atenolol	0.005766694
Africa	Uganda	Kampala	Carbamazepine	0.015622343
Africa	Uganda	Kampala	Cetirizine	0.0032
Africa	Uganda	Kampala	Codeine	0.001214734
Africa	Uganda	Kampala	Diclofenac	0.024958403
Africa	Uganda	Kampala	Furosemide	0.002015499
Africa	Uganda	Kampala	Gemfibrozil	0.082939189
Africa	Uganda	Kampala	Hydrochlorothiazide	7.42E-05
Africa	Uganda	Kampala	Lidocaine	0.003473193
Africa	Uganda	Kampala	Losartan	0.037279633
Africa	Uganda	Kampala	Pyrimethamine	0.053072306
Africa	Uganda	Kampala	Sulfamethoxazole	4.16
Africa	Uganda	Kampala	Trimethoprim	2.867126903
Africa	Uganda	Kampala	Venlafaxine	0.004114647
Asia	Bangladesh	Mahka	2,7,8,9-Tricyclazole	2.04E-05
Asia	Bangladesh	Mahka	2-Hydroxy-4-methoxybenzophenone	0.029101517
Asia	Bangladesh	Mahka	Acetovanillone	0.002000412
Asia	Bangladesh	Mahka	Caffeine	0.283409373
Asia	Bangladesh	Mahka	Carbendazim	0.000826039
Asia	Bangladesh	Mahka	Ciprofloxacin	0.082888889
Asia	Bangladesh	Mahka	Climbazole	0.001007164
Asia	Bangladesh	Mahka	DEET	0.001453026
Asia	Bangladesh	Mahka	Diuron	0.084
Asia	Bangladesh	Mahka	Fluconazole	0.000619572
Asia	Bangladesh	Mahka	Hexaconazole	0.000501107
Asia	Bangladesh	Mahka	Imidacloprid	1.96E-05
Asia	Bangladesh	Mahka	Lidocaine	0.0001554
Asia	Bangladesh	Mahka	Lincomycin	0.142345679
Asia	Bangladesh	Mahka	Propiconazole	0.003796468
Asia	Bangladesh	Mahka	Spiramycin	0.247834862
Asia	Bangladesh	Mahka	Tebuconazole	0.001524051
Asia	Bangladesh	Mahka	Triethyl citrate	0.002619295
Asia	Bangladesh	Mahka	Trimethoprim	0.0012385
Asia	Bangladesh	Mahka	Triphenyl phosphate	0.043291633
Asia	China	Beijing	1-(p-Chlorobenzoyl)-5-methoxy-2-methyl-Indol	0.017957202

Asia	China	Beijing	1,2,3,4-Tetrachlorobenzene	0.097376238
Asia	China	Beijing	1,2,3-Trichlorobenzene	0.075466667
Asia	China	Beijing	1,2,4-Trichlorobenzene	0.065147679
Asia	China	Beijing	1,2-Dichlorobenzene	0.318579995
Asia	China	Beijing	1,3,5-Trichlorobenzene	0.020018405
Asia	China	Beijing	1,3-Dichlorobenzene	0.02806
Asia	China	Beijing	1,4-Dichlorobenzene	0.115481884
Asia	China	Beijing	Acetaminophen	0.041378112
Asia	China	Beijing	Azithromycin	0.817333333
Asia	China	Beijing	Bezafibrate	0.022612698
Asia	China	Beijing	Caffeine	19.70793318
Asia	China	Beijing	Carbamazepine	0.018546978
Asia	China	Beijing	Chloramphenicol	0.001277983
Asia	China	Beijing	Chlortetracycline	0.003624
Asia	China	Beijing	DEET	0.00914121
Asia	China	Beijing	Diclofenac	0.02562396
Asia	China	Beijing	Doxycycline	0.000486295
Asia	China	Beijing	Erythromycin	0.12108
Asia	China	Beijing	Fluoxetine	0.002179681
Asia	China	Beijing	Gemfibrozil	0.006097973
Asia	China	Beijing	Hexachlorobenzene	47.25
Asia	China	Beijing	Ketoprofen	0.035821053
Asia	China	Beijing	Lincomycin	0.067222222
Asia	China	Beijing	Mefenamic acid	0.002672673
Asia	China	Beijing	Metoprolol	0.020724234
Asia	China	Beijing	Ofloxacin	0.00324
Asia	China	Beijing	Oxytetracycline	0.001020831
Asia	China	Beijing	Pentachlorobenzene	16.14285714
Asia	China	Beijing	Propranolol	0.002520176
Asia	China	Beijing	Sulfadiazine	0.001734612
Asia	China	Beijing	Sulfamethazine	8.41E-05
Asia	China	Beijing	Sulfamethoxazole	0.066766667
Asia	China	Beijing	Sulpiride	0.003028007
Asia	China	Beijing	Tetracycline	0.01797
Asia	China	Beijing	Trimethoprim	0.147009919
Asia	China	Cities in China	17beta-Estradiol	6.113253012
Asia	China	Cities in China	17α-ethinylestradiol	0.03412
Asia	China	Cities in China	4-Nonylphenol	64.41333333
Asia	China	Cities in China	4-tert-Octylphenol	4.234
Asia	China	Cities in China	Bisphenol A	0.251933333
Asia	China	Cities in China	Diethylstilbestrol	0.003035741
Asia	China	Cities in China	Estrone	0.007348643
Asia	China	Cities in China	Triclocarban	0.172368375
Asia	China	Cities in China	Triclosan	0.076716418
Asia	China	Ghangzhou	1-(p-Chlorobenzoyl)-5-methoxy-2-methyl-Indol	0.014104212
Asia	China	Ghangzhou	3-Chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-f	0.003962469
Asia	China	Ghangzhou	4-Nonylphenol	13.93333333
Asia	China	Ghangzhou	4-tert-Octylphenol	1.479
Asia	China	Ghangzhou	7-Acetyl-1,1,3,4,4,6-hexamethyltetraline	0.264713049
Asia	China	Ghangzhou	Acetamiprid	0.003891517
Asia	China	Ghangzhou	Aldosterone	0.000147952

Asia	China	Ghangzhou	Beclomethasone	0.000710867
Asia	China	Ghangzhou	Betamethasone	0.000371901
Asia	China	Ghangzhou	Bisphenol A	0.372
Asia	China	Ghangzhou	Budesonide	0.003651685
Asia	China	Ghangzhou	Caffeine	3.14643595
Asia	China	Ghangzhou	Carbamazepine	0.000109075
Asia	China	Ghangzhou	Chloramphenicol	2.43E-05
Asia	China	Ghangzhou	Clobetasol propionate	0.015507914
Asia	China	Ghangzhou	Clobetasone butyrate	0.011367671
Asia	China	Ghangzhou	Clofibric acid	0.000411587
Asia	China	Ghangzhou	Clothianidin	0.000132759
Asia	China	Ghangzhou	Corticosterone	0.000201013
Asia	China	Ghangzhou	Cortisone	0.000894177
Asia	China	Ghangzhou	Cyclopenta[g]-2-benzopyran, 1,3,4,6,7,8-hexah	1.474214902
Asia	China	Ghangzhou	DEET	4.03E-06
Asia	China	Ghangzhou	Deflazacort	0.000944743
Asia	China	Ghangzhou	Deoxycorticosterone acetate	0.003072848
Asia	China	Ghangzhou	Dexamethasone	0.00074568
Asia	China	Ghangzhou	Diclofenac	0.080366057
Asia	China	Ghangzhou	Fludrocortisone acetate	0.002266154
Asia	China	Ghangzhou	Flunisolide	0.000130015
Asia	China	Ghangzhou	Fluorometholone	0.00043147
Asia	China	Ghangzhou	Gemfibrozil	0.001280405
Asia	China	Ghangzhou	Hydrocortisone	0.000895757
Asia	China	Ghangzhou	Ibuprofen	0.015666041
Asia	China	Ghangzhou	Imidacloprid	0.000390591
Asia	China	Ghangzhou	Mefenamic acid	0.000930931
Asia	China	Ghangzhou	Methylprednisolone	0.000621497
Asia	China	Ghangzhou	Musk ketone	0.107662417
Asia	China	Ghangzhou	Naproxen	0.000383497
Asia	China	Ghangzhou	Ofloxacin	2.00E-06
Asia	China	Ghangzhou	Prednisolone	0.000285736
Asia	China	Ghangzhou	Prednisone	0.00045108
Asia	China	Ghangzhou	Propylparaben	1.04E-06
Asia	China	Ghangzhou	Roxithromycin	1.18E-05
Asia	China	Ghangzhou	Sulfamethazine	1.28E-07
Asia	China	Ghangzhou	Sulfamethoxazole	0.004231667
Asia	China	Ghangzhou	Tetracycline	0.00016
Asia	China	Ghangzhou	Thiamethoxam	9.78E-05
Asia	China	Ghangzhou	Triamcinolone	9.24E-05
Asia	China	Ghangzhou	Triamcinolone acetonide	6.44E-05
Asia	China	Ghangzhou	Triclocarban	0.128494143
Asia	China	Ghangzhou	Triclosan	0.027157015
Asia	China	Haikou	2,2,4-Trimethyl-1,3-pentanediol diisobutyrate	0.019233559
Asia	China	Haikou	2,3-Dichlorobenzoic acid	0.010660248
Asia	China	Haikou	2,4,7,9-Tetramethyl-5-decyne-4,7-diol	0.007255814
Asia	China	Haikou	2-Chlorobenzothiazole	0.000266904
Asia	China	Haikou	7-Acetyl-1,1,3,4,4,6-hexamethyltetraline	0.023977631
Asia	China	Haikou	Atrazine	0.016666667
Asia	China	Haikou	Benzene, (methylsulfonyl)-	0.000240211
Asia	China	Haikou	Caffeine	3.848644885

Asia	China	Haikou	Climbazole	0.024658162
Asia	China	Haikou	Cyclopenta[g]-2-benzopyran, 1,3,4,6,7,8-hexah	0.111713722
Asia	China	Haikou	DEET	0.003112392
Asia	China	Haikou	Galaxolidone	0.015178571
Asia	China	Haikou	Griseofulvin	0.000990099
Asia	China	Haikou	Ibuprofen	0.037786116
Asia	China	Haikou	Ketamine	0.00094582
Asia	China	Haikou	Musk ketone	0.014127072
Asia	China	Haikou	N-Butylbenzenesulfonamide	0.002387367
Asia	China	Haikou	Tribenzylamine	0.14252029
Asia	China	Haikou	Triethyl citrate	0.003838174
Asia	China	Haikou	Triphenyl phosphate	0.568256912
Asia	China	Haikou	Tris(2-chloroethyl) phosphate	0.0556653
Asia	China	Hangzhou	Acetamiprid	0.001575872
Asia	China	Hangzhou	Clothianidin	0.000102131
Asia	China	Hangzhou	Dinotefuran	2.92E-05
Asia	China	Hangzhou	Imidacloprid	9.67E-05
Asia	China	Hangzhou	Nitenpyram	2.34E-05
Asia	China	Hangzhou	Thiamethoxam	0.000105531
Asia	China	Harbin	Mirex	0.008531628
Asia	China	Jinan, Zibo, Weifang	Arsenic	0.286867828
Asia	China	Jinan, Zibo, Weifang	Chromium	4.8
Asia	China	Jinan, Zibo, Weifang	Copper	103
Asia	China	Jinan, Zibo, Weifang	Nickel	42.8
Asia	China	Jinan, Zibo, Weifang	Perfluorobutanoic acid	0.436540909
Asia	China	Jinan, Zibo, Weifang	Perfluorohexanoic acid	20.35131468
Asia	China	Jinan, Zibo, Weifang	Perfluorononanoic acid	307.325
Asia	China	Jinan, Zibo, Weifang	Perfluorooctanoic acid	4,047.00
Asia	China	Jinan, Zibo, Weifang	Perfluoropentanoic acid	1.112441211
Asia	China	Jinan, Zibo, Weifang	Zinc	72.48979451
Asia	China	Pearl River Delta Region cities	2,2-Bis(4-hydroxy-3-isopropylphenyl)propane	0.10693617
Asia	China	Pearl River Delta Region cities	3,3'-Dimethylbisphenol A	0.000412231
Asia	China	Pearl River Delta Region cities	4,4'-Dihydroxytetraphenylmethane	0.000764444
Asia	China	Pearl River Delta Region cities	4,4'-Sulfonyldiphenol	5.45E-05
Asia	China	Pearl River Delta Region cities	Bisphenol A	0.4305
Asia	China	Pearl River Delta Region cities	Bisphenol AF	0.00015742
Asia	China	Pearl River Delta Region cities	Bisphenol F	0.033170845
Asia	China	Pearl River Delta Region cities	Bisphenol P	0.003066667
Asia	China	Pearl River Delta Region cities	bisphenol TMC	0.007199313
Asia	China	Pearl River Delta Region cities	Bisphenol Z	0.000571518
Asia	China	Shangai	(5-Chloro-2-hydroxyphenyl)phenylmethanone	0.000584314
Asia	China	Shangai	2-Amino-5-chlorobenzophenone	0.000371795
Asia	China	Shangai	Alprazolam	0.001525802
Asia	China	Shangai	Amitriptyline	0.000674791
Asia	China	Shangai	Bromazepam	0.000163291
Asia	China	Shangai	Carbamazepine	0.004236038
Asia	China	Shangai	Desmethyldiazepam	0.000121849
Asia	China	Shangai	Diazepam	0.006820972
Asia	China	Shangai	Doxepin	0.000463184
Asia	China	Shangai	Estazolam	0.000355644
Asia	China	Shangai	Fluoxetine	0.000344675

Asia	China	Shangai	Lorazepam	8.29E-05
Asia	China	Shangai	Mianserin	5.56E-05
Asia	China	Shangai	Oxazepam	8.05E-05
Asia	China	Shangai	Temazepam	2.10E-05
Asia	China	Shenyang	Perfluorobutanesulfonic acid	4.72E-06
Asia	China	Shenyang	Perfluorononanoic acid	0.1192125
Asia	China	Shenyang	Perfluorooctanoic acid	0.00435758
Asia	China	Shenyang	Perfluoropentanoic acid	1.37E-06
Asia	China	Shenyang	Perfluoropropanesulfonic acid	5.22E-08
Asia	China	Suzhou	Cephalexin	1.49527619
Asia	China	Suzhou	Ciprofloxacin	0.165342222
Asia	China	Suzhou	Enrofloxacin	0.026983246
Asia	China	Suzhou	Lincomycin	0.401503704
Asia	China	Suzhou	Norfloxacin	0.034945834
Asia	China	Suzhou	Ofloxacin	0.0158036
Asia	China	Suzhou	Oxytetracycline	0.007892392
Asia	China	Suzhou	Roxithromycin	0.011134706
Asia	China	Suzhou	Sulfadiazine	0.004556824
Asia	China	Suzhou	Sulfamethoxazole	0.250298333
Asia	China	Suzhou	Sulfaquinoxaline	0.001171321
Asia	China	Suzhou	Tetracycline	0.479226
Asia	China	Suzhou	Tylosin	0.00867551
Asia	China	Wuhan	Albuterol	0.000395062
Asia	China	Wuhan	Caffeine	0.34607579
Asia	China	Wuhan	Carbamazepine	0.000603661
Asia	China	Wuhan	Clarithromycin	0.03632
Asia	China	Wuhan	Clindamycin	0.2969
Asia	China	Wuhan	Cotinine	6.42E-06
Asia	China	Wuhan	Dextrorphan	0.000266106
Asia	China	Wuhan	Fluconazole	4.29E-05
Asia	China	Wuhan	Gabapentin	8.79E-05
Asia	China	Wuhan	Lincomycin	0.024938272
Asia	China	Wuhan	Metformin	5.16E-05
Asia	China	Wuhan	Metoprolol	0.000597772
Asia	China	Wuhan	Metoprolol acid	0.006016
Asia	China	Wuhan	Metronidazole	3.58E-05
Asia	China	Wuhan	Nicotine	2.81E-05
Asia	China	Wuhan	Ofloxacin	0.000405
Asia	China	Wuhan	Paraxantine	0.083189818
Asia	China	Wuhan	Sulfamethoxazole	0.00315
Asia	China	Wuhan	trans-3'-Hydroxycotinine	7.81E-05
Asia	China	Wuhan	Trimethoprim	0.005697099
Asia	China	Yangtze	1,2,3-Benzotriazole	0.139734346
Asia	China	Yangtze	2-Ethylhexyl-2-cyano-3,3-diphenylacrylate	1.096879152
Asia	China	Yangtze	2-Hydroxyatrazine	0.01780161
Asia	China	Yangtze	2-Isopropyl-6-methyl-4-pyrimidone	0.001947977
Asia	China	Yangtze	4,4'-Sulfonyldiphenol	0.000407498
Asia	China	Yangtze	4,5-Dichloro-2-octyl-3(2H)-isothiazolone	0.032472348
Asia	China	Yangtze	5-Methyl-1H-benzotriazole	0.01067943
Asia	China	Yangtze	Acetamiprid	0.002280289
Asia	China	Yangtze	Amantadine	0.044390774

Asia	China	Yangtze	Atrazine	2.1094285
Asia	China	Yangtze	Benzothiazole-2-sulfonic acid	0.024308555
Asia	China	Yangtze	Carbamazepine	0.01121576
Asia	China	Yangtze	Carbendazim	0.066319419
Asia	China	Yangtze	DEET	0.012394357
Asia	China	Yangtze	Diazepam	0.010515499
Asia	China	Yangtze	Didecyldimethylammonium	0.014081721
Asia	China	Yangtze	Dimethoate	0.009107496
Asia	China	Yangtze	Diphenyl oxide	0.012740385
Asia	China	Yangtze	Diuron	0.4140615
Asia	China	Yangtze	Hexa(methoxymethyl)melamine	0.156097034
Asia	China	Yangtze	Imidacloprid	0.004414875
Asia	China	Yangtze	Isoproturon	2.163910667
Asia	China	Yangtze	Metalaxyl	0.000389322
Asia	China	Yangtze	Metolachlor	4.028373973
Asia	China	Yangtze	Metoprolol acid	0.010479895
Asia	China	Yangtze	N,N-Bis(2-hydroxyethyl)dodecanamide	0.021114013
Asia	China	Yangtze	N,N-dimethylpyridin-4-amine	0.00826243
Asia	China	Yangtze	N-Acetylaminoantipyrine	0.006602034
Asia	China	Yangtze	Naproxen	0.010661366
Asia	China	Yangtze	N-Butylbenzenesulfonamide	0.01333185
Asia	China	Yangtze	N-Ethyltoluene-2-sulphonamide	0.00136934
Asia	China	Yangtze	N-Laurylamidopropyl-N,N-dimethylbetaine	0.005408757
Asia	China	Yangtze	Phenazone	0.003493472
Asia	China	Yangtze	Propiconazole	0.432564202
Asia	China	Yangtze	Sulfamethoxazole	0.036306833
Asia	China	Yangtze	Tebuconazole	0.061130322
Asia	China	Yangtze	Terbutryn	0.066295098
Asia	China	Yangtze	Thiamethoxam	0.0002665
Asia	China	Yangtze	Triethyl citrate	0.053843295
Asia	China	Yangtze	Triethyl phosphate	4.229150206
Asia	China	Yangtze	Triisobutyl phosphate	0.994477055
Asia	China	Yangtze	Tris(1,3-dichloro-2-propyl) phosphate	1.52783859
Asia	China	Yangtze	Tris(2-chloroethyl) phosphate	1.364539075
Asia	India	Guwahati	Acetaminophen	0.29707474
Asia	India	Guwahati	Caffeine	0.406455185
Asia	India	Guwahati	Carbamazepine	0.007297723
Asia	India	Guwahati	Crotamiton	0.001503085
Asia	India	Guwahati	Theophylline	7.641953066
Asia	India	Kanpur, Varanasi	Perfluorobutanesulfonic acid	5.20E-06
Asia	India	Kanpur, Varanasi	Perfluorohexanoic acid	1.79E-05
Asia	India	Kanpur, Varanasi	Perfluorononanoic acid	0.001625
Asia	India	Kanpur, Varanasi	Perfluorooctanoic acid	2.84E-05
Asia	India	Kanpur, Varanasi	Perfluoropropanoic acid	1.48E-07
Asia	Indonesia	Cipeles	Barium	1.223913069
Asia	Indonesia	Cipeles	Chromium	0.215384615
Asia	Indonesia	Cipeles	Cobalt	24.52830189
Asia	Indonesia	Cipeles	Copper	67.75
Asia	Indonesia	Cipeles	Iron	79.875
Asia	Indonesia	Cipeles	Lead	47.13114828
Asia	Indonesia	Cipeles	Manganese	0.011

Asia	Indonesia	Cipeles	Zinc	657.9591709
Asia	Indonesia	Jakarta	(1-Hydroxycyclohexyl)(phenyl)methanone	0.006158409
Asia	Indonesia	Jakarta	2-(Methylthio)benzothiazole	0.175686275
Asia	Indonesia	Jakarta	2,2,4-Trimethyl-1,3-pentanediol diisobutyrate	0.803107935
Asia	Indonesia	Jakarta	2,6-Diisopropylnaphthalene	3.82658185
Asia	Indonesia	Jakarta	2-Hydroxy-4-methoxybenzophenone	0.084597433
Asia	Indonesia	Jakarta	3-Methylindole	0.756647451
Asia	Indonesia	Jakarta	7-Acetyl-1,1,3,4,4,6-hexamethyltetraline	1.688025238
Asia	Indonesia	Jakarta	Benzothiazole	0.001958651
Asia	Indonesia	Jakarta	Benzyl 2-naphthyl ether	3.57500009
Asia	Indonesia	Jakarta	Bisphenol A	0.167333333
Asia	Indonesia	Jakarta	Bumetrizole	0.193240121
Asia	Indonesia	Jakarta	Caffeine	27.55508838
Asia	Indonesia	Jakarta	Carbofuran	0.705148374
Asia	Indonesia	Jakarta	Chloroxylenol	0.043892557
Asia	Indonesia	Jakarta	Coumarin	0.028446679
Asia	Indonesia	Jakarta	Cyclopenta[g]-2-benzopyran, 1,3,4,6,7,8-hexah	16.98048578
Asia	Indonesia	Jakarta	DEET	0.755043228
Asia	Indonesia	Jakarta	Diclofenac	0.012645591
Asia	Indonesia	Jakarta	Ibuprofen	0.072795497
Asia	Indonesia	Jakarta	Indole	0.594169407
Asia	Indonesia	Jakarta	Isoprocarb	0.016115149
Asia	Indonesia	Jakarta	Mefenamic acid	0.726726727
Asia	Indonesia	Jakarta	Naphthalene	1.758333333
Asia	Indonesia	Jakarta	N-Butylbenzenesulfonamide	0.00054792
Asia	Indonesia	Jakarta	N-Ethyl-4-methylbenzenesulfonamide	0.00381266
Asia	Indonesia	Jakarta	Nicotine	0.016302921
Asia	Indonesia	Jakarta	Phenanthrene	0.190609322
Asia	Indonesia	Jakarta	Propyphenazone	0.006209865
Asia	Indonesia	Jakarta	Triclosan	0.01119403
Asia	Indonesia	Jakarta	Triethyl citrate	0.00988935
Asia	Indonesia	Jakarta	Tris(2-chloroethyl) phosphate	2.478431219
Asia	Iran	Ahvaz	17beta-Estradiol	1.648192771
Asia	Iran	Ekbatam Dam	Bisphenol A	0.003033333
Asia	Iran	Hamadan	17beta-Estradiol	1.096385542
Asia	Iran	Hamadan	17α-ethinylestradiol	0.00176
Asia	Iran	Hamadan	2,4-D isooctyl ester	0.03991499
Asia	Iran	Hamadan	4-Nonylphenol	0.468666667
Asia	Iran	Hamadan	Bisphenol A	0.300333333
Asia	Iran	Tehran	1-(p-Chlorobenzoyl)-5-methoxy-2-methyl-Indol	0.009673004
Asia	Iran	Tehran	Diclofenac	0.004159734
Asia	Iran	Tehran	Ibuprofen	0.001298311
Asia	Iran	Tehran	Naproxen	0.004306011
Asia	Malaysia	Cities in Malaysia	17beta-Estradiol	1.283156627
Asia	Malaysia	Cities in Malaysia	17α-ethinylestradiol	0.051535
Asia	Malaysia	Cities in Malaysia	1H-1,2,4-Triazole	2.41E-05
Asia	Malaysia	Cities in Malaysia	Albuterol	0.000769968
Asia	Malaysia	Cities in Malaysia	Bisphenol A	8.45555
Asia	Malaysia	Cities in Malaysia	Estriol	0.186741021
Asia	Malaysia	Cities in Malaysia	Estrone	0.003530271
Asia	Malaysia	Cities in Malaysia	Methylparaben	0.000267

Asia	Malaysia	Cities in Malaysia	Sulfadiazine	0.024219447
Asia	Malaysia	Cities in Malaysia	Sulfadimethoxine	0.008086471
Asia	Malaysia	Cities in Malaysia	Sulfamethazine	4.75E-05
Asia	Malaysia	Cities in Malaysia	Sulfamethoxazole	0.070633333
Asia	Malaysia	Cities in Malaysia	Sulfapyridine	1.92E-05
Asia	Malaysia	Cities in Malaysia	Triclocarban	0.178548012
Asia	Malaysia	Kelantan	17beta-Estradiol	0.296385542
Asia	Malaysia	Kelantan	17α-ethinylestradiol	0.004827111
Asia	Malaysia	Kelantan	1H-1,2,4-Triazole	2.47E-05
Asia	Malaysia	Kelantan	Estriol	0.00445794
Asia	Malaysia	Kelantan	Methylparaben	0.0001589
Asia	Malaysia	Kelantan	Perfluoro-3-(1H-perfluoroethoxy)propane	5.29E-05
Asia	Malaysia	Kelantan	Triclocarban	0.224150397
Asia	Malaysia	Kuala Lumpur	17beta-Estradiol	0.024096386
Asia	Malaysia	Kuala Lumpur	17α-ethinylestradiol	0.00087
Asia	Malaysia	Kuala Lumpur	Bisphenol A	0.002374667
Asia	Malaysia	Kuala Lumpur	Caffeine	0.046004908
Asia	Malaysia	Kuala Lumpur	Ciprofloxacin	0.01124
Asia	Malaysia	Kuala Lumpur	Dexamethasone	0.000226647
Asia	Malaysia	Kuala Lumpur	Diazinon	0.006256735
Asia	Malaysia	Kuala Lumpur	Diclofenac	0.000949418
Asia	Malaysia	Kuala Lumpur	Estrone	3.32E-05
Asia	Malaysia	Kuala Lumpur	Primidone	9.16E-07
Asia	Malaysia	Kuala Lumpur	Progesterone	4.07E-06
Asia	Malaysia	Kuala Lumpur	Propranolol	1.58E-05
Asia	Malaysia	Kuala Lumpur	Sulfamethoxazole	0.000318333
Asia	Malaysia	Kuala Lumpur	Testosterone	4.00E-06
Asia	Pakistan	Islamabad	Diclofenac	9.517470882
Asia	Pakistan	Lahore	1-(p-Chlorobenzoyl)-5-methoxy-2-methyl-Indol	7.78E-05
Asia	Pakistan	Lahore	2-Ethylhexyl-2-cyano-3,3-diphenylacrylate	0.04753426
Asia	Pakistan	Lahore	2-Hydroxy-4-methoxybenzophenone	0.000512252
Asia	Pakistan	Lahore	Acetaminophen	0.019350353
Asia	Pakistan	Lahore	Acetophenone	0.000119522
Asia	Pakistan	Lahore	Aspartame	0.000418387
Asia	Pakistan	Lahore	Atenolol	0.000181369
Asia	Pakistan	Lahore	Benzyl 4-hydroxybenzoate	3.20E-05
Asia	Pakistan	Lahore	Caffeine	0.288648366
Asia	Pakistan	Lahore	Ciprofloxacin	0.066888889
Asia	Pakistan	Lahore	Clenbuterol	0.000407831
Asia	Pakistan	Lahore	Diazepam	2.97E-05
Asia	Pakistan	Lahore	Diclofenac	0.000410982
Asia	Pakistan	Lahore	Enrofloxacin	0.000872251
Asia	Pakistan	Lahore	Fenoprofen	5.13E-05
Asia	Pakistan	Lahore	Fluoxetine	0.003091783
Asia	Pakistan	Lahore	Gemfibrozil	0.000105743
Asia	Pakistan	Lahore	Ibuprofen	0.000574109
Asia	Pakistan	Lahore	Ketoprofen	0.009652632
Asia	Pakistan	Lahore	Mefenamic acid	0.008948949
Asia	Pakistan	Lahore	Methylparaben	0.000362
Asia	Pakistan	Lahore	Metoprolol	0.000118524
Asia	Pakistan	Lahore	Miconazole	0.030682792

Asia	Pakistan	Lahore	Naproxen	0.002054645
Asia	Pakistan	Lahore	Norfloxacin	0.002083333
Asia	Pakistan	Lahore	Ofloxacin	0.00191
Asia	Pakistan	Lahore	Oxytetracycline	0.000811688
Asia	Pakistan	Lahore	Phenazone	0.000456835
Asia	Pakistan	Lahore	Propylparaben	0.0002
Asia	Pakistan	Lahore	Propyphenazone	8.07E-05
Asia	Pakistan	Lahore	Sulfamethazine	1.92E-05
Asia	Pakistan	Lahore	Sulfamethoxazole	0.0019
Asia	Pakistan	Lahore	Tetracycline	0.02036
Asia	Singapore	Singapore	1,2-Bis(2,4,6-tribromophenoxy)ethane	1.137010585
Asia	Singapore	Singapore	1,2-Dibromo-4-(1,2-dibromoethyl)cyclohexane	0.000388908
Asia	Singapore	Singapore	2-Hydroxy-4-methoxybenzophenone	0.023805134
Asia	Singapore	Singapore	4-Nonylphenol	3.943333333
Asia	Singapore	Singapore	Acetaminophen	0.019313313
Asia	Singapore	Singapore	Acetic acid, (4-octylphenoxy)-	0.060517799
Asia	Singapore	Singapore	Acetic acid, 2-(4-nonylphenoxy)-	0.511206897
Asia	Singapore	Singapore	Bisphenol A	0.119833333
Asia	Singapore	Singapore	Caffeine	6.317016605
Asia	Singapore	Singapore	Carbamazepine	0.004575338
Asia	Singapore	Singapore	Chloramphenicol	0.00013816
Asia	Singapore	Singapore	Corticosterone	0.000168862
Asia	Singapore	Singapore	Cortisone	0.000139978
Asia	Singapore	Singapore	Crotamiton	0.003023832
Asia	Singapore	Singapore	DEET	0.014080692
Asia	Singapore	Singapore	Dichlorodiphenyltrichloroethane	0.1049
Asia	Singapore	Singapore	Diclofenac	0.003494176
Asia	Singapore	Singapore	Dieldrin	0.0676
Asia	Singapore	Singapore	Endosulfan sulfate	0.000327234
Asia	Singapore	Singapore	Enzacamene	0.002672403
Asia	Singapore	Singapore	Estriol	0.008638941
Asia	Singapore	Singapore	Estrone	0.001085595
Asia	Singapore	Singapore	Ethylene glycol nonylphenyl ether	1.754439176
Asia	Singapore	Singapore	Fenoprofen	0.011864407
Asia	Singapore	Singapore	Fipronil	0.33593295
Asia	Singapore	Singapore	Gemfibrozil	0.015540541
Asia	Singapore	Singapore	Hexabromobenzene	0.306250008
Asia	Singapore	Singapore	Ibuprofen	0.003377111
Asia	Singapore	Singapore	Ketoprofen	0.011052632
Asia	Singapore	Singapore	Naproxen	0.006994536
Asia	Singapore	Singapore	Octylphenol	0.136783636
Asia	Singapore	Singapore	PBDE 154	0.000135928
Asia	Singapore	Singapore	PBDE 28	2.04E-05
Asia	Singapore	Singapore	PBDE 47	0.001917857
Asia	Singapore	Singapore	Pentabromotoluene	6.09E-05
Asia	Singapore	Singapore	Polychlorinated biphenyls	0.000894568
Asia	Singapore	Singapore	Salicylic acid	0.004315
Asia	Singapore	Singapore	Sulpiride	1.66E-05
Asia	Singapore	Singapore	Triclosan	0.001869851
Asia	South Korea	Seoul	Atenolol	0.022155812
Asia	South Korea	Seoul	Atrazine	0.001705

Asia	South Korea	Seoul	Benzophenone	0.002312139
Asia	South Korea	Seoul	Bisphenol A	0.030333333
Asia	South Korea	Seoul	Butylated hydroxyanisole	0.000161567
Asia	South Korea	Seoul	Caffeine	0.629686663
Asia	South Korea	Seoul	Carbamazepine	0.015195616
Asia	South Korea	Seoul	DEET	0.005043228
Asia	South Korea	Seoul	Diazepam	0.000191816
Asia	South Korea	Seoul	Diclofenac	0.013727121
Asia	South Korea	Seoul	Diphenylhydantoin sodium	0.086724283
Asia	South Korea	Seoul	Estrone	0.00282881
Asia	South Korea	Seoul	Fluoxetine	0.002927162
Asia	South Korea	Seoul	Gemfibrozil	0.006165541
Asia	South Korea	Seoul	Ibuprofen	0.006941839
Asia	South Korea	Seoul	Meprobamate	4.57E-06
Asia	South Korea	Seoul	Musk ketone	0.394145314
Asia	South Korea	Seoul	Naproxen	0.029672131
Asia	South Korea	Seoul	Octylphenol	0.015979397
Asia	South Korea	Seoul	Primidone	1.11E-05
Asia	South Korea	Seoul	Sulfamethoxazole	0.234166667
Asia	South Korea	Seoul	Triclosan	0.020447761
Asia	South Korea	Seoul	Trimethoprim	0.044585991
Asia	South Korea	Seoul	Tris(2-chloroethyl) phosphate	0.251156533
Asia	South Korea	Seoul	Tris(2-chloroisopropyl)phosphate	0.41650711
Asia	Taiwan	Taipei	1,2,3-Benzotriazole	0.014625773
Asia	Taiwan	Taipei	5-Methyl-1H-benzotriazole	0.002027767
Asia	Thailand	Bangkok	Acetaminophen	0.015016763
Asia	Thailand	Bangkok	Aspirin	0.051747732
Asia	Thailand	Bangkok	Atenolol	0.003309975
Asia	Thailand	Bangkok	Caffeine	3.896501072
Asia	Thailand	Bangkok	Ciprofloxacin	0.221111111
Asia	Thailand	Bangkok	Diclofenac	0.017287854
Asia	Thailand	Bangkok	Ibuprofen	0.015148218
Asia	Thailand	Bangkok	Mefenamic acid	0.11021021
Asia	Thailand	Bangkok	Naproxen	0.011748634
Asia	Thailand	Bangkok	Roxithromycin	0.001382353
Asia	Thailand	Bangkok	Sulfamethazine	0.000240563
Asia	Thailand	Bangkok	Sulfamethoxazole	0.033333333
Asia	Thailand	Bangkok	Sulfathiazole	0.000143282
Asia	Thailand	Bangkok	Trimethoprim	0.018639421
Asia	Vietnam	Da Nang	1,3-Dimethylnaphthalene	0.001527851
Asia	Vietnam	Da Nang	2,6-Dimethylnaphthalene	0.024300001
Asia	Vietnam	Da Nang	3,5-Dimethylphenol	0.000613375
Asia	Vietnam	Da Nang	4-tert-Octylphenol	0.3684
Asia	Vietnam	Da Nang	Aldrin	0.807796142
Asia	Vietnam	Da Nang	Antipyrine	0.001175115
Asia	Vietnam	Da Nang	beta-Sitosterol	4,471.36
Asia	Vietnam	Da Nang	Bis(2-ethylhexyl)phthalate	42.24630755
Asia	Vietnam	Da Nang	Caffeine	1.40339526
Asia	Vietnam	Da Nang	Carbamazepin	0.002893412
Asia	Vietnam	Da Nang	Carbofuran	0.006957742
Asia	Vietnam	Da Nang	Cholesterol	1,154.33

Asia	Vietnam	Da Nang	cis-Chlordane	0.077096761
Asia	Vietnam	Da Nang	Clarithromycin	0.440266667
Asia	Vietnam	Da Nang	Coprostanol	963.8211901
Asia	Vietnam	Da Nang	Cotinine	0.000825864
Asia	Vietnam	Da Nang	Cyclohexanamine, N-cyclohexyl-	0.589461087
Asia	Vietnam	Da Nang	Di(2-ethylhexyl)adipate	13.10346641
Asia	Vietnam	Da Nang	Dicyclohexylamine	0.589461087
Asia	Vietnam	Da Nang	Diethyl phthalate	0.001458892
Asia	Vietnam	Da Nang	Di-n-butyl phthalate	0.619765394
Asia	Vietnam	Da Nang	Diuron	0.587333333
Asia	Vietnam	Da Nang	Docosane	7.363333333
Asia	Vietnam	Da Nang	Dotriacontane	34.04928571
Asia	Vietnam	Da Nang	Eicosane	1,142.34
Asia	Vietnam	Da Nang	Fenobucarb	6.531777468
Asia	Vietnam	Da Nang	Heneicosane	2.219136364
Asia	Vietnam	Da Nang	Heptadecane	149.403263
Asia	Vietnam	Da Nang	Hexacosane	670,972.35
Asia	Vietnam	Da Nang	Hexadecane	183.7724236
Asia	Vietnam	Da Nang	Isoprothiolane	0.022949195
Asia	Vietnam	Da Nang	Lincomycin	0.922880658
Asia	Vietnam	Da Nang	Metformin	0.000262866
Asia	Vietnam	Da Nang	Octacosane	19.05076923
Asia	Vietnam	Da Nang	Octadecane	66.01217217
Asia	Vietnam	Da Nang	p,p'-DDE	0.024546067
Asia	Vietnam	Da Nang	PCB 1	2.66E-05
Asia	Vietnam	Da Nang	PCB 18	3.09E-05
Asia	Vietnam	Da Nang	PCB 205	0.015533274
Asia	Vietnam	Da Nang	Pentacosane	11.74545455
Asia	Vietnam	Da Nang	Pentadecane	1.010596491
Asia	Vietnam	Da Nang	Phenanthrene	0.004632258
Asia	Vietnam	Da Nang	Propranolol	0.009449743
Asia	Vietnam	Da Nang	Siduron	0.327090911
Asia	Vietnam	Da Nang	Stigmasterol	11.46904043
Asia	Vietnam	Da Nang	Sulpiride	0.001066728
Asia	Vietnam	Da Nang	trans-Chlordane	0.074648517
Asia	Vietnam	Da Nang	Tricosane	22,987.29
Asia	Vietnam	Da Nang	Tricyclazole	9.23E-05
Asia	Vietnam	Da Nang	Undecane	0.08305814
Asia	Vietnam	Hanoi	1,2,5,6,9,10-Hexabromocyclododecane	0.681553398
Asia	Vietnam	Hanoi	1,2-Dichlorobenzene	0.000944
Asia	Vietnam	Hanoi	1-Chloronaphthalene	0.010657143
Asia	Vietnam	Hanoi	2(3H)-Benzothiazolone	0.049993336
Asia	Vietnam	Hanoi	2-(Methylthio)-benzothiazol	0.145295686
Asia	Vietnam	Hanoi	2,4-Dichloroaniline	1.018408602
Asia	Vietnam	Hanoi	2,6-Dimethylnaphthalene	0.050944001
Asia	Vietnam	Hanoi	2-Chloronaphthalene	0.003860029
Asia	Vietnam	Hanoi	2-Ethyl-1-hexanol	0.101410344
Asia	Vietnam	Hanoi	2-Methyl-4,6-dinitrophenol	3.806
Asia	Vietnam	Hanoi	2-Methylnaphthalene	0.004128631
Asia	Vietnam	Hanoi	2-Phenylphenol	1.547777844
Asia	Vietnam	Hanoi	3-&4-Methylphenol	0.484649808

Asia	Vietnam	Hanoi	3,4-Dichloroaniline	4.887703226
Asia	Vietnam	Hanoi	4-Methyl-2,6-di-t-butylphenol	0.19631728
Asia	Vietnam	Hanoi	4-n-Nonylphenol	19.81608
Asia	Vietnam	Hanoi	4-tert-Octylphenol	0.9802
Asia	Vietnam	Hanoi	Acenaphthene	0.005210191
Asia	Vietnam	Hanoi	Acenaphthylene	0.036827195
Asia	Vietnam	Hanoi	Acetaminophen	0.267914282
Asia	Vietnam	Hanoi	Acetamiprid	0.001904018
Asia	Vietnam	Hanoi	Acetochlor	0.786492133
Asia	Vietnam	Hanoi	Acetohexamide	0.854721241
Asia	Vietnam	Hanoi	Acetophenone	0.000975579
Asia	Vietnam	Hanoi	a-HCH	0.0007159
Asia	Vietnam	Hanoi	Alachlor	2.605971626
Asia	Vietnam	Hanoi	Amoxicillin	7.885964912
Asia	Vietnam	Hanoi	Ampicillin	1.023333333
Asia	Vietnam	Hanoi	Anthraquinone	0.022171428
Asia	Vietnam	Hanoi	Atenolol	0.004176422
Asia	Vietnam	Hanoi	Atrazine	0.034544444
Asia	Vietnam	Hanoi	Azithromycin	41.06666667
Asia	Vietnam	Hanoi	Bensulfuron-methyl	0.07017855
Asia	Vietnam	Hanoi	Benzyl alcohol	0.006926252
Asia	Vietnam	Hanoi	beta-Sitosterol	23,125.21
Asia	Vietnam	Hanoi	Biphenyl	0.036834285
Asia	Vietnam	Hanoi	Bis(2-ethylhexyl)phthalate	672.8346893
Asia	Vietnam	Hanoi	Bisphenol A	0.1418
Asia	Vietnam	Hanoi	Butachlor	114.3657953
Asia	Vietnam	Hanoi	Butyl benzyl phtalate	0.0090426
Asia	Vietnam	Hanoi	Caffeine	21.58431884
Asia	Vietnam	Hanoi	Carbendazim	0.036649659
Asia	Vietnam	Hanoi	Carbofuran	0.012815577
Asia	Vietnam	Hanoi	Chloramphenicol	0.020001017
Asia	Vietnam	Hanoi	Cholesterol	10,877.71
Asia	Vietnam	Hanoi	Cimetidine	0.001939105
Asia	Vietnam	Hanoi	Ciprofloxacin	1.96
Asia	Vietnam	Hanoi	Clarithromycin	0.64192
Asia	Vietnam	Hanoi	Clofentezine	1.347826087
Asia	Vietnam	Hanoi	Coprostanol	11,804.46
Asia	Vietnam	Hanoi	Cotinine	0.009328829
Asia	Vietnam	Hanoi	Cyclohexanamine, N-cyclohexyl-	1.534555138
Asia	Vietnam	Hanoi	Cyprodinil	0.001389728
Asia	Vietnam	Hanoi	Decane	16.07467727
Asia	Vietnam	Hanoi	Dexamethasone	0.0003143
Asia	Vietnam	Hanoi	Di(2-ethylhexyl)adipate	4.79896845
Asia	Vietnam	Hanoi	Diazepam	0.001152174
Asia	Vietnam	Hanoi	Dicyclohexylamine	1.534555138
Asia	Vietnam	Hanoi	Diethofencarb	0.103789538
Asia	Vietnam	Hanoi	Diethyl phthalate	0.166354402
Asia	Vietnam	Hanoi	Dimethoate	0.031837521
Asia	Vietnam	Hanoi	Di-n-butyl phthalate	0.286712253
Asia	Vietnam	Hanoi	Diphenyl ether	0.009437776
Asia	Vietnam	Hanoi	Diuron	0.3996

Asia	Vietnam	Hanoi	Docosane	15.46180556
Asia	Vietnam	Hanoi	Dodecane	0.957513888
Asia	Vietnam	Hanoi	Dotriacontane	131.9634286
Asia	Vietnam	Hanoi	Eicosane	2,703.57
Asia	Vietnam	Hanoi	Ethalfluralin	0.093022565
Asia	Vietnam	Hanoi	Ethoxyquin	0.015562499
Asia	Vietnam	Hanoi	Fenobucarb	1.692888808
Asia	Vietnam	Hanoi	Fenofibrate	0.005494505
Asia	Vietnam	Hanoi	Flutolanil	0.014918033
Asia	Vietnam	Hanoi	Griseofulvin	0.313381188
Asia	Vietnam	Hanoi	Heneicosane	11.44165909
Asia	Vietnam	Hanoi	Heptadecane	169.9206637
Asia	Vietnam	Hanoi	Hexachlorobenzene	0.029186125
Asia	Vietnam	Hanoi	Hexacosane	1,507,847.70
Asia	Vietnam	Hanoi	Hexadecane	94.78261902
Asia	Vietnam	Hanoi	Hexamethylenetetramine	0.000844651
Asia	Vietnam	Hanoi	Imidacloprid	0.000950438
Asia	Vietnam	Hanoi	Isophorone	0.002601687
Asia	Vietnam	Hanoi	Isoprothiolane	0.009381406
Asia	Vietnam	Hanoi	Ketoprofen	0.004273684
Asia	Vietnam	Hanoi	Lidocaine	0.002854183
Asia	Vietnam	Hanoi	Lincomycin	1.859259259
Asia	Vietnam	Hanoi	L-Menthol	0.281745862
Asia	Vietnam	Hanoi	Losartan	0.043926812
Asia	Vietnam	Hanoi	Malathion	0.034649818
Asia	Vietnam	Hanoi	Mefenamic Acid	0.023063063
Asia	Vietnam	Hanoi	Metformin	0.00521027
Asia	Vietnam	Hanoi	Metolcarb	0.047491095
Asia	Vietnam	Hanoi	Metoprolol	0.027325905
Asia	Vietnam	Hanoi	Metribuzin DA	0.008708245
Asia	Vietnam	Hanoi	Molinate	0.061810313
Asia	Vietnam	Hanoi	Nicotine	0.035741038
Asia	Vietnam	Hanoi	Nonadecane	1,073.94
Asia	Vietnam	Hanoi	Nonane	2.812729851
Asia	Vietnam	Hanoi	Nonylphenol	19.81608
Asia	Vietnam	Hanoi	Octacosane	51.37269231
Asia	Vietnam	Hanoi	Octadecane	569.4723305
Asia	Vietnam	Hanoi	Ofloxacin	0.0525
Asia	Vietnam	Hanoi	Oleandomycin	0.087274411
Asia	Vietnam	Hanoi	Oxadixyl	0.022724423
Asia	Vietnam	Hanoi	p,p'-DDE	0.425412049
Asia	Vietnam	Hanoi	PCB 1	2.08E-05
Asia	Vietnam	Hanoi	PCB 101	0.000567433
Asia	Vietnam	Hanoi	PCB 105	0.000281515
Asia	Vietnam	Hanoi	PCB 110	0.001943298
Asia	Vietnam	Hanoi	PCB 118	0.00160828
Asia	Vietnam	Hanoi	PCB 149	0.005308063
Asia	Vietnam	Hanoi	PCB 18	0.059398182
Asia	Vietnam	Hanoi	PCB 22	0.000190956
Asia	Vietnam	Hanoi	PCB 28	0.001206618
Asia	Vietnam	Hanoi	PCB 33	0.000333949

Asia	Vietnam	Hanoi	PCB 37	0.001346641
Asia	Vietnam	Hanoi	PCB 99	0.000895296
Asia	Vietnam	Hanoi	Pentacosane	45.81977273
Asia	Vietnam	Hanoi	Pentadecane	0.262086842
Asia	Vietnam	Hanoi	Phenacetin	0.000672554
Asia	Vietnam	Hanoi	Phenanthrene	0.012916774
Asia	Vietnam	Hanoi	Phenol	0.020733766
Asia	Vietnam	Hanoi	Phenylethyl alcohol	0.026590518
Asia	Vietnam	Hanoi	Piperonyl butoxide	0.063534667
Asia	Vietnam	Hanoi	Procymidone	0.017340951
Asia	Vietnam	Hanoi	Promecarb	0.249060199
Asia	Vietnam	Hanoi	Prometryn	0.14410142
Asia	Vietnam	Hanoi	Propazine	0.062564821
Asia	Vietnam	Hanoi	Propranolol	0.041610418
Asia	Vietnam	Hanoi	Pyrene	0.032443836
Asia	Vietnam	Hanoi	Quinoline	0.025820525
Asia	Vietnam	Hanoi	Roxithromycin	0.008688235
Asia	Vietnam	Hanoi	Siduron	0.057975328
Asia	Vietnam	Hanoi	Simazine	0.936
Asia	Vietnam	Hanoi	Spiramycin	0.888438532
Asia	Vietnam	Hanoi	Stigmasterol	14.39833962
Asia	Vietnam	Hanoi	Sulfacetamide	0.013546798
Asia	Vietnam	Hanoi	Sulfadiazine	0.009741302
Asia	Vietnam	Hanoi	Sulfamethoxazole	6.176666667
Asia	Vietnam	Hanoi	Sulfapyridine	5.12E-05
Asia	Vietnam	Hanoi	Sulfosulfuron	0.026692373
Asia	Vietnam	Hanoi	Tebuthiuron	0.059295077
Asia	Vietnam	Hanoi	Terbutryn	0.025735083
Asia	Vietnam	Hanoi	Testosterone	0.00147
Asia	Vietnam	Hanoi	Tetradecane	11.64574255
Asia	Vietnam	Hanoi	Theophylline	7.924616612
Asia	Vietnam	Hanoi	Thiabendazole	0.032639694
Asia	Vietnam	Hanoi	Triclosan	0.02358209
Asia	Vietnam	Hanoi	Tricosane	82,912.88
Asia	Vietnam	Hanoi	Tricyclazole	2.40E-05
Asia	Vietnam	Hanoi	Tridecane	2.217203885
Asia	Vietnam	Hanoi	Trimethoprim	0.09368012
Asia	Vietnam	Hanoi	Trinexapac-ethyl	0.000966418
Asia	Vietnam	Hanoi	Triphenylphosphate	0.124341746
Asia	Vietnam	Hanoi	Tylosin	2.259183673
Asia	Vietnam	Hanoi	Undecane	0.59667093
Asia	Vietnam	Hanoi	Warfarin	0.037393812
Asia	Vietnam	Hochiminh	2(3H)-Benzothiazolone	0.281383798
Asia	Vietnam	Hochiminh	2-(Methylthio)-benzothiazol	0.170168627
Asia	Vietnam	Hochiminh	2,6-Dimethylnaphthalene	0.124070003
Asia	Vietnam	Hochiminh	2-Ethyl-1-hexanol	0.07932454
Asia	Vietnam	Hochiminh	2-Methylnaphthalene	0.007738589
Asia	Vietnam	Hochiminh	3-&4-Methylphenol	0.654600606
Asia	Vietnam	Hochiminh	3,4-Dichloroaniline	1.32083871
Asia	Vietnam	Hochiminh	4-Methyl-2,6-di-t-butylphenol	0.024751275
Asia	Vietnam	Hochiminh	4-n-Nonylphenol	80.87781333

Asia	Vietnam	Hochiminh	4-tert-Octylphenol	7.64498
Asia	Vietnam	Hochiminh	Acetaminophen	0.046599233
Asia	Vietnam	Hochiminh	Acetamiprid	0.001244515
Asia	Vietnam	Hochiminh	a-HCH	0.001164251
Asia	Vietnam	Hochiminh	Atenolol	0.001962077
Asia	Vietnam	Hochiminh	Atrazine	0.0376
Asia	Vietnam	Hochiminh	Benzyl alcohol	0.001850122
Asia	Vietnam	Hochiminh	beta-Sitosterol	9,827.01
Asia	Vietnam	Hochiminh	Biphenyl	0.19411428
Asia	Vietnam	Hochiminh	Bis(2-ethylhexyl)phthalate	498.7012402
Asia	Vietnam	Hochiminh	Bisphenol A	0.40876
Asia	Vietnam	Hochiminh	Butyl benzyl phtalate	0.020776236
Asia	Vietnam	Hochiminh	Caffeine	18.81733459
Asia	Vietnam	Hochiminh	Carbendazim	0.007490292
Asia	Vietnam	Hochiminh	Cholesterol	4,498.57
Asia	Vietnam	Hochiminh	Clarithromycin	0.169866667
Asia	Vietnam	Hochiminh	Coprostanol	4,058.16
Asia	Vietnam	Hochiminh	Cotinine	0.002211037
Asia	Vietnam	Hochiminh	Cyclohexanamine, N-cyclohexyl-	0.091885502
Asia	Vietnam	Hochiminh	Decane	1.678147367
Asia	Vietnam	Hochiminh	Di(2-ethylhexyl)adipate	15.39836134
Asia	Vietnam	Hochiminh	Dicyclohexylamine	0.091885502
Asia	Vietnam	Hochiminh	Diethyl phthalate	0.108339359
Asia	Vietnam	Hochiminh	Di-n-butyl phthalate	0.278275966
Asia	Vietnam	Hochiminh	Diuron	0.549133333
Asia	Vietnam	Hochiminh	Docosane	73.29552778
Asia	Vietnam	Hochiminh	Dodecane	0.125044171
Asia	Vietnam	Hochiminh	Dotriacontane	110.9407143
Asia	Vietnam	Hochiminh	Eicosane	19,627.01
Asia	Vietnam	Hochiminh	Ethoxyquin	0.015045833
Asia	Vietnam	Hochiminh	Fenobucarb	1.366666602
Asia	Vietnam	Hochiminh	Griseofulvin	0.001485149
Asia	Vietnam	Hochiminh	Heneicosane	80.00068182
Asia	Vietnam	Hochiminh	Heptadecane	710.4019399
Asia	Vietnam	Hochiminh	Hexachlorobenzene	0.333850065
Asia	Vietnam	Hochiminh	Hexacosane	4,100,973.87
Asia	Vietnam	Hochiminh	Hexadecane	327.0499373
Asia	Vietnam	Hochiminh	Isophorone	0.003837711
Asia	Vietnam	Hochiminh	Lidocaine	0.009825434
Asia	Vietnam	Hochiminh	Lincomycin	2.173135802
Asia	Vietnam	Hochiminh	L-Menthol	0.20171706
Asia	Vietnam	Hochiminh	Metformin	0.000502654
Asia	Vietnam	Hochiminh	Nicotine	0.048135895
Asia	Vietnam	Hochiminh	Nonadecane	8,618.22
Asia	Vietnam	Hochiminh	Nonane	0.031851561
Asia	Vietnam	Hochiminh	Nonylphenol	80.87781333
Asia	Vietnam	Hochiminh	Octacosane	137.4438462
Asia	Vietnam	Hochiminh	Octadecane	2,018.88
Asia	Vietnam	Hochiminh	Oleandomycin	0.004880052
Asia	Vietnam	Hochiminh	p,p'-DDE	0.069559745
Asia	Vietnam	Hochiminh	PCB 1	2.17E-05

Asia	Vietnam	Hochiminh	PCB 156	0.001613699
Asia	Vietnam	Hochiminh	PCB 180	0.003053479
Asia	Vietnam	Hochiminh	PCB 187	0.002442783
Asia	Vietnam	Hochiminh	PCB 28	9.96E-05
Asia	Vietnam	Hochiminh	PCB 33	4.44E-05
Asia	Vietnam	Hochiminh	Pentacosane	100.2952273
Asia	Vietnam	Hochiminh	Pentadecane	1.548824561
Asia	Vietnam	Hochiminh	Phenanthrene	0.066658066
Asia	Vietnam	Hochiminh	Phenylethyl alcohol	0.001192
Asia	Vietnam	Hochiminh	Piperonyl butoxide	0.0218
Asia	Vietnam	Hochiminh	Promecarb	0.118047491
Asia	Vietnam	Hochiminh	Prometryn	0.001824184
Asia	Vietnam	Hochiminh	Pyrene	0.166356164
Asia	Vietnam	Hochiminh	Quinoline	0.0024605
Asia	Vietnam	Hochiminh	Siduron	0.083105382
Asia	Vietnam	Hochiminh	Stigmasterol	9.043466307
Asia	Vietnam	Hochiminh	Sulfamethoxazole	0.809022222
Asia	Vietnam	Hochiminh	Sulfanilamide	0.001915151
Asia	Vietnam	Hochiminh	Sulpiride	0.002350704
Asia	Vietnam	Hochiminh	Tetradecane	9.348630261
Asia	Vietnam	Hochiminh	Tricosane	466,771.21
Asia	Vietnam	Hochiminh	Tricyclazole	0.000185053
Asia	Vietnam	Hochiminh	Tridecane	3.741428848
Asia	Vietnam	Hochiminh	Trimethoprim	0.04830149
Asia	Vietnam	Hochiminh	Triphenylphosphate	0.052198663
Asia	Vietnam	Hochiminh	Undecane	0.058338372
Asia	Vietnam	Hue City	beta-Sitosterol	280.5610065
Asia	Vietnam	Hue City	Cholesterol	125.2030532
Asia	Vietnam	Hue City	Cyclohexanamine, N-cyclohexyl-	0.029263158
Asia	Vietnam	Hue City	Dicyclohexylamine	0.029263158
Asia	Vietnam	Hue City	Hexacosane	44,270.06
Asia	Vietnam	Hue City	PCB 1	1.08E-05
Asia	Vietnam	Hue City	Stigmasterol	1.580808625
Europe	Danemark	Harrestrup	2,6-Dichlorobenzamide	0.004397835
Europe	Danemark	Harrestrup	2-Hydroxyatrazine	0.000272554
Europe	Danemark	Harrestrup	4-Nitrophenol	0.00117855
Europe	Danemark	Harrestrup	4-Nonylphenol	0.4
Europe	Danemark	Harrestrup	Acenaphthene	0.003821656
Europe	Danemark	Harrestrup	Alkylbenzenesulfonate, linear	1.228070175
Europe	Danemark	Harrestrup	Aminomethylphosphonic acid	3.87E-06
Europe	Danemark	Harrestrup	Chloroform	0.02
Europe	Danemark	Harrestrup	Dalapon	0.025378007
Europe	Danemark	Harrestrup	Dichlorprop	0.003203262
Europe	Danemark	Harrestrup	Diuron	0.3
Europe	Danemark	Harrestrup	Fluoranthene	0.1
Europe	Danemark	Harrestrup	Fluorene	0.001589825
Europe	Danemark	Harrestrup	Glyphosate	1.19E-06
Europe	Danemark	Harrestrup	Isoproturon	0.066666667
Europe	Danemark	Harrestrup	MCPA	0.020643112
Europe	Danemark	Harrestrup	Mecoprop	0.004617414
Europe	Danemark	Harrestrup	Metamitron	0.003825923

Europe	Danemark	Harrestrup	o-Cresol	0.000606391
Europe	Danemark	Harrestrup	Phenanthrene	0.003225807
Europe	Danemark	Harrestrup	Pyrene	0.01369863
Europe	Danemark	Harrestrup	Terbutylazine	0.002201107
Europe	Danemark	Harrestrup	Trichloroacetic acid	2.57498142
Europe	Danemark	Harrestrup	Trichloroethylene	0.074144193
Europe	France	Caudebec	Aspirin	0.000403094
Europe	France	Caudebec	Caffeine	0.338242488
Europe	France	Caudebec	Carbamazepine	0.005854476
Europe	France	Caudebec	Diclofenac	0.018409318
Europe	France	Caudebec	Enoxacin	1.07E-06
Europe	France	Caudebec	Flumequine	1.64E-05
Europe	France	Caudebec	Gemfibrozil	0.012851351
Europe	France	Caudebec	Ibuprofen	0.006001126
Europe	France	Caudebec	Ketoprofen	0.001821053
Europe	France	Caudebec	Naproxen	0.01882623
Europe	France	Caudebec	Norfloxacin	0.011633334
Europe	France	Caudebec	Ornidazole	0.000867437
Europe	France	Caudebec	Sulfamethoxazole	0.179333333
Europe	France	Caudebec	Trimethoprim	0.013623497
Europe	France	Epinay-sur-seine	2,2',3,4,4',5'-Hexachlorobiphenyl	0.017728025
Europe	France	Epinay-sur-seine	2,2',4,4',5,5'-Hexachlorobiphenyl	0.021912932
Europe	France	Epinay-sur-seine	2,2',5,5'-Tetrachlorobiphenyl	0.004360501
Europe	France	Epinay-sur-seine	2,3,3',4,4'-Pentachlorobiphenyl	0.000835336
Europe	France	Epinay-sur-seine	2,3,3',4',6-Pentachlorobiphenyl	0.003295303
Europe	France	Epinay-sur-seine	2,4,4'-Trichlorobiphenyl	0.000458333
Europe	France	Epinay-sur-seine	3,3',4,4'-Tetrachlorobiphenyl	0.000777895
Europe	France	Epinay-sur-seine	Benzyl butyl phthalate	0.026783069
Europe	France	Epinay-sur-seine	DEHP	46.68513574
Europe	France	Epinay-sur-seine	Dibutyl phthalate	0.026825824
Europe	France	Epinay-sur-seine	Diethyl phthalate	0.000150093
Europe	France	Epinay-sur-seine	Dimethyl phthalate	0.000966132
Europe	France	Epinay-sur-seine	Di-n-octyl phthalate	0.064583333
Europe	France	Epinay-sur-seine	PBDE 153	0.00010137
Europe	France	Epinay-sur-seine	PBDE 154	8.87E-06
Europe	France	Epinay-sur-seine	PBDE 209	0.001091739
Europe	France	Epinay-sur-seine	PBDE 28	6.58E-06
Europe	France	Epinay-sur-seine	PBDE 47	0.000435714
Europe	France	Epinay-sur-seine	PBDE 99	0.00138655
Europe	France	Epinay-sur-seine	PCB 118	0.00343343
Europe	France	Epinay-sur-seine	PCB 180	0.039016677
Europe	France	Epinay-sur-seine	PCB101	0.004946244
Europe	France	Honfleur	Flumequine	1.48E-05
Europe	France	Honfleur	Norfloxacin	0.001083333
Europe	France	Honfleur	Ornidazole	0.000196401
Europe	France	Honfleur	Sulfamethoxazole	0.772
Europe	France	Honfleur	Trimethoprim	0.018082096
Europe	France	La Bouille	Flumequine	1.55E-05
Europe	France	La Bouille	Norfloxacin	0.001083333
Europe	France	La Bouille	Ornidazole	0.000163667
Europe	France	La Bouille	Sulfamethoxazole	0.113666667

Europe	France	La Bouille	Trimethoprim	0.009660298
Europe	France	Poses	Flumequine	1.38E-05
Europe	France	Poses	Norfloxacin	0.004516667
Europe	France	Poses	Ofloxacin	0.005
Europe	France	Poses	Ornidazole	0.00085107
Europe	France	Poses	Sulfamethoxazole	0.137333333
Europe	France	Poses	Trimethoprim	0.024274595
Europe	France	Tancarville	Enrofloxacin	0.005235602
Europe	France	Tancarville	Flumequine	7.22E-06
Europe	France	Tancarville	Norfloxacin	0.002633333
Europe	France	Tancarville	Sarafloxacin	4.19E-06
Europe	France	Tancarville	Sulfamethoxazole	0.121666667
Europe	France	Tancarville	Trimethoprim	0.016719747
Europe	Germany	Mainz	Acridine	0.013523325
Europe	Germany	Mainz	Carbamazepine	0.147055751
Europe	Germany	Mainz	Oxcarbazepine	0.024536003
Europe	Greece	Ioannina	Acetaminophen	0.007238524
Europe	Greece	Ioannina	Caffeine	5.063688271
Europe	Greece	Ioannina	Carbamazepine	0.032639351
Europe	Greece	Ioannina	Cimetidine	0.000321998
Europe	Greece	Ioannina	Ciprofloxacin	0.249333333
Europe	Greece	Ioannina	Diclofenac	0.052579035
Europe	Greece	Ioannina	Erythromycin	0.2404
Europe	Greece	Ioannina	Fenofibrate	0.013469388
Europe	Greece	Ioannina	Gemfibrozil	0.084070946
Europe	Greece	Ioannina	Ibuprofen	0.042232645
Europe	Greece	Ioannina	Ketoprofen	0.009578947
Europe	Greece	Ioannina	Phenazone	0.006105037
Europe	Greece	Ioannina	Salicylic acid	0.019754
Europe	Greece	Ioannina	Sulfamethoxazole	0.2945
Europe	Greece	Ioannina	Triclosan	0.044776119
Europe	Italy	Milan	11-Nor-9-carboxy-delta-9-tetrahydrocannabino	0.00143128
Europe	Italy	Milan	17beta-Estradiol	0.424096386
Europe	Italy	Milan	2-Hydroxy-4-methoxybenzophenone	0.001169195
Europe	Italy	Milan	3-(Benzoyloxy)-8-azabicyclo[3.2.1]octane-2-car	0.000286892
Europe	Italy	Milan	4-tert-Octylphenol	0.5744
Europe	Italy	Milan	Acetaminophen	0.001383151
Europe	Italy	Milan	Albuterol	0.012585548
Europe	Italy	Milan	Amoxicillin	0.041649123
Europe	Italy	Milan	Atenolol	0.013520198
Europe	Italy	Milan	Benzoylecgonine	0.002442489
Europe	Italy	Milan	Bezafibrate	0.033936508
Europe	Italy	Milan	Bisphenol A	0.070133333
Europe	Italy	Milan	Caffeine	9.425149975
Europe	Italy	Milan	Carbamazepine	0.020607754
Europe	Italy	Milan	Ciprofloxacin	0.126888889
Europe	Italy	Milan	Clarithromycin	1.0304
Europe	Italy	Milan	Clofibric acid	0.000590884
Europe	Italy	Milan	Cocaethylene	1.54E-05
Europe	Italy	Milan	Cocaine	0.000921444
Europe	Italy	Milan	Codeine	0.000844828

Europe	Italy	Milan	Cotinine	0.000434783
Europe	Italy	Milan	Diazepam	0.014143223
Europe	Italy	Milan	Diclofenac	0.092279534
Europe	Italy	Milan	Ecgonidine	0.000199085
Europe	Italy	Milan	Enalapril	0.000211816
Europe	Italy	Milan	Ensulizole	0.006617158
Europe	Italy	Milan	Enzacamene	0.00039752
Europe	Italy	Milan	Estrone	0.003281837
Europe	Italy	Milan	Furosemide	0.000481049
Europe	Italy	Milan	Gemfibrozil	0.004219595
Europe	Italy	Milan	Hydrochlorothiazide	0.000310787
Europe	Italy	Milan	Ibuprofen	0.005628518
Europe	Italy	Milan	Ketamine	0.001776249
Europe	Italy	Milan	Ketoprofen	0.002989474
Europe	Italy	Milan	Lincomycin	0.021679012
Europe	Italy	Milan	MDMA	8.90E-05
Europe	Italy	Milan	Methadone	0.00240508
Europe	Italy	Milan	Methamphetamine	8.23E-05
Europe	Italy	Milan	Morphine	0.000283057
Europe	Italy	Milan	Naproxen	0.013420765
Europe	Italy	Milan	Nicotine	0.041391304
Europe	Italy	Milan	Nonylphenol	1.091846131
Europe	Italy	Milan	Norcocaine	2.17E-05
Europe	Italy	Milan	Ofloxacin	0.01532
Europe	Italy	Milan	Paraxantine	0.938817554
Europe	Italy	Milan	Perfluorooctanoic acid	0.001096664
Europe	Italy	Milan	Ranitidine	2.29E-05
Europe	Italy	Milan	Sulfamethoxazole	0.019366667
Europe	Italy	Milan	Sulisobenzone	0.001831507
Europe	Italy	Milan	Triclocarban	0.062146471
Europe	Italy	Milan	Triclosan	0.041253731
Europe	Italy	Rome	Carbamazepine	0.007681072
Europe	Italy	Rome	Diclofenac	0.019966722
Europe	Italy	Rome	Gemfibrozil	0.01097973
Europe	Italy	Rome	Ibuprofen	0.007448405
Europe	Italy	Rome	Ketoprofen	0.015789474
Europe	Italy	Rome	Naproxen	0.028153005
Europe	Italy	Venice	(-)-Ambroxide	0.002810966
Europe	Italy	Venice	1,3-Dioxolane, 2,4-dimethyl-2-(5,6,7,8-tetrahy	0.018523223
Europe	Italy	Venice	2'-Acetonaphthone	0.000774828
Europe	Italy	Venice	2-Cyclohexyl-2-phenylacetonitrile	0.07201041
Europe	Italy	Venice	3-(4-tert-Butylphenyl)propanal	0.057089547
Europe	Italy	Venice	3,7-Dimethylnona-2,6-dienenitrile	0.016092714
Europe	Italy	Venice	4-(4-Methyl-3-pentenyl)cyclohex-3-ene-1-carb	0.076892733
Europe	Italy	Venice	4-Formyl-2-methoxyphenyl isobutyrate	0.000750676
Europe	Italy	Venice	Benzyl salicylate	0.030710288
Europe	Italy	Venice	Hexyl salicylate	0.039605188
Europe	Italy	Venice	Pentyl 2-hydroxybenzoate	0.065686152
Europe	Macedonia	Cities in Macedonia	2-(2,4,5-Trichlorophenoxy)propionic acid	0.001382432
Europe	Macedonia	Cities in Macedonia	5,5-Diphenylhydantoin	0.009034574
Europe	Macedonia	Cities in Macedonia	Aclonifen	0.012309091

Europe	Macedonia	Cities in Macedonia	Ametryn	1.25472728
Europe	Macedonia	Cities in Macedonia	Amidosulfuron	0.001078663
Europe	Macedonia	Cities in Macedonia	Benfuracarb	0.442335055
Europe	Macedonia	Cities in Macedonia	Bentazone	1.91E-05
Europe	Macedonia	Cities in Macedonia	Carbamazepine	0.000781013
Europe	Macedonia	Cities in Macedonia	Carbendazim	0.000725954
Europe	Macedonia	Cities in Macedonia	Carbosulfan	0.449016452
Europe	Macedonia	Cities in Macedonia	Carboxin	0.000218979
Europe	Macedonia	Cities in Macedonia	Chloramben	0.014035897
Europe	Macedonia	Cities in Macedonia	Cyanazine	1.36E-05
Europe	Macedonia	Cities in Macedonia	Cycluron	0.00086898
Europe	Macedonia	Cities in Macedonia	Cymiazole	7.84E-05
Europe	Macedonia	Cities in Macedonia	Dalapon	0.01166627
Europe	Macedonia	Cities in Macedonia	DEET	0.000550231
Europe	Macedonia	Cities in Macedonia	Deethylatrazine	1.45E-05
Europe	Macedonia	Cities in Macedonia	Dicamba	5.91E-05
Europe	Macedonia	Cities in Macedonia	Dimethoate	0.000421172
Europe	Macedonia	Cities in Macedonia	Dioxacarb	0.000119109
Europe	Macedonia	Cities in Macedonia	Ethoxyquin	0.002725312
Europe	Macedonia	Cities in Macedonia	Felbamate	0.000111502
Europe	Macedonia	Cities in Macedonia	Fenarimol	0.000388919
Europe	Macedonia	Cities in Macedonia	Fenbuconazole	0.026203175
Europe	Macedonia	Cities in Macedonia	Fenoxycarb	9.88
Europe	Macedonia	Cities in Macedonia	Forchlorfenuron	0.000778362
Europe	Macedonia	Cities in Macedonia	Hexaconazole	0.007170011
Europe	Macedonia	Cities in Macedonia	Imazalil	0.000728202
Europe	Macedonia	Cities in Macedonia	Imidacloprid	2.26E-05
Europe	Macedonia	Cities in Macedonia	Ipconazole	0.021780183
Europe	Macedonia	Cities in Macedonia	Lamotrigine	0.013623638
Europe	Macedonia	Cities in Macedonia	Linuron	0.000938386
Europe	Macedonia	Cities in Macedonia	Mevinphos	0.001184905
Europe	Macedonia	Cities in Macedonia	Oxadixyl	8.26E-05
Europe	Macedonia	Cities in Macedonia	Picloram	0.000100065
Europe	Macedonia	Cities in Macedonia	Primidone	2.53E-05
Europe	Macedonia	Cities in Macedonia	Propiconazole	0.002933302
Europe	Macedonia	Cities in Macedonia	Propoxur	0.002356911
Europe	Macedonia	Cities in Macedonia	Prosulfocarb	0.002916437
Europe	Macedonia	Cities in Macedonia	Pymetrozine	0.00060517
Europe	Macedonia	Cities in Macedonia	Tebuconazole	0.02506217
Europe	Macedonia	Cities in Macedonia	Tepraloxydim	0.0001705
Europe	Macedonia	Cities in Macedonia	Thiamethoxam	6.07E-06
Europe	Macedonia	Cities in Macedonia	Tralkoxydim	0.00271513
Europe	Portugal	Aveiro	2-Phenylphenol	0.019266667
Europe	Portugal	Aveiro	4-Nonylphenol	0.214
Europe	Portugal	Aveiro	Bisphenol A	0.005233333
Europe	Portugal	Aveiro	Butylparaben	0.000246614
Europe	Portugal	Aveiro	Ethylparaben	4.05E-05
Europe	Portugal	Aveiro	Methylparaben	0.00125
Europe	Portugal	Aveiro	Octylphenol	0.0011633
Europe	Portugal	Aveiro	Propylparaben	0.0003752
Europe	Romania	Cluj-Napoca	Caffeine	0.838742635

Europe	Romania	Cluj-Napoca	Carbamazepine	0.005599481
Europe	Romania	Cluj-Napoca	Cyclopenta[g]-2-benzopyran, 1,3,4,6,7,8-hexah	0.284768434
Europe	Romania	Cluj-Napoca	Ibuprofen	0.002333959
Europe	Romania/Moldova	Iasi, Cahul	1-(p-Chlorobenzoyl)-5-methoxy-2-methyl-Indol	0.000270196
Europe	Romania/Moldova	Iasi, Cahul	2-(Phenylsulfonyl)aniline	0.023985996
Europe	Romania/Moldova	Iasi, Cahul	2,4-Di-tert-butylphenol	0.184084925
Europe	Romania/Moldova	Iasi, Cahul	2,6-Di-tert-butyl-4-(hydroxymethyl)phenol	0.001856148
Europe	Romania/Moldova	Iasi, Cahul	2,6-Di-tert-butyl-4-nitrophenol	0.010709024
Europe	Romania/Moldova	Iasi, Cahul	2-tert-Butyl-4-methoxyphenol	0.006479186
Europe	Romania/Moldova	Iasi, Cahul	3,5-Dibromo-4-hydroxybenzoic acid	5.35E-05
Europe	Romania/Moldova	Iasi, Cahul	3,5-Di-tert-butyl-4-hydroxybenzaldehyde	0.023361354
Europe	Romania/Moldova	Iasi, Cahul	3-Methylindole	0.067449522
Europe	Romania/Moldova	Iasi, Cahul	3-Phenoxybenzoic acid	7.92E-05
Europe	Romania/Moldova	Iasi, Cahul	4-Formylaminoantipyrine	0.001137178
Europe	Romania/Moldova	Iasi, Cahul	5-Chloro-2-methyl-3(2H)-isothiazolone	0.000441424
Europe	Romania/Moldova	Iasi, Cahul	5-Methyl-1H-benzotriazole	0.000360576
Europe	Romania/Moldova	Iasi, Cahul	7,9-Di-tert-butyl-1-oxaspiro(4,5)deca-6,9-diene	0.004873689
Europe	Romania/Moldova	Iasi, Cahul	7-Acetyl-1,1,3,4,4,6-hexamethyltetraline	0.082003499
Europe	Romania/Moldova	Iasi, Cahul	Acesulfame	4.65E-06
Europe	Romania/Moldova	Iasi, Cahul	Acetochlor	0.544285213
Europe	Romania/Moldova	Iasi, Cahul	Acetyl tributyl citrate	0.005897134
Europe	Romania/Moldova	Iasi, Cahul	Amisulpride	8.70E-06
Europe	Romania/Moldova	Iasi, Cahul	Atenolol	0.000535862
Europe	Romania/Moldova	Iasi, Cahul	Atrazine	0.019
Europe	Romania/Moldova	Iasi, Cahul	Bentazone	0.000185033
Europe	Romania/Moldova	Iasi, Cahul	Benzenesulfonic acid, 4-methyl-, butyl ester	0.004242604
Europe	Romania/Moldova	Iasi, Cahul	Bis(2-chloro-1-methylethyl) 2-chloropropyl pho	0.026550755
Europe	Romania/Moldova	Iasi, Cahul	Butylated hydroxytoluene	0.038575252
Europe	Romania/Moldova	Iasi, Cahul	Caffeine	0.10906173
Europe	Romania/Moldova	Iasi, Cahul	Carbamazepine	0.003663601
Europe	Romania/Moldova	Iasi, Cahul	Carbendazim	0.000275036
Europe	Romania/Moldova	Iasi, Cahul	Cholesterol	23.430341
Europe	Romania/Moldova	Iasi, Cahul	Cyclamic acid	1.02E-07
Europe	Romania/Moldova	Iasi, Cahul	Cyclopenta[g]-2-benzopyran, 1,3,4,6,7,8-hexah	0.502508634
Europe	Romania/Moldova	Iasi, Cahul	DEET	0.000244957
Europe	Romania/Moldova	Iasi, Cahul	Diclofenac	0.001497504
Europe	Romania/Moldova	Iasi, Cahul	Dioxypyramidon	2.67E-05
Europe	Romania/Moldova	Iasi, Cahul	Diphenyl o-isopropylphenylphenyl phosphate	0.339448222
Europe	Romania/Moldova	Iasi, Cahul	Diphenylsulfone	0.025644546
Europe	Romania/Moldova	Iasi, Cahul	Fipronil	0.012409788
Europe	Romania/Moldova	Iasi, Cahul	Fluconazole	4.03E-05
Europe	Romania/Moldova	Iasi, Cahul	Gabapentin	0.001538969
Europe	Romania/Moldova	Iasi, Cahul	Imidacloprid	1.63E-05
Europe	Romania/Moldova	Iasi, Cahul	Lamotrigine	0.003215517
Europe	Romania/Moldova	Iasi, Cahul	Lidocaine	0.0004662
Europe	Romania/Moldova	Iasi, Cahul	Metformin	0.000171342
Europe	Romania/Moldova	Iasi, Cahul	Methanone, [1,1'-biphenyl]-4-ylphenyl-	0.07903762
Europe	Romania/Moldova	Iasi, Cahul	Metolachlor	0.398018662
Europe	Romania/Moldova	Iasi, Cahul	Metoprolol	0.000885794
Europe	Romania/Moldova	Iasi, Cahul	Metoprolol acid	0.001587368
Europe	Romania/Moldova	Iasi, Cahul	Metribuzin-DA	0.000158332

Europe	Romania/Moldova	Iasi, Cahul	N-(1,3-Dimethylbutyl)-N'-phenyl-p-phenylened	0.350495495
Europe	Romania/Moldova	Iasi, Cahul	N-Acetylaminoantipyrine	0.008042103
Europe	Romania/Moldova	Iasi, Cahul	Octadecyl 3-(3,5-di-tert-butyl-4-hydroxyphenyl	0.995833333
Europe	Romania/Moldova	Iasi, Cahul	Octinoxate	0.073969359
Europe	Romania/Moldova	Iasi, Cahul	Octyl dimethyl 4-aminobenzoic acid	0.11761039
Europe	Romania/Moldova	Iasi, Cahul	Perfluorooctanoic acid	0.000149105
Europe	Romania/Moldova	Iasi, Cahul	Phenazone	0.004672648
Europe	Romania/Moldova	Iasi, Cahul	Phenol, 2,6-bis(1,1-dimethylethyl)-4-(1,1,3,3-te	1.666421529
Europe	Romania/Moldova	Iasi, Cahul	Phenol, 2,6-bis(1,1-dimethylethyl)-4-[(2,4,6-trir	0.065384615
Europe	Romania/Moldova	Iasi, Cahul	Propyphenazone	0.016115154
Europe	Romania/Moldova	Iasi, Cahul	Ranitidine	1.51E-05
Europe	Romania/Moldova	Iasi, Cahul	Saccharin	0.002664464
Europe	Romania/Moldova	Iasi, Cahul	Simetone	0.000154881
Europe	Romania/Moldova	Iasi, Cahul	Sotalol	2.41E-05
Europe	Romania/Moldova	Iasi, Cahul	Sucralose	9.41E-08
Europe	Romania/Moldova	Iasi, Cahul	Sulfamethoxazole	0.016666667
Europe	Romania/Moldova	Iasi, Cahul	Sulpiride	2.30E-05
Europe	Romania/Moldova	Iasi, Cahul	Tebuconazole	0.000583928
Europe	Romania/Moldova	Iasi, Cahul	Terbutylazine	0.001209036
Europe	Romania/Moldova	Iasi, Cahul	Tiapride	1.79E-05
Europe	Romania/Moldova	Iasi, Cahul	Tramadol	0.000591898
Europe	Romania/Moldova	Iasi, Cahul	Trimethoprim	0.001795825
Europe	Romania/Moldova	Iasi, Cahul	Triphenyl phosphate	0.148932473
Europe	Romania/Moldova	Iasi, Cahul	Tris(2-chloroisopropyl)phosphate	0.086880671
Europe	Serbia	Novi Sad	[1,1’-biphenyl]-2-ol	0.433133352
Europe	Serbia	Novi Sad	1,2-benzenedicarboxylic acid, dibutyl ester	0.262018855
Europe	Serbia	Novi Sad	1h-indole	0.911443256
Europe	Serbia	Novi Sad	2-pyrrolidinone, 1-methyl-5- (3-pyridinyl)-	0.003033512
Europe	Serbia	Novi Sad	7,9-di-tert-butyl-1-oxaspi- ro[4.5]deca-6,9-dien	0.039667302
Europe	Serbia	Novi Sad	7-acetyl-6-ethyl-1,1,4,4-tetramethyl tetralin	2.834848405
Europe	Serbia	Novi Sad	Benzo[e]pyrene	0.255875
Europe	Serbia	Novi Sad	beta-Sitosterol	38.67614122
Europe	Serbia	Novi Sad	Cholesterol	73.96762337
Europe	Serbia	Novi Sad	Diazinone	91.38586887
Europe	Serbia	Novi Sad	Docosane	8.201944444
Europe	Serbia	Novi Sad	Dodecane	0.619655003
Europe	Serbia	Novi Sad	Heneicosane	2.623977273
Europe	Serbia	Novi Sad	Heptadecane	184.9215766
Europe	Serbia	Novi Sad	Hexacosane	752,167.48
Europe	Serbia	Novi Sad	Hexadecane	119.9553205
Europe	Serbia	Novi Sad	Nonadecane	1,145.13
Europe	Serbia	Novi Sad	Octadecane	773.1956192
Europe	Serbia	Novi Sad	Pentacosane	21.73886364
Europe	Serbia	Novi Sad	Pentadecane	0.373587719
Europe	Serbia	Novi Sad	Perylene	0.177391304
Europe	Serbia	Novi Sad	Tetradecane	18.88941584
Europe	Serbia	Novi Sad	Tridecane	0.864594482
Europe	Slovenia	Maribor	2H-Benzotriazole, 2-methyl-	2.82E-05
Europe	Slovenia	Maribor	Atrazine	0.005366667
Europe	Slovenia	Maribor	Caffeine	0.245880048

Europe	Slovenia	Maribor	Carbamazepine	0.00160907
Europe	Slovenia	Maribor	Deethylatrazine	3.58E-05
Europe	Slovenia	Maribor	Metolachlor	0.0474235
Europe	Slovenia	Maribor	Propyphenazone	0.000279444
Europe	Slovenia	Maribor	Terbutylazine	8.24E-05
Europe	Spain	Cáceres	Perfluorobutanesulfonic acid	1.76E-06
Europe	Spain	Cáceres	Perfluorobutanoic acid	5.90E-07
Europe	Spain	Cáceres	Perfluorohexanoic acid	2.31E-05
Europe	Spain	Cáceres	Perfluorononanoic acid	0.018
Europe	Spain	Cáceres	Perfluorooctanoic acid	0.000256162
Europe	Spain	Cáceres	Perfluoropentanoic acid	1.04E-06
Europe	Spain	Castille-La Mancha	Cyclopenta[g]-2-benzopyran, 1,3,4,6,7,8-hexah	0.788089532
Europe	Spain	Castille-La Mancha	Naphthalene	0.015333333
Europe	Spain	Castille-La Mancha	Phenanthrene	0.002731183
Europe	Spain	Granada	Acetaminophen	0.192932063
Europe	Spain	Granada	Caffeine	15.37694832
Europe	Spain	Granada	Ibuprofen	0.49587242
Europe	Spain	Madrid	11-Nor-9-carboxy-delta-9-tetrahydrocannabino	0.003085308
Europe	Spain	Madrid	17beta-Estradiol	0.084822047
Europe	Spain	Madrid	7-Aminoflunitrazepam	0.038869258
Europe	Spain	Madrid	Acetaminophen	0.010032117
Europe	Spain	Madrid	Albuterol	0.001104561
Europe	Spain	Madrid	Amoxicillin	0.001354242
Europe	Spain	Madrid	Atenolol	0.016703264
Europe	Spain	Madrid	Azithromycin	18.96666667
Europe	Spain	Madrid	Benzoylecgonine	0.001275927
Europe	Spain	Madrid	Cadmium	0.86875
Europe	Spain	Madrid	Caffeine	13.89919965
Europe	Spain	Madrid	Carbamazepine	0.060386963
Europe	Spain	Madrid	Carbendazim	0.003668343
Europe	Spain	Madrid	Chlorotoluron	0.001499153
Europe	Spain	Madrid	Ciprofloxacin	0.479777778
Europe	Spain	Madrid	Citalopram	0.007742043
Europe	Spain	Madrid	Clarithromycin	2.704
Europe	Spain	Madrid	Cocaethylene	8.95E-05
Europe	Spain	Madrid	Copper	27.23
Europe	Spain	Madrid	Cotinine	0.019963211
Europe	Spain	Madrid	Desmethyldiazepam	0.007619048
Europe	Spain	Madrid	Diazepam	0.005230179
Europe	Spain	Madrid	Diazinon	0.199334869
Europe	Spain	Madrid	Dibutyl phthalate	0.16197796
Europe	Spain	Madrid	Diclofenac	0.071534276
Europe	Spain	Madrid	Dimethoate	0.003072665
Europe	Spain	Madrid	Diuron	0.447412088
Europe	Spain	Madrid	Erythromycin	1.2768
Europe	Spain	Madrid	Estrone	0.001955548
Europe	Spain	Madrid	Famotidine	0.000182252
Europe	Spain	Madrid	Fluoxetine	0.013581209
Europe	Spain	Madrid	Gemfibrozil	0.133588145
Europe	Spain	Madrid	Glycerol tributyrate	0.001550076
Europe	Spain	Madrid	Ibuprofen	0.050059976

Europe	Spain	Madrid	Imidacloprid	0.000277022
Europe	Spain	Madrid	Iron	37.18125
Europe	Spain	Madrid	Ketoprofen	0.018167154
Europe	Spain	Madrid	Lead	47.38442697
Europe	Spain	Madrid	Lincomycin	0.009741548
Europe	Spain	Madrid	Loratadine	0.021022361
Europe	Spain	Madrid	Lorazepam	0.000591281
Europe	Spain	Madrid	Manganese	0.003329412
Europe	Spain	Madrid	MDMA	0.000148926
Europe	Spain	Madrid	Mepivacaine	0.006532663
Europe	Spain	Madrid	Mercury	2.512
Europe	Spain	Madrid	Methadone	0.002496517
Europe	Spain	Madrid	Methamphetamine	0.000152381
Europe	Spain	Madrid	Metribuzin	0.000374466
Europe	Spain	Madrid	Metronidazole	0.016951668
Europe	Spain	Madrid	Morphine	7.04E-05
Europe	Spain	Madrid	Naproxen	0.061076349
Europe	Spain	Madrid	Nicotine	0.007860725
Europe	Spain	Madrid	Ofloxacin	0.03576
Europe	Spain	Madrid	Omeprazole	0.008206033
Europe	Spain	Madrid	Oxazepam	0.001662666
Europe	Spain	Madrid	Paraxantine	28.71070924
Europe	Spain	Madrid	Pirimicarb	3.55E-05
Europe	Spain	Madrid	Primidone	0.001938953
Europe	Spain	Madrid	Propiconazole	0.007750411
Europe	Spain	Madrid	Simazine	0.006740816
Europe	Spain	Madrid	Sulfamethoxazole	1.1035
Europe	Spain	Madrid	Tebuconazole	0.145780844
Europe	Spain	Madrid	Terbutylazine	6.68E-05
Europe	Spain	Madrid	Tributyl phosphate	0.475245459
Europe	Spain	Madrid	Trimethoprim	0.298540363
Europe	Spain	Madrid	Venlafaxine	0.051854465
Europe	Spain	Madrid	Zinc	71.57754963
Europe	Sweden	Linkoping	Atenolol	0.011825227
Europe	Sweden	Linkoping	Bisoprolol	0.000316642
Europe	Sweden	Linkoping	Budesonide	0.001878618
Europe	Sweden	Linkoping	Carbamazepine	0.011318653
Europe	Sweden	Linkoping	Ciprofloxacin	0.033822222
Europe	Sweden	Linkoping	Clarithromycin	0.02724
Europe	Sweden	Linkoping	Clindamycin	0.1546
Europe	Sweden	Linkoping	Codeine	0.002502743
Europe	Sweden	Linkoping	Diclofenac	0.007572379
Europe	Sweden	Linkoping	Fexofenadine	0.000490969
Europe	Sweden	Linkoping	Flecainide	0.004460968
Europe	Sweden	Linkoping	Fluconazole	0.000502121
Europe	Sweden	Linkoping	Metoprolol	0.009986072
Europe	Sweden	Linkoping	Naloxone	0.000344667
Europe	Sweden	Linkoping	Oxazepam	0.000248807
Europe	Sweden	Linkoping	Risperidone	0.000555001
Europe	Sweden	Linkoping	Sotalol	0.000122257
Europe	Sweden	Linkoping	Tramadol	0.009770013

Europe	Sweden	Linkoping	Trimethoprim	0.024677107
Europe	Sweden	Linkoping	Venlafaxine	0.004516197
Europe	Switzerland	Gossau	Perfluorobutanesulfonic acid	8.99E-08
Europe	Switzerland	Gossau	Perfluorobutanoic acid	6.56E-08
Europe	Switzerland	Gossau	Perfluorohexanoic acid	1.19E-06
Europe	Switzerland	Gossau	Perfluorononanoic acid	0.0016
Europe	Switzerland	Gossau	Perfluorooctanoic acid	2.01E-05
Europe	Switzerland	Gossau	Perfluoropropanoic acid	1.26E-08
Europe	Turkey	Alasehir	(+/-)-beta-Hexabromocyclododecane	0.024271845
Europe	Turkey	Alasehir	(+/-)-gamma-Hexabromocyclododecane	0.024271845
Europe	Turkey	Alasehir	(+/-)-α-Hexabromocyclododecane	0.024271845
Europe	Turkey	Alasehir	(2R,6S)-Fenpropimorph	0.009041591
Europe	Turkey	Alasehir	1,1-Dichloroethane	0.002147642
Europe	Turkey	Alasehir	1,2,3,4,5,6-Hexachlorocyclohexane	0.125
Europe	Turkey	Alasehir	1,2,3-Trichlorobenzene	0.015833333
Europe	Turkey	Alasehir	1,2,4,5-Tetrachlorobenzene	0.001213592
Europe	Turkey	Alasehir	1,2,4-Trichlorobenzene	0.021097046
Europe	Turkey	Alasehir	1,2,4-Trimethylbenzene	0.001358307
Europe	Turkey	Alasehir	1,2,5,6,9,10-Hexabromocyclododecane	0.024271845
Europe	Turkey	Alasehir	1,2-Dichloroethane	0.005
Europe	Turkey	Alasehir	1,3,5-Trichlorobenzene	0.006134969
Europe	Turkey	Alasehir	1,3-Dichlorobenzene	0.005
Europe	Turkey	Alasehir	1,4-Dichlorobenzene	0.009057971
Europe	Turkey	Alasehir	11H-Benzo[a]fluorene	0.190665245
Europe	Turkey	Alasehir	17beta-Estradiol	1.506024096
Europe	Turkey	Alasehir	17α-ethinylestradiol	0.05
Europe	Turkey	Alasehir	1-Chloro-2,4-dinitrobenzene	0.008333333
Europe	Turkey	Alasehir	1-Chloronaphthalene	0.000357143
Europe	Turkey	Alasehir	1-Methylnaphthalene	0.000220848
Europe	Turkey	Alasehir	2,2',3,4,4',5'-Hexachlorobiphenyl	0.010514843
Europe	Turkey	Alasehir	2,2',4,4',5,5'-Hexachlorobiphenyl	0.010514843
Europe	Turkey	Alasehir	2,2',5,5'-Tetrachlorobiphenyl	0.001040196
Europe	Turkey	Alasehir	2,3,4,5,6-Pentachlorotoluene	0.057471264
Europe	Turkey	Alasehir	2,3,5,6-Tetrachloronitrobenzene	0.001262626
Europe	Turkey	Alasehir	2,3,7,8-Tetrachlorodibenzo-p-dioxin	2.48E-06
Europe	Turkey	Alasehir	2,4,4'-Trichlorobiphenyl	0.000378788
Europe	Turkey	Alasehir	2,4',5-Trichlorobiphenyl	0.000347222
Europe	Turkey	Alasehir	2,4,5-Trichlorophenoxyacetic acid	0.01914242
Europe	Turkey	Alasehir	2,4,6-Trinitro-1,3-dimethyl-5-tert-butylbenzene	0.094714783
Europe	Turkey	Alasehir	2,4,6-Tris(tert-butyl)phenol	0.000232558
Europe	Turkey	Alasehir	2,6-Dimethylphenol	0.001285417
Europe	Turkey	Alasehir	2,6-Di-tert-butylphenol	4.72E-05
Europe	Turkey	Alasehir	2-Amino-4-chlorophenol	0.01386444
Europe	Turkey	Alasehir	2-Chloronaphthalene	0.000180375
Europe	Turkey	Alasehir	2-Mercaptobenzothiazole	0.37038229
Europe	Turkey	Alasehir	2-Methyl-4,6-dinitrophenol	0.025
Europe	Turkey	Alasehir	3,3',5,5'-Tetrabromobisphenol A	0.15624999
Europe	Turkey	Alasehir	3,6-Dimethylphenanthrene	0.000932836
Europe	Turkey	Alasehir	4-(2-Methylbutan-2-yl)phenol	0.0005
Europe	Turkey	Alasehir	4,4'-Dibromodiphenyl ether	0.006666667
Europe	Turkey	Alasehir	4,4'-Methylenebis(N,N-dimethylaniline)	0.001808973

Europe	Turkey	Alasehir	4,5-Dichloro-2-octyl-3(2H)-isothiazolone	0.004556218
Europe	Turkey	Alasehir	4-Aminoazobenzene	0.352112674
Europe	Turkey	Alasehir	4-Chloroaniline	0.007480053
Europe	Turkey	Alasehir	4-tert-Octylphenol	0.025
Europe	Turkey	Alasehir	Acenaphthene	0.002898089
Europe	Turkey	Alasehir	Acetochlor	1.237011848
Europe	Turkey	Alasehir	Aclonifen	0.001515152
Europe	Turkey	Alasehir	Alachlor	1.237011848
Europe	Turkey	Alasehir	Aldrin	2.135006271
Europe	Turkey	Alasehir	alpha-Cypermethrin	0.001330495
Europe	Turkey	Alasehir	Aluminum	630,666.51
Europe	Turkey	Alasehir	Anthracene	0.005
Europe	Turkey	Alasehir	Antimony	0.262909764
Europe	Turkey	Alasehir	Arsenic	0.120709428
Europe	Turkey	Alasehir	Azinphos-methyl	0.008395692
Europe	Turkey	Alasehir	Bentazone	0.000182119
Europe	Turkey	Alasehir	Benzene	0.016093988
Europe	Turkey	Alasehir	Benzo(a)pyrene	0.003775
Europe	Turkey	Alasehir	Benzo(b)fluoranthene	0.016666667
Europe	Turkey	Alasehir	Benzo(e)pyrene	0.00625
Europe	Turkey	Alasehir	Benzo(g,h,i)perylene	0.25
Europe	Turkey	Alasehir	Benzo(k)fluoranthene	0.016666667
Europe	Turkey	Alasehir	Benzyl benzoate	0.000219255
Europe	Turkey	Alasehir	Benzyl butyl phthalate	0.000662947
Europe	Turkey	Alasehir	beta-Cypermethrin	0.001330495
Europe	Turkey	Alasehir	Bifenox	0.00045208
Europe	Turkey	Alasehir	Biphenyl	0.003571428
Europe	Turkey	Alasehir	Bis(2-ethylhexyl) terephthalate	3.807565837
Europe	Turkey	Alasehir	Bisphenol A	0.01602499
Europe	Turkey	Alasehir	Boron	0.099226521
Europe	Turkey	Alasehir	Boscalid	0.029411765
Europe	Turkey	Alasehir	Bromide	50
Europe	Turkey	Alasehir	Bromofos	0.001515152
Europe	Turkey	Alasehir	Bromophos-ethyl	0.002631579
Europe	Turkey	Alasehir	Bromopropylate	0.014619883
Europe	Turkey	Alasehir	Bromoxynil	0.001062022
Europe	Turkey	Alasehir	Buprofezin	0.00093174
Europe	Turkey	Alasehir	Butralin	0.00524109
Europe	Turkey	Alasehir	C10-13 chloro alkanes	0.5
Europe	Turkey	Alasehir	Cadmium	3.026772138
Europe	Turkey	Alasehir	Cadusafos	0.007029308
Europe	Turkey	Alasehir	Carbaryl	0.25
Europe	Turkey	Alasehir	Carbon tetrachloride	0.006973501
Europe	Turkey	Alasehir	Carboxin	0.002262184
Europe	Turkey	Alasehir	Chlorantraniliprole	0.874125874
Europe	Turkey	Alasehir	Chlordane	0.490508816
Europe	Turkey	Alasehir	Chlorfenvinphos	0.025
Europe	Turkey	Alasehir	Chlorobenzilate	0.042808219
Europe	Turkey	Alasehir	Chloroform	0.02
Europe	Turkey	Alasehir	Chlorothalonil	0.001937984
Europe	Turkey	Alasehir	Chlorpyrifos	5.140937091

Europe	Turkey	Alasehir	Chromium	0.961745469
Europe	Turkey	Alasehir	Chrysene	0.000675676
Europe	Turkey	Alasehir	Clofentezine	0.01470296
Europe	Turkey	Alasehir	Clofibric acid	0.001372872
Europe	Turkey	Alasehir	Cobalt	23.03655405
Europe	Turkey	Alasehir	Copper	115.0984812
Europe	Turkey	Alasehir	Cumene	0.002439024
Europe	Turkey	Alasehir	Cyanide	0.017006803
Europe	Turkey	Alasehir	Cybutryne	8.56E-05
Europe	Turkey	Alasehir	Cyclanilide	0.010369141
Europe	Turkey	Alasehir	Cyfluthrin	0.056137012
Europe	Turkey	Alasehir	Cypermethrin	125,000
Europe	Turkey	Alasehir	Cyprodinil	0.000503525
Europe	Turkey	Alasehir	Cyromazine	0.001373626
Europe	Turkey	Alasehir	Decamethylcyclopentasiloxane	1.084285239
Europe	Turkey	Alasehir	Deethylatrazine	0.001578283
Europe	Turkey	Alasehir	DEHP	3.320119157
Europe	Turkey	Alasehir	Dibutyl phthalate	0.243908092
Europe	Turkey	Alasehir	Dichlobenil	0.000108131
Europe	Turkey	Alasehir	Dichlorodiphenyltrichloroethane	4.05
Europe	Turkey	Alasehir	Dichloromethane	0.05
Europe	Turkey	Alasehir	Dichlorvos	0.000157437
Europe	Turkey	Alasehir	Dicofol	0.002688172
Europe	Turkey	Alasehir	Dieldrin	0.25
Europe	Turkey	Alasehir	Diethofencarb	0.001520681
Europe	Turkey	Alasehir	Diethyl phthalate	1.46E-05
Europe	Turkey	Alasehir	Difenoconazole	0.068477647
Europe	Turkey	Alasehir	Diisobutyl adipate	0.000576415
Europe	Turkey	Alasehir	Dimethenamid	0.016390284
Europe	Turkey	Alasehir	Dimethomorph	0.000413786
Europe	Turkey	Alasehir	Dinobuton	0.002923977
Europe	Turkey	Alasehir	Di-n-octyl phthalate	0.032050781
Europe	Turkey	Alasehir	Diphenyl oxide	0.002643031
Europe	Turkey	Alasehir	Diphenylamine	0.000131579
Europe	Turkey	Alasehir	Endosulfan	0.5
Europe	Turkey	Alasehir	Endrin	0.25
Europe	Turkey	Alasehir	Epoxiconazole	0.003435098
Europe	Turkey	Alasehir	Ethylene thiourea	0.002906977
Europe	Turkey	Alasehir	Fenarimol	0.013210128
Europe	Turkey	Alasehir	Fenhexamid	0.005464481
Europe	Turkey	Alasehir	Fenitrothion	0.038402458
Europe	Turkey	Alasehir	Fenpropathrin	0.607182343
Europe	Turkey	Alasehir	Fenthion	10
Europe	Turkey	Alasehir	Fluazifop-P-butyl	0.011601754
Europe	Turkey	Alasehir	Fluoranthene	0.033684444
Europe	Turkey	Alasehir	Fluorene	0.000684616
Europe	Turkey	Alasehir	Flutolanil	0.003415301
Europe	Turkey	Alasehir	Hexachloro-1,3-butadiene	0.5
Europe	Turkey	Alasehir	Hexachlorobenzene	4.505
Europe	Turkey	Alasehir	Hexaconazole	0.00835179
Europe	Turkey	Alasehir	Hexythiazox	0.080491514

Europe	Turkey	Alasehir	Imazalil	0.005462879
Europe	Turkey	Alasehir	Imazapyr	1.03E-05
Europe	Turkey	Alasehir	Indeno(1,2,3-cd)pyrene	0.25
Europe	Turkey	Alasehir	Iron	248.1151412
Europe	Turkey	Alasehir	Isodrin	0.05
Europe	Turkey	Alasehir	Lead	27.68102369
Europe	Turkey	Alasehir	Lindane	0.000219298
Europe	Turkey	Alasehir	Linuron	0.007958285
Europe	Turkey	Alasehir	Mandipropamid	0.012118274
Europe	Turkey	Alasehir	Mercury	8.25
Europe	Turkey	Alasehir	Mesitylene	0.001280082
Europe	Turkey	Alasehir	Mesotrione	0.003965736
Europe	Turkey	Alasehir	Metamitron	0.002391202
Europe	Turkey	Alasehir	Methoxyfenozide	0.017901898
Europe	Turkey	Alasehir	Methyl parathion	0.000682874
Europe	Turkey	Alasehir	Metrafenone	0.001184834
Europe	Turkey	Alasehir	Molinate	0.001556856
Europe	Turkey	Alasehir	Monocrotophos	0.000337838
Europe	Turkey	Alasehir	Myclobutanil	0.0428068
Europe	Turkey	Alasehir	Naphthalene	0.020833333
Europe	Turkey	Alasehir	N-Ethyl-N-(2-methyl-2-propenyl)-2,6-dinitro-4-(	0.00074228
Europe	Turkey	Alasehir	Nickel	9.524838574
Europe	Turkey	Alasehir	Nitrobenzene	0.002582645
Europe	Turkey	Alasehir	Nitrofen	0.001101322
Europe	Turkey	Alasehir	Nonylphenol	0.003846154
Europe	Turkey	Alasehir	Omethoate	0.00398996
Europe	Turkey	Alasehir	Oxadiazon	0.009429361
Europe	Turkey	Alasehir	Oxadixyl	0.001706038
Europe	Turkey	Alasehir	o-Xylene	0.001697793
Europe	Turkey	Alasehir	p,p'-DDD	0.004092527
Europe	Turkey	Alasehir	p,p'-DDE	0.060767947
Europe	Turkey	Alasehir	PBDE 100	0.002169197
Europe	Turkey	Alasehir	PBDE 47	0.007142857
Europe	Turkey	Alasehir	PBDE 153	0.006849315
Europe	Turkey	Alasehir	PBDE 154	0.001809955
Europe	Turkey	Alasehir	PBDE 28	0.001754386
Europe	Turkey	Alasehir	PCB 180	0.033927546
Europe	Turkey	Alasehir	PCB101	0.016443629
Europe	Turkey	Alasehir	p-Chlorocresol	0.000189251
Europe	Turkey	Alasehir	Penconazole	0.159754014
Europe	Turkey	Alasehir	Pendimethalin	0.061063133
Europe	Turkey	Alasehir	Pentabromodiphenyl ether	4
Europe	Turkey	Alasehir	Pentachlorobenzene	0.357142857
Europe	Turkey	Alasehir	Pentachlorophenol	9.380863039
Europe	Turkey	Alasehir	Permethrin	52.45792417
Europe	Turkey	Alasehir	Perylene	0.02173913
Europe	Turkey	Alasehir	Phenanthrene	0.004543651
Europe	Turkey	Alasehir	Picloram	0.000254257
Europe	Turkey	Alasehir	Piperonyl butoxide	0.001666667
Europe	Turkey	Alasehir	Polychlorinated biphenyls	0.005200979
Europe	Turkey	Alasehir	Prochloraz	0.063943561

Europe	Turkey	Alasehir	Procymidone	0.000772082
Europe	Turkey	Alasehir	Prometryn	0.001291671
Europe	Turkey	Alasehir	Propazine	0.000350385
Europe	Turkey	Alasehir	Propham	0.000543596
Europe	Turkey	Alasehir	Propiconazole	0.014629934
Europe	Turkey	Alasehir	Propylbenzene	0.003770739
Europe	Turkey	Alasehir	Propyzamide	0.009938434
Europe	Turkey	Alasehir	Prothiofos	0.5125
Europe	Turkey	Alasehir	Pyraclostrobin	0.067721776
Europe	Turkey	Alasehir	Pyrene	0.003424658
Europe	Turkey	Alasehir	Pyridaben	13.88888889
Europe	Turkey	Alasehir	Pyrimethanil	0.006666667
Europe	Turkey	Alasehir	Pyriproxyfen	19.92031873
Europe	Turkey	Alasehir	Quinoxyfen	0.163398693
Europe	Turkey	Alasehir	Quizalofop-P-ethyl	0.014220705
Europe	Turkey	Alasehir	Silver	32.20902905
Europe	Turkey	Alasehir	Spiroxamine	0.052366272
Europe	Turkey	Alasehir	Styrene	0.001959248
Europe	Turkey	Alasehir	Tebuconazole	0.050130178
Europe	Turkey	Alasehir	Tebuthiuron	0.001806125
Europe	Turkey	Alasehir	Terbutryn	2.70E-05
Europe	Turkey	Alasehir	Terbutylazine	0.00078611
Europe	Turkey	Alasehir	Thiabendazole	0.000350039
Europe	Turkey	Alasehir	Thiometon	0.1
Europe	Turkey	Alasehir	Thiophanate-methyl	0.01751864
Europe	Turkey	Alasehir	Tin	16.90002768
Europe	Turkey	Alasehir	Titanium	236.0789384
Europe	Turkey	Alasehir	Tolclofos-methyl	0.378787879
Europe	Turkey	Alasehir	Tributylstannylium	1.25
Europe	Turkey	Alasehir	Trichlorobenzene	0.125
Europe	Turkey	Alasehir	Trichloroethylene	0.005616984
Europe	Turkey	Alasehir	Triclosan	0.014179104
Europe	Turkey	Alasehir	Tridecane	0.067291886
Europe	Turkey	Alasehir	Trifloxystrobin	0.302680074
Europe	Turkey	Alasehir	Trifluralin	0.166666667
Europe	Turkey	Alasehir	Trinexapac-ethyl	0.000373134
Europe	Turkey	Alasehir	Vanadium	3.928668271
Europe	Turkey	Alasehir	Vinclozolin	0.000805672
Europe	Turkey	Alasehir	Xylene (m)	0.003502274
Europe	Turkey	Alasehir	zeta-Cypermethrin	0.001330495
Europe	Turkey	Alasehir	Zinc	147.1004991
Europe	Turkey	Istanbul	17beta-Estradiol	1.225301205
Europe	Turkey	Istanbul	17α-ethinylestradiol	0.014
Europe	Turkey	Istanbul	Amoxicillin	0.107473684
Europe	Turkey	Istanbul	Atenolol	0.003075433
Europe	Turkey	Istanbul	Caffeine	11.50941283
Europe	Turkey	Istanbul	Ciprofloxacin	6.139555556
Europe	Turkey	Istanbul	Diclofenac	0.007237937
Europe	Turkey	Istanbul	Erythromycin	0.0882
Europe	Turkey	Istanbul	Estriol	0.001054348
Europe	Turkey	Istanbul	Estrone	0.001256576

Europe	Turkey	Istanbul	Ibuprofen	0.008844278
Europe	Turkey	Istanbul	Naproxen	0.089661202
Europe	Turkey	Istanbul	Propranolol	0.038217168
Europe	Turkey	Istanbul	Sulfamethoxazole	0.238166667
Europe	Turkey	Kemalpasa	(+/-)-beta-Hexabromocyclododecane	0.024271845
Europe	Turkey	Kemalpasa	(+/-)-gamma-Hexabromocyclododecane	0.024271845
Europe	Turkey	Kemalpasa	(+/-)-α-Hexabromocyclododecane	0.024271845
Europe	Turkey	Kemalpasa	(2R,6S)-Fenpropimorph	0.009041591
Europe	Turkey	Kemalpasa	1,1-Dichloroethane	0.012264152
Europe	Turkey	Kemalpasa	1,2,3,4,5,6-Hexachlorocyclohexane	0.125
Europe	Turkey	Kemalpasa	1,2,3-Trichlorobenzene	0.1398
Europe	Turkey	Kemalpasa	1,2,4,5-Tetrachlorobenzene	0.001213592
Europe	Turkey	Kemalpasa	1,2,4-Trichlorobenzene	0.021097046
Europe	Turkey	Kemalpasa	1,2,4-Trimethylbenzene	0.003485845
Europe	Turkey	Kemalpasa	1,2,5,6,9,10-Hexabromocyclododecane	0.024271845
Europe	Turkey	Kemalpasa	1,2-Dichloroethane	0.005
Europe	Turkey	Kemalpasa	1,3,5-Trichlorobenzene	0.006134969
Europe	Turkey	Kemalpasa	1,3-Dichlorobenzene	0.005
Europe	Turkey	Kemalpasa	1,4-Dichlorobenzene	0.009057971
Europe	Turkey	Kemalpasa	11H-Benzo[a]fluorene	1.443802249
Europe	Turkey	Kemalpasa	17beta-Estradiol	1.506024096
Europe	Turkey	Kemalpasa	17α-ethinylestradiol	0.05
Europe	Turkey	Kemalpasa	1-Chloro-2,4-dinitrobenzene	0.008333333
Europe	Turkey	Kemalpasa	1-Chloronaphthalene	0.000357143
Europe	Turkey	Kemalpasa	1-Methylnaphthalene	0.00188596
Europe	Turkey	Kemalpasa	2,2',3,4,4',5'-Hexachlorobiphenyl	0.010514843
Europe	Turkey	Kemalpasa	2,2',4,4',5,5'-Hexachlorobiphenyl	0.010514843
Europe	Turkey	Kemalpasa	2,2',5,5'-Tetrachlorobiphenyl	0.001040196
Europe	Turkey	Kemalpasa	2,3,4,5,6-Pentachlorotoluene	0.057471264
Europe	Turkey	Kemalpasa	2,3,5,6-Tetrachloronitrobenzene	0.001262626
Europe	Turkey	Kemalpasa	2,3,7,8-Tetrachlorodibenzo-p-dioxin	6.20E-06
Europe	Turkey	Kemalpasa	2,4,4'-Trichlorobiphenyl	0.000378788
Europe	Turkey	Kemalpasa	2,4',5-Trichlorobiphenyl	0.000347222
Europe	Turkey	Kemalpasa	2,4,5-Trichlorophenoxyacetic acid	0.01914242
Europe	Turkey	Kemalpasa	2,4,6-Trinitro-1,3-dimethyl-5-tert-butylbenzene	6.906495104
Europe	Turkey	Kemalpasa	2,4,6-Tris(tert-butyl)phenol	0.000232558
Europe	Turkey	Kemalpasa	2,6-Dimethylphenol	9.26E-06
Europe	Turkey	Kemalpasa	2,6-Di-tert-butylphenol	4.72E-05
Europe	Turkey	Kemalpasa	2-Amino-4-chlorophenol	0.019488838
Europe	Turkey	Kemalpasa	2-Chloronaphthalene	0.000180375
Europe	Turkey	Kemalpasa	2-Mercaptobenzothiazole	10.47839096
Europe	Turkey	Kemalpasa	2-Methyl-4,6-dinitrophenol	0.025
Europe	Turkey	Kemalpasa	3,3',5,5'-Tetrabromobisphenol A	0.15624999
Europe	Turkey	Kemalpasa	3,6-Dimethylphenanthrene	0.000932836
Europe	Turkey	Kemalpasa	4-(2-Methylbutan-2-yl)phenol	0.007826848
Europe	Turkey	Kemalpasa	4,4'-Dibromodiphenyl ether	0.006666667
Europe	Turkey	Kemalpasa	4,4'-Methylenebis(N,N-dimethylaniline)	0.001808973
Europe	Turkey	Kemalpasa	4,5-Dichloro-2-octyl-3(2H)-isothiazolone	0.004556218
Europe	Turkey	Kemalpasa	4-Aminoazobenzene	0.352112674
Europe	Turkey	Kemalpasa	4-Chloroaniline	0.001329787
Europe	Turkey	Kemalpasa	4-tert-Octylphenol	0.025

Europe	Turkey	Kemalpasa	Acenaphthene	0.002898089
Europe	Turkey	Kemalpasa	Acetochlor	1.237011848
Europe	Turkey	Kemalpasa	Aclonifen	0.109431818
Europe	Turkey	Kemalpasa	Alachlor	1.237011848
Europe	Turkey	Kemalpasa	Aldrin	2.135006271
Europe	Turkey	Kemalpasa	alpha-Cypermethrin	0.001330495
Europe	Turkey	Kemalpasa	Aluminum	400,101.76
Europe	Turkey	Kemalpasa	Anthracene	0.005
Europe	Turkey	Kemalpasa	Antimony	0.276111718
Europe	Turkey	Kemalpasa	Arsenic	0.053046318
Europe	Turkey	Kemalpasa	Azinphos-methyl	0.008395692
Europe	Turkey	Kemalpasa	Bentazone	0.000586423
Europe	Turkey	Kemalpasa	Benzene	0.03048096
Europe	Turkey	Kemalpasa	Benzo(a)pyrene	0.001
Europe	Turkey	Kemalpasa	Benzo(b)fluoranthene	0.016666667
Europe	Turkey	Kemalpasa	Benzo(e)pyrene	0.00625
Europe	Turkey	Kemalpasa	Benzo(g,h,i)perylene	0.25
Europe	Turkey	Kemalpasa	Benzo(k)fluoranthene	0.016666667
Europe	Turkey	Kemalpasa	Benzyl benzoate	0.001269315
Europe	Turkey	Kemalpasa	Benzyl butyl phthalate	0.087594557
Europe	Turkey	Kemalpasa	beta-Cypermethrin	0.001330495
Europe	Turkey	Kemalpasa	Bifenox	0.00045208
Europe	Turkey	Kemalpasa	Biphenyl	0.020683928
Europe	Turkey	Kemalpasa	Bis(2-ethylhexyl) terephthalate	6.246697447
Europe	Turkey	Kemalpasa	Bisphenol A	1.067381061
Europe	Turkey	Kemalpasa	Boron	0.596876315
Europe	Turkey	Kemalpasa	Boscalid	0.072941176
Europe	Turkey	Kemalpasa	Bromide	22,572
Europe	Turkey	Kemalpasa	Bromofos	0.001515152
Europe	Turkey	Kemalpasa	Bromophos-ethyl	0.002631579
Europe	Turkey	Kemalpasa	Bromopropylate	0.14119883
Europe	Turkey	Kemalpasa	Bromoxynil	0.001062022
Europe	Turkey	Kemalpasa	Buprofezin	0.589064399
Europe	Turkey	Kemalpasa	Butralin	0.00524109
Europe	Turkey	Kemalpasa	C10-13 chloro alkanes	0.5
Europe	Turkey	Kemalpasa	Cadmium	19.27988868
Europe	Turkey	Kemalpasa	Cadusafos	0.007029308
Europe	Turkey	Kemalpasa	Carbaryl	0.25
Europe	Turkey	Kemalpasa	Carbon tetrachloride	0.006973501
Europe	Turkey	Kemalpasa	Carboxin	0.002262184
Europe	Turkey	Kemalpasa	Chlorantraniliprole	0.874125874
Europe	Turkey	Kemalpasa	Chlordane	0.490508816
Europe	Turkey	Kemalpasa	Chlorfenvinphos	0.025
Europe	Turkey	Kemalpasa	Chlorobenzilate	0.042808219
Europe	Turkey	Kemalpasa	Chloroform	0.35087288
Europe	Turkey	Kemalpasa	Chlorothalonil	0.001937984
Europe	Turkey	Kemalpasa	Chlorpyrifos	5.140937091
Europe	Turkey	Kemalpasa	Chromium	437.3002113
Europe	Turkey	Kemalpasa	Chrysene	0.000675676
Europe	Turkey	Kemalpasa	Clofentezine	0.020029629
Europe	Turkey	Kemalpasa	Clofibric acid	0.001372872

Europe	Turkey	Kemalpasa	Cobalt	36.50169362
Europe	Turkey	Kemalpasa	Copper	4,640.00
Europe	Turkey	Kemalpasa	Cumene	0.002439024
Europe	Turkey	Kemalpasa	Cyanide	0.133333333
Europe	Turkey	Kemalpasa	Cybutryne	8.56E-05
Europe	Turkey	Kemalpasa	Cyclanilide	0.010369141
Europe	Turkey	Kemalpasa	Cyfluthrin	0.013320647
Europe	Turkey	Kemalpasa	Cypermethrin	1,951,875
Europe	Turkey	Kemalpasa	Cyprodinil	0.131009567
Europe	Turkey	Kemalpasa	Cyromazine	0.001373626
Europe	Turkey	Kemalpasa	Decamethylcyclopentasiloxane	1.281159798
Europe	Turkey	Kemalpasa	Deethylatrazine	0.001578283
Europe	Turkey	Kemalpasa	DEHP	6.398502344
Europe	Turkey	Kemalpasa	Dibutyl phthalate	0.001033352
Europe	Turkey	Kemalpasa	Dichlobenil	0.000108131
Europe	Turkey	Kemalpasa	Dichlorodiphenyltrichloroethane	4.05
Europe	Turkey	Kemalpasa	Dichloromethane	0.2539625
Europe	Turkey	Kemalpasa	Dichlorvos	0.000157437
Europe	Turkey	Kemalpasa	Dicofol	0.002688172
Europe	Turkey	Kemalpasa	Dieldrin	0.25
Europe	Turkey	Kemalpasa	Diethofencarb	0.001520681
Europe	Turkey	Kemalpasa	Diethyl phthalate	0.009464086
Europe	Turkey	Kemalpasa	Difenoconazole	0.068477647
Europe	Turkey	Kemalpasa	Diisobutyl adipate	0.000576415
Europe	Turkey	Kemalpasa	Dimethenamid	0.016390284
Europe	Turkey	Kemalpasa	Dimethomorph	0.000413786
Europe	Turkey	Kemalpasa	Dinobuton	0.002923977
Europe	Turkey	Kemalpasa	Di-n-octyl phthalate	0.013020833
Europe	Turkey	Kemalpasa	Diphenyl oxide	0.005221712
Europe	Turkey	Kemalpasa	Diphenylamine	0.000131579
Europe	Turkey	Kemalpasa	Endosulfan	0.5
Europe	Turkey	Kemalpasa	Endrin	0.25
Europe	Turkey	Kemalpasa	Epoxiconazole	0.155317955
Europe	Turkey	Kemalpasa	Ethylene thiourea	0.002906977
Europe	Turkey	Kemalpasa	Fenarimol	0.004102524
Europe	Turkey	Kemalpasa	Fenhexamid	0.005464481
Europe	Turkey	Kemalpasa	Fenitrothion	0.038402458
Europe	Turkey	Kemalpasa	Fenpropathrin	0.607182343
Europe	Turkey	Kemalpasa	Fenthion	10
Europe	Turkey	Kemalpasa	Fluazifop-P-butyl	0.011601754
Europe	Turkey	Kemalpasa	Fluoranthene	0.0161
Europe	Turkey	Kemalpasa	Fluorene	0.002648298
Europe	Turkey	Kemalpasa	Flutolanil	0.003415301
Europe	Turkey	Kemalpasa	Hexachloro-1,3-butadiene	0.5
Europe	Turkey	Kemalpasa	Hexachlorobenzene	11.035
Europe	Turkey	Kemalpasa	Hexaconazole	0.00835179
Europe	Turkey	Kemalpasa	Hexythiazox	0.080491514
Europe	Turkey	Kemalpasa	Imazalil	0.005462879
Europe	Turkey	Kemalpasa	Imazapyr	1.03E-05
Europe	Turkey	Kemalpasa	Indeno(1,2,3-cd)pyrene	0.25
Europe	Turkey	Kemalpasa	Iron	183.4812314

Europe	Turkey	Kemalpasa	Isodrin	0.05
Europe	Turkey	Kemalpasa	Lead	1,112.44
Europe	Turkey	Kemalpasa	Lindane	0.000219298
Europe	Turkey	Kemalpasa	Linuron	0.007958285
Europe	Turkey	Kemalpasa	Mandipropamid	0.012118274
Europe	Turkey	Kemalpasa	Mercury	4.7225
Europe	Turkey	Kemalpasa	Mesitylene	0.001280082
Europe	Turkey	Kemalpasa	Mesotrione	0.003965736
Europe	Turkey	Kemalpasa	Metamitron	0.002391202
Europe	Turkey	Kemalpasa	Methoxyfenozide	0.101691729
Europe	Turkey	Kemalpasa	Methyl parathion	0.000682874
Europe	Turkey	Kemalpasa	Metrafenone	0.001184834
Europe	Turkey	Kemalpasa	Molinate	0.001556856
Europe	Turkey	Kemalpasa	Monocrotophos	0.000337838
Europe	Turkey	Kemalpasa	Myclobutanil	0.008942303
Europe	Turkey	Kemalpasa	Naphthalene	0.04852899
Europe	Turkey	Kemalpasa	N-Ethyl-N-(2-methyl-2-propenyl)-2,6-dinitro-4-(	0.00074228
Europe	Turkey	Kemalpasa	Nickel	7,008.03
Europe	Turkey	Kemalpasa	Nitrobenzene	0.002582645
Europe	Turkey	Kemalpasa	Nitrofen	0.001101322
Europe	Turkey	Kemalpasa	Nonylphenol	0.135480766
Europe	Turkey	Kemalpasa	Omethoate	0.000442269
Europe	Turkey	Kemalpasa	Oxadiazon	0.009429361
Europe	Turkey	Kemalpasa	Oxadixyl	0.001706038
Europe	Turkey	Kemalpasa	o-Xylene	0.010488277
Europe	Turkey	Kemalpasa	p,p'-DDD	0.004092527
Europe	Turkey	Kemalpasa	p,p'-DDE	0.060767947
Europe	Turkey	Kemalpasa	PBDE 100	0.002169197
Europe	Turkey	Kemalpasa	PBDE 47	0.007142857
Europe	Turkey	Kemalpasa	PBDE 153	0.006849315
Europe	Turkey	Kemalpasa	PBDE 154	0.001809955
Europe	Turkey	Kemalpasa	PBDE 28	0.001754386
Europe	Turkey	Kemalpasa	PCB 180	0.033927546
Europe	Turkey	Kemalpasa	PCB101	0.016443629
Europe	Turkey	Kemalpasa	p-Chlorocresol	0.000189251
Europe	Turkey	Kemalpasa	Penconazole	0.018809879
Europe	Turkey	Kemalpasa	Pendimethalin	0.061063133
Europe	Turkey	Kemalpasa	Pentabromodiphenyl ether	4
Europe	Turkey	Kemalpasa	Pentachlorobenzene	0.357142857
Europe	Turkey	Kemalpasa	Pentachlorophenol	9.380863039
Europe	Turkey	Kemalpasa	Permethrin	10.99714059
Europe	Turkey	Kemalpasa	Perylene	0.02173913
Europe	Turkey	Kemalpasa	Phenanthrene	0.011249758
Europe	Turkey	Kemalpasa	Picloram	0.000254257
Europe	Turkey	Kemalpasa	Piperonyl butoxide	0.014308333
Europe	Turkey	Kemalpasa	Polychlorinated biphenyls	0.005200979
Europe	Turkey	Kemalpasa	Prochloraz	0.054444108
Europe	Turkey	Kemalpasa	Procymidone	0.000772082
Europe	Turkey	Kemalpasa	Prometryn	0.001291671
Europe	Turkey	Kemalpasa	Propazine	0.000350385
Europe	Turkey	Kemalpasa	Propham	0.000543596

Europe	Turkey	Kemalpasa	Propiconazole	0.014629934
Europe	Turkey	Kemalpasa	Propylbenzene	0.003770739
Europe	Turkey	Kemalpasa	Propyzamide	0.036808045
Europe	Turkey	Kemalpasa	Prothiofos	20.00069678
Europe	Turkey	Kemalpasa	Pyraclostrobin	0.067721776
Europe	Turkey	Kemalpasa	Pyrene	0.014195205
Europe	Turkey	Kemalpasa	Pyridaben	13.88888889
Europe	Turkey	Kemalpasa	Pyrimethanil	0.174144328
Europe	Turkey	Kemalpasa	Pyriproxyfen	19.92031873
Europe	Turkey	Kemalpasa	Quinoxyfen	0.163398693
Europe	Turkey	Kemalpasa	Quizalofop-P-ethyl	0.014220705
Europe	Turkey	Kemalpasa	Silver	418.6381341
Europe	Turkey	Kemalpasa	Spiroxamine	0.052366272
Europe	Turkey	Kemalpasa	Styrene	0.004170259
Europe	Turkey	Kemalpasa	Tebuconazole	0.200345535
Europe	Turkey	Kemalpasa	Tebuthiuron	0.001806125
Europe	Turkey	Kemalpasa	Terbutryn	2.70E-05
Europe	Turkey	Kemalpasa	Terbutylazine	0.00078611
Europe	Turkey	Kemalpasa	Thiabendazole	0.000350039
Europe	Turkey	Kemalpasa	Thiometon	0.1
Europe	Turkey	Kemalpasa	Thiophanate-methyl	0.048076923
Europe	Turkey	Kemalpasa	Tin	25.83626093
Europe	Turkey	Kemalpasa	Titanium	5.253424658
Europe	Turkey	Kemalpasa	Tolclofos-methyl	0.378787879
Europe	Turkey	Kemalpasa	Tributylstannylium	1.25
Europe	Turkey	Kemalpasa	Trichlorobenzene	0.125
Europe	Turkey	Kemalpasa	Trichloroethylene	0.022243258
Europe	Turkey	Kemalpasa	Triclosan	0.014179104
Europe	Turkey	Kemalpasa	Tridecane	0.067291886
Europe	Turkey	Kemalpasa	Trifloxystrobin	0.302680074
Europe	Turkey	Kemalpasa	Trifluralin	0.166666667
Europe	Turkey	Kemalpasa	Trinexapac-ethyl	0.000373134
Europe	Turkey	Kemalpasa	Vanadium	2.931117582
Europe	Turkey	Kemalpasa	Vinclozolin	0.000805672
Europe	Turkey	Kemalpasa	Xylene (m)	0.256682591
Europe	Turkey	Kemalpasa	zeta-Cypermethrin	0.001330495
Europe	Turkey	Kemalpasa	Zinc	4,719.86
Europe	Turkey	Yunusemre	(+/-)-beta-Hexabromocyclododecane	0.024271845
Europe	Turkey	Yunusemre	(+/-)-gamma-Hexabromocyclododecane	0.024271845
Europe	Turkey	Yunusemre	(+/-)-α-Hexabromocyclododecane	0.024271845
Europe	Turkey	Yunusemre	(2R,6S)-Fenpropimorph	0.009041591
Europe	Turkey	Yunusemre	1,1-Dichloroethane	0.000943396
Europe	Turkey	Yunusemre	1,2,3,4,5,6-Hexachlorocyclohexane	0.125
Europe	Turkey	Yunusemre	1,2,3-Trichlorobenzene	0.015833333
Europe	Turkey	Yunusemre	1,2,4,5-Tetrachlorobenzene	0.001213592
Europe	Turkey	Yunusemre	1,2,4-Trichlorobenzene	0.021097046
Europe	Turkey	Yunusemre	1,2,4-Trimethylbenzene	0.001358307
Europe	Turkey	Yunusemre	1,2,5,6,9,10-Hexabromocyclododecane	0.024271845
Europe	Turkey	Yunusemre	1,2-Dichloroethane	0.005
Europe	Turkey	Yunusemre	1,3,5-Trichlorobenzene	0.006134969
Europe	Turkey	Yunusemre	1,3-Dichlorobenzene	0.005

Europe	Turkey	Yunusemre	1,4-Dichlorobenzene	0.009057971
Europe	Turkey	Yunusemre	11H-Benzo[a]fluorene	0.079373821
Europe	Turkey	Yunusemre	17beta-Estradiol	1.506024096
Europe	Turkey	Yunusemre	17α-ethinylestradiol	0.05
Europe	Turkey	Yunusemre	1-Chloro-2,4-dinitrobenzene	0.008333333
Europe	Turkey	Yunusemre	1-Chloronaphthalene	0.000357143
Europe	Turkey	Yunusemre	1-Methylnaphthalene	0.001084874
Europe	Turkey	Yunusemre	2,2',3,4,4',5'-Hexachlorobiphenyl	0.010514843
Europe	Turkey	Yunusemre	2,2',4,4',5,5'-Hexachlorobiphenyl	0.010514843
Europe	Turkey	Yunusemre	2,2',5,5'-Tetrachlorobiphenyl	0.001040196
Europe	Turkey	Yunusemre	2,3,4,5,6-Pentachlorotoluene	0.057471264
Europe	Turkey	Yunusemre	2,3,5,6-Tetrachloronitrobenzene	0.001262626
Europe	Turkey	Yunusemre	2,3,7,8-Tetrachlorodibenzo-p-dioxin	2.48E-06
Europe	Turkey	Yunusemre	2,4,4'-Trichlorobiphenyl	0.000378788
Europe	Turkey	Yunusemre	2,4',5-Trichlorobiphenyl	0.000347222
Europe	Turkey	Yunusemre	2,4,5-Trichlorophenoxyacetic acid	0.01914242
Europe	Turkey	Yunusemre	2,4,6-Trinitro-1,3-dimethyl-5-tert-butylbenzene	0.009416196
Europe	Turkey	Yunusemre	2,4,6-Tris(tert-butyl)phenol	0.000232558
Europe	Turkey	Yunusemre	2,6-Dimethylphenol	0.000130378
Europe	Turkey	Yunusemre	2,6-Di-tert-butylphenol	0.072946648
Europe	Turkey	Yunusemre	2-Amino-4-chlorophenol	0.012363388
Europe	Turkey	Yunusemre	2-Chloronaphthalene	0.000180375
Europe	Turkey	Yunusemre	2-Mercaptobenzothiazole	0.260922934
Europe	Turkey	Yunusemre	2-Methyl-4,6-dinitrophenol	0.025
Europe	Turkey	Yunusemre	3,3',5,5'-Tetrabromobisphenol A	0.15624999
Europe	Turkey	Yunusemre	3,6-Dimethylphenanthrene	0.000932836
Europe	Turkey	Yunusemre	4-(2-Methylbutan-2-yl)phenol	0.008039328
Europe	Turkey	Yunusemre	4,4'-Dibromodiphenyl ether	0.006666667
Europe	Turkey	Yunusemre	4,4'-Methylenebis(N,N-dimethylaniline)	0.001808973
Europe	Turkey	Yunusemre	4,5-Dichloro-2-octyl-3(2H)-isothiazolone	0.004556218
Europe	Turkey	Yunusemre	4-Aminoazobenzene	0.352112674
Europe	Turkey	Yunusemre	4-Chloroaniline	0.001329787
Europe	Turkey	Yunusemre	4-tert-Octylphenol	0.025
Europe	Turkey	Yunusemre	Acenaphthene	0.002898089
Europe	Turkey	Yunusemre	Acetochlor	1.237011848
Europe	Turkey	Yunusemre	Aclonifen	0.001515152
Europe	Turkey	Yunusemre	Alachlor	1.237011848
Europe	Turkey	Yunusemre	Aldrin	2.135006271
Europe	Turkey	Yunusemre	alpha-Cypermethrin	0.001330495
Europe	Turkey	Yunusemre	Aluminum	319,118.55
Europe	Turkey	Yunusemre	Anthracene	0.009625
Europe	Turkey	Yunusemre	Antimony	0.087715152
Europe	Turkey	Yunusemre	Arsenic	0.020816215
Europe	Turkey	Yunusemre	Azinphos-methyl	0.008395692
Europe	Turkey	Yunusemre	Bentazone	0.000182119
Europe	Turkey	Yunusemre	Benzene	0.01322029
Europe	Turkey	Yunusemre	Benzo(a)pyrene	0.001
Europe	Turkey	Yunusemre	Benzo(b)fluoranthene	0.016666667
Europe	Turkey	Yunusemre	Benzo(e)pyrene	0.00625
Europe	Turkey	Yunusemre	Benzo(g,h,i)perylene	0.25
Europe	Turkey	Yunusemre	Benzo(k)fluoranthene	0.016666667

Europe	Turkey	Yunusemre	Benzyl benzoate	0.000334986
Europe	Turkey	Yunusemre	Benzyl butyl phthalate	0.000662947
Europe	Turkey	Yunusemre	beta-Cypermethrin	0.001330495
Europe	Turkey	Yunusemre	Bifenox	0.00045208
Europe	Turkey	Yunusemre	Biphenyl	0.003571428
Europe	Turkey	Yunusemre	Bis(2-ethylhexyl) terephthalate	22.09178482
Europe	Turkey	Yunusemre	Bisphenol A	0.232375388
Europe	Turkey	Yunusemre	Boron	0.232509791
Europe	Turkey	Yunusemre	Boscalid	0.029411765
Europe	Turkey	Yunusemre	Bromide	272
Europe	Turkey	Yunusemre	Bromofos	0.001515152
Europe	Turkey	Yunusemre	Bromophos-ethyl	0.002631579
Europe	Turkey	Yunusemre	Bromopropylate	0.014619883
Europe	Turkey	Yunusemre	Bromoxynil	0.001062022
Europe	Turkey	Yunusemre	Buprofezin	0.00093174
Europe	Turkey	Yunusemre	Butralin	0.00524109
Europe	Turkey	Yunusemre	C10-13 chloro alkanes	2.239
Europe	Turkey	Yunusemre	Cadmium	17.93842097
Europe	Turkey	Yunusemre	Cadusafos	0.007029308
Europe	Turkey	Yunusemre	Carbaryl	0.25
Europe	Turkey	Yunusemre	Carbon tetrachloride	0.006973501
Europe	Turkey	Yunusemre	Carboxin	0.002262184
Europe	Turkey	Yunusemre	Chlorantraniliprole	0.874125874
Europe	Turkey	Yunusemre	Chlordane	0.490508816
Europe	Turkey	Yunusemre	Chlorfenvinphos	0.025
Europe	Turkey	Yunusemre	Chlorobenzilate	0.042808219
Europe	Turkey	Yunusemre	Chloroform	0.02
Europe	Turkey	Yunusemre	Chlorothalonil	0.001937984
Europe	Turkey	Yunusemre	Chlorpyrifos	5.140937091
Europe	Turkey	Yunusemre	Chromium	2.561150939
Europe	Turkey	Yunusemre	Chrysene	0.000675676
Europe	Turkey	Yunusemre	Clofentezine	0.005175983
Europe	Turkey	Yunusemre	Clofibric acid	0.001372872
Europe	Turkey	Yunusemre	Cobalt	12.32219692
Europe	Turkey	Yunusemre	Copper	8,226.61
Europe	Turkey	Yunusemre	Cumene	0.002439024
Europe	Turkey	Yunusemre	Cyanide	0.053061224
Europe	Turkey	Yunusemre	Cybutryne	8.56E-05
Europe	Turkey	Yunusemre	Cyclanilide	0.010369141
Europe	Turkey	Yunusemre	Cyfluthrin	0.000475737
Europe	Turkey	Yunusemre	Cypermethrin	125,000
Europe	Turkey	Yunusemre	Cyprodinil	0.000503525
Europe	Turkey	Yunusemre	Cyromazine	0.001373626
Europe	Turkey	Yunusemre	Decamethylcyclopentasiloxane	0.349912307
Europe	Turkey	Yunusemre	Deethylatrazine	0.001578283
Europe	Turkey	Yunusemre	DEHP	8.72861215
Europe	Turkey	Yunusemre	Dibutyl phthalate	0.001033352
Europe	Turkey	Yunusemre	Dichlobenil	0.000108131
Europe	Turkey	Yunusemre	Dichlorodiphenyltrichloroethane	4.05
Europe	Turkey	Yunusemre	Dichloromethane	0.05
Europe	Turkey	Yunusemre	Dichlorvos	0.000157437

Europe	Turkey	Yunusemre	Dicofol	0.002688172
Europe	Turkey	Yunusemre	Dieldrin	0.25
Europe	Turkey	Yunusemre	Diethofencarb	0.001520681
Europe	Turkey	Yunusemre	Diethyl phthalate	0.051305324
Europe	Turkey	Yunusemre	Difenoconazole	0.068477647
Europe	Turkey	Yunusemre	Diisobutyl adipate	0.007721072
Europe	Turkey	Yunusemre	Dimethenamid	0.016390284
Europe	Turkey	Yunusemre	Dimethomorph	0.000413786
Europe	Turkey	Yunusemre	Dinobuton	0.002923977
Europe	Turkey	Yunusemre	Di-n-octyl phthalate	1.740169271
Europe	Turkey	Yunusemre	Diphenyl oxide	0.001351309
Europe	Turkey	Yunusemre	Diphenylamine	0.000131579
Europe	Turkey	Yunusemre	Endosulfan	0.5
Europe	Turkey	Yunusemre	Endrin	0.25
Europe	Turkey	Yunusemre	Epoxiconazole	0.003435098
Europe	Turkey	Yunusemre	Ethylene thiourea	0.002906977
Europe	Turkey	Yunusemre	Fenarimol	0.021862351
Europe	Turkey	Yunusemre	Fenhexamid	0.005464481
Europe	Turkey	Yunusemre	Fenitrothion	0.038402458
Europe	Turkey	Yunusemre	Fenpropathrin	0.607182343
Europe	Turkey	Yunusemre	Fenthion	10
Europe	Turkey	Yunusemre	Fluazifop-P-butyl	0.011601754
Europe	Turkey	Yunusemre	Fluoranthene	0.009625
Europe	Turkey	Yunusemre	Fluorene	0.001695029
Europe	Turkey	Yunusemre	Flutolanil	0.003415301
Europe	Turkey	Yunusemre	Hexachloro-1,3-butadiene	0.5
Europe	Turkey	Yunusemre	Hexachlorobenzene	4.505
Europe	Turkey	Yunusemre	Hexaconazole	0.00835179
Europe	Turkey	Yunusemre	Hexythiazox	0.080491514
Europe	Turkey	Yunusemre	Imazalil	0.005462879
Europe	Turkey	Yunusemre	Imazapyr	1.03E-05
Europe	Turkey	Yunusemre	Indeno(1,2,3-cd)pyrene	0.25
Europe	Turkey	Yunusemre	Iron	334.2188577
Europe	Turkey	Yunusemre	Isodrin	0.05
Europe	Turkey	Yunusemre	Lead	67.56033592
Europe	Turkey	Yunusemre	Lindane	0.000219298
Europe	Turkey	Yunusemre	Linuron	0.007958285
Europe	Turkey	Yunusemre	Mandipropamid	0.012118274
Europe	Turkey	Yunusemre	Mercury	18.24
Europe	Turkey	Yunusemre	Mesitylene	0.001280082
Europe	Turkey	Yunusemre	Mesotrione	0.003965736
Europe	Turkey	Yunusemre	Metamitron	0.002391202
Europe	Turkey	Yunusemre	Methoxyfenozide	0.017901898
Europe	Turkey	Yunusemre	Methyl parathion	0.000682874
Europe	Turkey	Yunusemre	Metrafenone	0.001184834
Europe	Turkey	Yunusemre	Molinate	0.001556856
Europe	Turkey	Yunusemre	Monocrotophos	0.000337838
Europe	Turkey	Yunusemre	Myclobutanil	0.052968713
Europe	Turkey	Yunusemre	Naphthalene	0.020833333
Europe	Turkey	Yunusemre	N-Ethyl-N-(2-methyl-2-propenyl)-2,6-dinitro-4-(	0.00074228
Europe	Turkey	Yunusemre	Nickel	38.40062995

Europe	Turkey	Yunusemre	Nitrobenzene	0.002582645
Europe	Turkey	Yunusemre	Nitrofen	0.001101322
Europe	Turkey	Yunusemre	Nonylphenol	0.01451923
Europe	Turkey	Yunusemre	Omethoate	0.000200803
Europe	Turkey	Yunusemre	Oxadiazon	0.009429361
Europe	Turkey	Yunusemre	Oxadixyl	0.001706038
Europe	Turkey	Yunusemre	o-Xylene	0.001697793
Europe	Turkey	Yunusemre	p,p'-DDD	0.004092527
Europe	Turkey	Yunusemre	p,p'-DDE	0.060767947
Europe	Turkey	Yunusemre	PBDE 100	0.002169197
Europe	Turkey	Yunusemre	PBDE 47	0.007142857
Europe	Turkey	Yunusemre	PBDE 153	0.006849315
Europe	Turkey	Yunusemre	PBDE 154	0.001809955
Europe	Turkey	Yunusemre	PBDE 28	0.001754386
Europe	Turkey	Yunusemre	PCB 180	0.033927546
Europe	Turkey	Yunusemre	PCB101	0.016443629
Europe	Turkey	Yunusemre	p-Chlorocresol	0.000189251
Europe	Turkey	Yunusemre	Penconazole	0.216191581
Europe	Turkey	Yunusemre	Pendimethalin	0.061063133
Europe	Turkey	Yunusemre	Pentabromodiphenyl ether	4
Europe	Turkey	Yunusemre	Pentachlorobenzene	0.357142857
Europe	Turkey	Yunusemre	Pentachlorophenol	9.380863039
Europe	Turkey	Yunusemre	Permethrin	5.211914969
Europe	Turkey	Yunusemre	Perylene	0.02173913
Europe	Turkey	Yunusemre	Phenanthrene	0.005370086
Europe	Turkey	Yunusemre	Picloram	0.000254257
Europe	Turkey	Yunusemre	Piperonyl butoxide	0.001666667
Europe	Turkey	Yunusemre	Polychlorinated biphenyls	0.005200979
Europe	Turkey	Yunusemre	Prochloraz	0.067567695
Europe	Turkey	Yunusemre	Procymidone	0.000772082
Europe	Turkey	Yunusemre	Prometryn	0.001291671
Europe	Turkey	Yunusemre	Propazine	0.000350385
Europe	Turkey	Yunusemre	Propham	0.000543596
Europe	Turkey	Yunusemre	Propiconazole	0.014629934
Europe	Turkey	Yunusemre	Propylbenzene	0.003770739
Europe	Turkey	Yunusemre	Propyzamide	0.009938434
Europe	Turkey	Yunusemre	Prothiofos	56.50787151
Europe	Turkey	Yunusemre	Pyraclostrobin	0.067721776
Europe	Turkey	Yunusemre	Pyrene	0.003424658
Europe	Turkey	Yunusemre	Pyridaben	13.88888889
Europe	Turkey	Yunusemre	Pyrimethanil	0.006666667
Europe	Turkey	Yunusemre	Pyriproxyfen	19.92031873
Europe	Turkey	Yunusemre	Quinoxyfen	0.163398693
Europe	Turkey	Yunusemre	Quizalofop-P-ethyl	0.014220705
Europe	Turkey	Yunusemre	Silver	22.7094841
Europe	Turkey	Yunusemre	Spiroxamine	0.052366272
Europe	Turkey	Yunusemre	Styrene	0.001959248
Europe	Turkey	Yunusemre	Tebuconazole	0.005839275
Europe	Turkey	Yunusemre	Tebuthiuron	0.001806125
Europe	Turkey	Yunusemre	Terbutryn	2.70E-05
Europe	Turkey	Yunusemre	Terbutylazine	0.00078611

Europe	Turkey	Yunusemre	Thiabendazole	0.000350039
Europe	Turkey	Yunusemre	Thiometon	0.1
Europe	Turkey	Yunusemre	Thiophanate-methyl	0.017011834
Europe	Turkey	Yunusemre	Tin	21.13805402
Europe	Turkey	Yunusemre	Titanium	5.253424658
Europe	Turkey	Yunusemre	Tolclofos-methyl	0.378787879
Europe	Turkey	Yunusemre	Tributylstannylium	1.25
Europe	Turkey	Yunusemre	Trichlorobenzene	0.125
Europe	Turkey	Yunusemre	Trichloroethylene	0.005616984
Europe	Turkey	Yunusemre	Triclosan	0.014179104
Europe	Turkey	Yunusemre	Tridecane	0.067291886
Europe	Turkey	Yunusemre	Trifloxystrobin	0.302680074
Europe	Turkey	Yunusemre	Trifluralin	0.166666667
Europe	Turkey	Yunusemre	Trinexapac-ethyl	0.000373134
Europe	Turkey	Yunusemre	Vanadium	1.718719303
Europe	Turkey	Yunusemre	Vinclozolin	0.000805672
Europe	Turkey	Yunusemre	Xylene (m)	0.000894614
Europe	Turkey	Yunusemre	zeta-Cypermethrin	0.001330495
Europe	Turkey	Yunusemre	Zinc	598.3816354
Europe	United Kingdom	London	1-(p-Chlorobenzoyl)-5-methoxy-2-methyl-Indol	0.003053211
Europe	United Kingdom	London	2-Ethoxybenzamide	5.12E-05
Europe	United Kingdom	London	Acetaminophen	0.378329288
Europe	United Kingdom	London	Albuterol	0.000840112
Europe	United Kingdom	London	Amitriptyline	0.148057472
Europe	United Kingdom	London	Atenolol	0.014793899
Europe	United Kingdom	London	Azithromycin	6.213333333
Europe	United Kingdom	London	Benzoylecgonine	0.000739537
Europe	United Kingdom	London	Bezafibrate	0.017873148
Europe	United Kingdom	London	Caffeine	2.124078494
Europe	United Kingdom	London	Carbamazepine	0.028937553
Europe	United Kingdom	London	Cetirizine	0.5156
Europe	United Kingdom	London	Chloramphenicol	0.000547952
Europe	United Kingdom	London	Clarithromycin	1.676
Europe	United Kingdom	London	Clenbuterol	6.02E-05
Europe	United Kingdom	London	Climbazole	0.008335153
Europe	United Kingdom	London	Clofibric acid	0.000115596
Europe	United Kingdom	London	Clopidol	0.000224404
Europe	United Kingdom	London	Cocaine	0.000646955
Europe	United Kingdom	London	Codeine	0.025775078
Europe	United Kingdom	London	Crotamiton	0.044528898
Europe	United Kingdom	London	Cyclophosphamide	0.004571461
Europe	United Kingdom	London	DEET	0.015575504
Europe	United Kingdom	London	Dextromethorphan	0.004842927
Europe	United Kingdom	London	Diazepam	0.174296675
Europe	United Kingdom	London	Diclofenac	0.016573513
Europe	United Kingdom	London	Dihydromorphine	0.000641658
Europe	United Kingdom	London	Diphenhydramine	0.004004487
Europe	United Kingdom	London	Dipyridamole	0.022043442
Europe	United Kingdom	London	Erythromycin	1.4284
Europe	United Kingdom	London	Fenoprofen	0.00032839
Europe	United Kingdom	London	Fluoxetine	0.006739447

Europe	United Kingdom	London	Furosemide	0.000824099
Europe	United Kingdom	London	Gabapentin	0.016005276
Europe	United Kingdom	London	Griseofulvin	0.001318812
Europe	United Kingdom	London	Hydrocodone	0.003639322
Europe	United Kingdom	London	Ibuprofen	0.015309568
Europe	United Kingdom	London	Ketamine	0.001365419
Europe	United Kingdom	London	Ketoconazole	0.001182
Europe	United Kingdom	London	Ketoprofen	0.013334788
Europe	United Kingdom	London	Lamotrigine	0.213341092
Europe	United Kingdom	London	Levofloxacin	0.004927632
Europe	United Kingdom	London	Lidocaine	0.008404817
Europe	United Kingdom	London	Lincomycin	0.011790123
Europe	United Kingdom	London	Mefenamic acid	0.023705706
Europe	United Kingdom	London	Mephedrone	0.000167113
Europe	United Kingdom	London	Methadone	0.00417841
Europe	United Kingdom	London	Metoprolol	0.00119006
Europe	United Kingdom	London	Morphine	0.002993126
Europe	United Kingdom	London	Naproxen	0.057169399
Europe	United Kingdom	London	Nifedipine	0.001588355
Europe	United Kingdom	London	Norcodeine	0.000191398
Europe	United Kingdom	London	Nortriptyline	0.036074821
Europe	United Kingdom	London	Oxazepam	0.000296375
Europe	United Kingdom	London	Oxcarbazepine	0.004662005
Europe	United Kingdom	London	Oxytetracycline	0.003416199
Europe	United Kingdom	London	Phenazone	0.000157146
Europe	United Kingdom	London	Pirenzepine	4.77E-05
Europe	United Kingdom	London	Primidone	0.000227587
Europe	United Kingdom	London	Propranolol	0.008554677
Europe	United Kingdom	London	Propyphenazone	0.000182969
Europe	United Kingdom	London	Quinoxaline-2-carboxylic acid	0.000504831
Europe	United Kingdom	London	Roxithromycin	0.001045588
Europe	United Kingdom	London	Sotalol	0.000543166
Europe	United Kingdom	London	Sucralose	2.28E-05
Europe	United Kingdom	London	Sulfadiazine	0.000481713
Europe	United Kingdom	London	Sulfadimethoxine	5.41E-06
Europe	United Kingdom	London	Sulfamerazine	2.48E-05
Europe	United Kingdom	London	Sulfamethazine	0.000570829
Europe	United Kingdom	London	Sulfamethoxazole	0.090408817
Europe	United Kingdom	London	Sulfanilamide	0.000127727
Europe	United Kingdom	London	Sulfapyridine	0.000203126
Europe	United Kingdom	London	Sulfathiazole	6.23E-06
Europe	United Kingdom	London	Sulpiride	0.001876607
Europe	United Kingdom	London	Temazepam	0.000242242
Europe	United Kingdom	London	Tetracycline	0.07965
Europe	United Kingdom	London	Theophylline	0.780484146
Europe	United Kingdom	London	Thiabendazole	0.000266029
Europe	United Kingdom	London	Tiamulin	9.57E-05
Europe	United Kingdom	London	Tramadol	0.024035062
Europe	United Kingdom	London	Triclosan	0.040686567
Europe	United Kingdom	London	Trimethoprim	0.054356872
Europe	United Kingdom	London	Tylosin	0.013530612

Europe	United Kingdom	London	Warfarin	0.001861738
Europe	United Kingdom	York	Acetaminophen	0.033599874
Europe	United Kingdom	York	Amitriptyline	0.025161261
Europe	United Kingdom	York	Atenolol	0.004099753
Europe	United Kingdom	York	Carbamazepine	0.013676055
Europe	United Kingdom	York	Cimetidine	0.000732052
Europe	United Kingdom	York	Citalopram	0.008885719
Europe	United Kingdom	York	Codeine	0.003634013
Europe	United Kingdom	York	Diazepam	0.001535806
Europe	United Kingdom	York	Diphenhydramine	0.005763877
Europe	United Kingdom	York	Erythromycin	0.5176
Europe	United Kingdom	York	Fexofenadine	0.023962198
Europe	United Kingdom	York	Gabapentin	0.01038804
Europe	United Kingdom	York	Hydrocodone	0.00169193
Europe	United Kingdom	York	Lidocaine	0.002910645
Europe	United Kingdom	York	Loratadine	1.651077941
Europe	United Kingdom	York	Metformin	0.000998332
Europe	United Kingdom	York	Norethindrone	0.004545455
Europe	United Kingdom	York	O-Desmethyl Venlafaxine	0.017113259
Europe	United Kingdom	York	Oxazepam	0.065084033
Europe	United Kingdom	York	Propranolol	0.003734409
Europe	United Kingdom	York	Raloxifene	0.033370412
Europe	United Kingdom	York	Ranitidine	0.000133395
Europe	United Kingdom	York	Sertraline	0.043807688
Europe	United Kingdom	York	Sitagliptin	0.001295311
Europe	United Kingdom	York	Sulfamethoxazole	0.053166667
Europe	United Kingdom	York	Temazepam	0.001205856
Europe	United Kingdom	York	Tramadol	0.012740601
Europe	United Kingdom	York	Triamterene	0.049500705
Europe	United Kingdom	York	Trimethoprim	0.036665785
Europe	United Kingdom	York	Venlafaxine	0.008574329
North America	Canada	Alberta	17α-ethinylestradiol	0.2882
North America	Canada	Alberta	Benzo(a)pyrene	29.58
North America	Canada	Alberta	Caffeine	7.074655598
North America	Canada	Alberta	Glyphosate	3.71E-06
North America	Canada	Alberta	Sulfamethazine	0.000381958
North America	Canada	Alberta	Sulfamethoxazole	0.151333333
North America	Canada	Alberta	Testosterone	0.00212
North America	Canada	Alberta	Triclosan	0.112835821
North America	Canada	Cowansville	Acetaminophen	0.000162443
North America	Canada	Cowansville	Caffeine	0.068963283
North America	Canada	Cowansville	Carbamazepine	0.008315957
North America	Canada	Cowansville	Cotinine	3.48E-05
North America	Canada	Cowansville	Gemfibrozil	0.001778716
North America	Canada	Cowansville	Ibuprofen	0.00061576
North America	Canada	Cowansville	Naproxen	0.006528962
North America	Canada	Cowansville	Sulfamethoxazole	0.787333333
North America	Canada	Cowansville	Sulfapyridine	7.43E-07
North America	Canada	Hamilton	(+/-)-Verapamil	0.002913574
North America	Canada	Hamilton	2-Hydroxyibuprofen	0.511812298
North America	Canada	Hamilton	3'-Azido-3'-deoxythymidine	0.130160213

North America	Canada	Hamilton	Alprazolam	0.000168008
North America	Canada	Hamilton	Amitriptyline	0.045885772
North America	Canada	Hamilton	Amlodipine	0.00034046
North America	Canada	Hamilton	Azithromycin	35.8
North America	Canada	Hamilton	Benzoylecgonine	0.012328724
North America	Canada	Hamilton	Benztropine	0.000185104
North America	Canada	Hamilton	Bezafibrate	5.88E-05
North America	Canada	Hamilton	Bisphenol A	0.730666667
North America	Canada	Hamilton	Caffeine	2.783215051
North America	Canada	Hamilton	Carbamazepine	0.023469942
North America	Canada	Hamilton	Ciprofloxacin	0.212
North America	Canada	Hamilton	Citalopram	0.039430761
North America	Canada	Hamilton	Clarithromycin	4.528
North America	Canada	Hamilton	Clinafloxacin	6.46E-06
North America	Canada	Hamilton	Clofibric acid	4.20E-06
North America	Canada	Hamilton	Clotrimazole	0.086449198
North America	Canada	Hamilton	Cloxacillin	0.00228
North America	Canada	Hamilton	Cocaine	0.003053079
North America	Canada	Hamilton	Cyclophosphamide	0.00257978
North America	Canada	Hamilton	DEET	0.006913545
North America	Canada	Hamilton	Diazepam	0.000160486
North America	Canada	Hamilton	Diclofenac	3.23E-05
North America	Canada	Hamilton	Dimethyl 2,6-dimethyl-4-(2-nitrophenyl)-3,5-py	0.001144977
North America	Canada	Hamilton	Diphenhydramine	0.034912235
North America	Canada	Hamilton	Drospirenone	0.000913242
North America	Canada	Hamilton	Erythromycin	0.12086
North America	Canada	Hamilton	Fenoprofen	6.58E-06
North America	Canada	Hamilton	Fluoxetine	0.01118392
North America	Canada	Hamilton	Furosemide	0.004175961
North America	Canada	Hamilton	Gemfibrozil	0.003978041
North America	Canada	Hamilton	Hydrochlorothiazide	9.89E-05
North America	Canada	Hamilton	Ibuprofen	0.13260788
North America	Canada	Hamilton	Iopamidol	2.72E-05
North America	Canada	Hamilton	Ketoprofen	4.44E-06
North America	Canada	Hamilton	Lincomycin	0.019037037
North America	Canada	Hamilton	Medroxyprogesterone acetate	0.000382999
North America	Canada	Hamilton	Melphalan	0.006166988
North America	Canada	Hamilton	Meprobamate	8.38E-05
North America	Canada	Hamilton	Metoprolol	0.020668524
North America	Canada	Hamilton	Metronidazole	0.00108516
North America	Canada	Hamilton	Miconazole	0.121659949
North America	Canada	Hamilton	Moxifloxacin	5.90E-06
North America	Canada	Hamilton	Naproxen	0.192896175
North America	Canada	Hamilton	Norfluoxetine	0.001529473
North America	Canada	Hamilton	Norverapamil	0.000116031
North America	Canada	Hamilton	Ofloxacin	0.0131
North America	Canada	Hamilton	Oxazepam	0.002270235
North America	Canada	Hamilton	Paraxantine	6.344246455
North America	Canada	Hamilton	Paroxetine	0.0019898
North America	Canada	Hamilton	Penicillin G	3.24E-05
North America	Canada	Hamilton	Penicillin V	2.09E-05

North America	Canada	Hamilton	Propoxyphene	0.000217898
North America	Canada	Hamilton	Propranolol	0.004416728
North America	Canada	Hamilton	Rosuvastatin	0.001553302
North America	Canada	Hamilton	Roxithromycin	7.35E-05
North America	Canada	Hamilton	Sertraline	0.052863436
North America	Canada	Hamilton	Sulfadimethoxine	1.89E-05
North America	Canada	Hamilton	Sulfamethazine	1.94E-06
North America	Canada	Hamilton	Sulfamethoxazole	0.518333333
North America	Canada	Hamilton	Theophylline	6.096040768
North America	Canada	Hamilton	Thiabendazole	0.001078119
North America	Canada	Hamilton	Triclocarban	0.008476889
North America	Canada	Hamilton	Triclosan	0.064955224
North America	Canada	Hamilton	Trimethoprim	0.148929594
North America	Canada	Hamilton	Venlafaxine	0.051428128
North America	Canada	Hamilton	Warfarin	0.000534033
North America	Canada	Saskatchewan	Acetaminophen	0.185196155
North America	Canada	Saskatchewan	Amoxicillin	0.140350877
North America	Canada	Saskatchewan	Aspirin	0.011601963
North America	Canada	Saskatchewan	Caffeine	3.70255758
North America	Canada	Saskatchewan	Carbamazepine	0.036427848
North America	Canada	Saskatchewan	Ciprofloxacin	0.066666667
North America	Canada	Saskatchewan	Cotinine	0.000602007
North America	Canada	Saskatchewan	DEET	0.014121037
North America	Canada	Saskatchewan	Diclofenac	0.043261231
North America	Canada	Saskatchewan	Erythromycin	1.18
North America	Canada	Saskatchewan	Gemfibrozil	0.709459459
North America	Canada	Saskatchewan	Ibuprofen	0.059662289
North America	Canada	Saskatchewan	Naproxen	0.295081967
North America	Canada	Saskatchewan	Ofloxacin	0.003
North America	Canada	Saskatchewan	Salicylic acid	0.0008
North America	Canada	Saskatchewan	Sulfamethoxazole	0.85
North America	Canada	Saskatchewan	Triclosan	0.032835821
North America	Canada	Saskatchewan	Trimethoprim	0.092887481
North America	Canada	Toronto	Aminomethylphosphonic acid	1.55E-05
North America	Canada	Toronto	Carbamazepine	0.001665273
North America	Canada	Toronto	Gemfibrozil	0.002195946
North America	Canada	Toronto	Glyphosate	2.58E-06
North America	Canada	Toronto	Naproxen	0.004480874
North America	Canada	Toronto	Sulfachloropyridazine	1.93E-05
North America	Mexico	Madin dam	2,2',4,4'-Tetrahydroxybenzophenone	0.001186147
North America	Mexico	Madin dam	Acenaphthene	0.000216408
North America	Mexico	Madin dam	Acenaphthylene	0.000923796
North America	Mexico	Madin dam	Acetaminophen	0.420560361
North America	Mexico	Madin dam	Anthracene	0.0006
North America	Mexico	Madin dam	Benz(a)anthracene	0.001267463
North America	Mexico	Madin dam	Benzo(g,h,i)perylene	0.6122
North America	Mexico	Madin dam	Chrysene	0.000832432
North America	Mexico	Madin dam	Diazinon	7.308516977
North America	Mexico	Madin dam	Dibenz(a,h)anthracene	0.218109084
North America	Mexico	Madin dam	Dichlorodiphenyltrichloroethane	0.04394
North America	Mexico	Madin dam	Fluoranthene	0.0023

North America	Mexico	Madin dam	Fluorene	0.000222496
North America	Mexico	Madin dam	Glybenclamide	1.425951834
North America	Mexico	Madin dam	Hexachlorobenzene	0.14028
North America	Mexico	Madin dam	Indeno(1,2,3-cd)pyrene	3.0564
North America	Mexico	Madin dam	Lindane	0.000702632
North America	Mexico	Madin dam	Mesulfenfos	0.587220043
North America	Mexico	Madin dam	Metformin	0.008098749
North America	Mexico	Madin dam	Naphthalene	0.0011125
North America	Mexico	Madin dam	Naproxen	0.000928962
North America	Mexico	Madin dam	Octyl dimethyl 4-aminobenzoic acid	0.018831169
North America	Mexico	Madin dam	p,p'-DDE	0.570003344
North America	Mexico	Madin dam	PCB 118	0.043240166
North America	Mexico	Madin dam	PCB 138	0.006519202
North America	Mexico	Madin dam	PCB 149	0.264654384
North America	Mexico	Madin dam	PCB 153	0.051007502
North America	Mexico	Madin dam	PCB 170	0.057541117
North America	Mexico	Madin dam	PCB 180	0.056998277
North America	Mexico	Madin dam	PCB 44	0.003599078
North America	Mexico	Madin dam	PCB101	0.043603241
North America	Mexico	Madin dam	Penicillin G	0.000193761
North America	Mexico	Madin dam	Penicillin V	4.60E-05
North America	Mexico	Madin dam	Phenanthrene	0.001034677
North America	Mexico	Madin dam	Pyrene	0.000575342
North America	USA	Aliso Viejo	Bifenthrin	3,368,826.71
North America	USA	Aliso Viejo	Dicamba	4.90E-05
North America	USA	Aliso Viejo	Diuron	0.002
North America	USA	Aliso Viejo	Fipronil	0.014891745
North America	USA	Aliso Viejo	Imidacloprid	3.32E-07
North America	USA	Aliso Viejo	Triclopyr	2.46E-05
North America	USA	Baltimore	Caffeine	1.228392743
North America	USA	Baltimore	Triclocarban	0.333712324
North America	USA	Baltimore	Triclosan	0.226298507
North America	USA	California	Dimethyl sulfone	0.000467598
North America	USA	California	Fipronil	0.88978177
North America	USA	Chicago	2-[2-(4-Nonylphenoxy)ethoxy]ethanol	0.802578797
North America	USA	Chicago	4-Nonylphenol	3.213333333
North America	USA	Chicago	Nonylphenoxypolyethoxyethanol	0.968932864
North America	USA	Cities in USA	(Z)-1,2-Dichloroethylene	0.061266727
North America	USA	Cities in USA	1,1-Dichloroethylene	0.003495775
North America	USA	Cities in USA	1,4-Dichlorobenzene	0.007347464
North America	USA	Cities in USA	1,4-Dioxane	0.005782741
North America	USA	Cities in USA	17beta-Estradiol	0.571445783
North America	USA	Cities in USA	1H-1,2,4-Triazole	0.000202776
North America	USA	Cities in USA	1-Methylnaphthalene	0.000419611
North America	USA	Cities in USA	3,4-Dichlorophenyl isocyanate	0.003583788
North America	USA	Cities in USA	3-Methylindole	0.000772582
North America	USA	Cities in USA	4-Hydroxy-2,5,6-trichloroisophthalonitrile	0.012491317
North America	USA	Cities in USA	4-Nonylphenol	0.695333333
North America	USA	Cities in USA	4-tert-Octylphenol	0.4569
North America	USA	Cities in USA	5-Methyl-1H-benzotriazole	0.002207106
North America	USA	Cities in USA	6-Chloro-1,3,5-triazine-2,4-diamine	0.054846507

North America	USA	Cities in USA	7-Acetyl-1,1,3,4,4,6-hexamethyltetraline	0.109577775
North America	USA	Cities in USA	Abacavir	1.69E-05
North America	USA	Cities in USA	Acephate	0.032363115
North America	USA	Cities in USA	Acetaminophen	0.004724524
North America	USA	Cities in USA	Acyclovir	0.000266399
North America	USA	Cities in USA	Albuterol	4.76E-05
North America	USA	Cities in USA	Anthracene	0.1088
North America	USA	Cities in USA	Anthraquinone	0.032857143
North America	USA	Cities in USA	Atenolol	0.00286825
North America	USA	Cities in USA	Atrazine	0.064244567
North America	USA	Cities in USA	Bentazone	6.48E-05
North America	USA	Cities in USA	Benzene	0.004387
North America	USA	Cities in USA	Benzo(a)pyrene	0.3016
North America	USA	Cities in USA	Benzophenone	0.002268288
North America	USA	Cities in USA	beta-Sitosterol	629.1858549
North America	USA	Cities in USA	Bisphenol A	0.032986667
North America	USA	Cities in USA	Bromacil	0.19603726
North America	USA	Cities in USA	Bromodichloromethane	0.00128391
North America	USA	Cities in USA	Bupropion	0.018761919
North America	USA	Cities in USA	Butane	0.010582257
North America	USA	Cities in USA	Butyraldehyde	0.007440493
North America	USA	Cities in USA	Caffeine	0.543241263
North America	USA	Cities in USA	Camphor	0.010265625
North America	USA	Cities in USA	Carbamazepine	0.006607396
North America	USA	Cities in USA	Carbaryl	0.274681
North America	USA	Cities in USA	Carbazole	0.006598967
North America	USA	Cities in USA	Carbendazim	0.002573587
North America	USA	Cities in USA	Carbon	2.27E-05
North America	USA	Cities in USA	Carisoprodol	0.000210919
North America	USA	Cities in USA	Chlorodibromomethane	0.000789044
North America	USA	Cities in USA	Chlorodifluoromethane	2.99E-05
North America	USA	Cities in USA	Chloroform	0.0364624
North America	USA	Cities in USA	Chlorpheniramine	0.001467073
North America	USA	Cities in USA	Cholesterol	71.91151511
North America	USA	Cities in USA	Cimetidine	0.001216686
North America	USA	Cities in USA	Citalopram	0.010417799
North America	USA	Cities in USA	Clarithromycin	0.00484
North America	USA	Cities in USA	Codeine	0.00059883
North America	USA	Cities in USA	Coprosterol	57.67095592
North America	USA	Cities in USA	Cotinine	0.000108898
North America	USA	Cities in USA	Cyclopenta[g]-2-benzopyran, 1,3,4,6,7,8-hexah	0.621940759
North America	USA	Cities in USA	Dechlorometolachlor	0.00050668
North America	USA	Cities in USA	DEET	0.005213256
North America	USA	Cities in USA	Deethylatrazine	0.000334794
North America	USA	Cities in USA	Deisopropylatrazine	0.000564689
North America	USA	Cities in USA	Dextromethorphan	0.006977297
North America	USA	Cities in USA	Diclofenac	0.006319468
North America	USA	Cities in USA	Dimethenamid	0.008294533
North America	USA	Cities in USA	Dimethyl 2,6-dimethyl-4-(2-nitrophenyl)-3,5-py	0.000345017
North America	USA	Cities in USA	Di-O-demethylcurcumin	0.000183663
North America	USA	Cities in USA	Diphenhydramine	0.002012893

North America	USA	Cities in USA	Diuron	0.21092825
North America	USA	Cities in USA	Erythromycin	0.0054
North America	USA	Cities in USA	Estrone	0.000602296
North America	USA	Cities in USA	Famotidine	1.47E-05
North America	USA	Cities in USA	Fexofenadine	0.064381822
North America	USA	Cities in USA	Fipronil	0.177956478
North America	USA	Cities in USA	Fluconazole	0.000873069
North America	USA	Cities in USA	Fluoranthene	0.4648
North America	USA	Cities in USA	Fluoxetine	0.000452707
North America	USA	Cities in USA	Hexazinone	0.000236787
North America	USA	Cities in USA	Hydrocodone	0.000856242
North America	USA	Cities in USA	Hydroxysimazine	0.00013834
North America	USA	Cities in USA	Ibuprofen	0.004219137
North America	USA	Cities in USA	Imazaquin	2.02E-05
North America	USA	Cities in USA	Imidacloprid	0.000182602
North America	USA	Cities in USA	Indole	0.000881667
North America	USA	Cities in USA	Isopropanol	0.00384951
North America	USA	Cities in USA	Lamivudine	3.36E-06
North America	USA	Cities in USA	Levofloxacin	0.002828947
North America	USA	Cities in USA	Lidocaine	0.004219096
North America	USA	Cities in USA	Menthol	0.002032362
North America	USA	Cities in USA	Meprobamate	0.000347631
North America	USA	Cities in USA	Metalaxyl	5.89E-05
North America	USA	Cities in USA	Metaxalone	0.00474625
North America	USA	Cities in USA	Metformin	0.000224747
North America	USA	Cities in USA	Methadone	0.005799744
North America	USA	Cities in USA	Methocarbamol	0.017656359
North America	USA	Cities in USA	Methyl tert-butyl ether	0.000556
North America	USA	Cities in USA	Methylprednisolone acetate	9.38E-05
North America	USA	Cities in USA	Metolachlor	0.465949269
North America	USA	Cities in USA	Metoprolol	0.002716775
North America	USA	Cities in USA	Myclobutanil	0.002161004
North America	USA	Cities in USA	N-(3,4-Dichlorophenyl)-N'-methylurea	0.000786274
North America	USA	Cities in USA	Naproxen	0.001005464
North America	USA	Cities in USA	Nicotine	0.001253749
North America	USA	Cities in USA	O-Desmethyl Venlafaxine	0.041076754
North America	USA	Cities in USA	Oryzalin	0.005504454
North America	USA	Cities in USA	Oxycodone	0.001251174
North America	USA	Cities in USA	Paraxantine	0.211396511
North America	USA	Cities in USA	p-Cresol	0.000384071
North America	USA	Cities in USA	Pentachlorophenol	46.22889306
North America	USA	Cities in USA	Pentanal	0.005720219
North America	USA	Cities in USA	Pentane	0.000717875
North America	USA	Cities in USA	Phenanthrene	0.010148387
North America	USA	Cities in USA	Phenol	0.000448133
North America	USA	Cities in USA	Prometon	0.000654621
North America	USA	Cities in USA	Propazine	0.000139397
North America	USA	Cities in USA	Propiconazole	0.007685748
North America	USA	Cities in USA	Propoxur	0.001704982
North America	USA	Cities in USA	Propranolol	0.001752357
North America	USA	Cities in USA	Pseudoephedrine	5.69E-05

North America	USA	Cities in USA	Pyraclostrobin	0.001803295
North America	USA	Cities in USA	Pyrene	0.042575342
North America	USA	Cities in USA	Ranitidine	0.00036713
North America	USA	Cities in USA	Sertraline	0.013186573
North America	USA	Cities in USA	Siduron	0.002118032
North America	USA	Cities in USA	Simazine	0.03762309
North America	USA	Cities in USA	Sitagliptin	0.000956847
North America	USA	Cities in USA	Sodium estrone sulfate	3.61E-07
North America	USA	Cities in USA	Stigmastanol	225.5207152
North America	USA	Cities in USA	Sulfamerazine	2.30E-06
North America	USA	Cities in USA	Sulfamethoxazole	0.224522667
North America	USA	Cities in USA	Sulfentrazone	0.000478004
North America	USA	Cities in USA	Sulfometuron-methyl	0.030202722
North America	USA	Cities in USA	Sulfosulfuron	0.002870756
North America	USA	Cities in USA	Tebuconazole	0.029010028
North America	USA	Cities in USA	Tebuthiuron	0.001356176
North America	USA	Cities in USA	Temazepam	0.000282223
North America	USA	Cities in USA	tert-Butyl radical	0.136272374
North America	USA	Cities in USA	Tetrachloroethylene	0.079656413
North America	USA	Cities in USA	Tetracycline	0.001866
North America	USA	Cities in USA	Thiabendazole	0.000654131
North America	USA	Cities in USA	Toluene	0.0016405
North America	USA	Cities in USA	Tolyltriazole	0.008893082
North America	USA	Cities in USA	Tramadol	0.018203089
North America	USA	Cities in USA	Triamterene	0.12761113
North America	USA	Cities in USA	Tributyl phosphate	0.068100959
North America	USA	Cities in USA	Trichloroethylene	0.125247516
North America	USA	Cities in USA	Triclopyr	0.009059442
North America	USA	Cities in USA	Triclosan	0.022340299
North America	USA	Cities in USA	Trimethoprim	0.011685103
North America	USA	Cities in USA	Tris(1,3-dichloro-2-propyl) phosphate	0.103153231
North America	USA	Cities in USA	Tris(2-butoxyethyl) phosphate	0.396603932
North America	USA	Cities in USA	Tris(2-chloroethyl) phosphate	0.034260667
North America	USA	Cities in USA	Venlafaxine	0.016303421
North America	USA	Cities in USA	Warfarin	6.64E-05
North America	USA	Denver	1-(3-Chlorophenyl)piperazine	0.031678077
North America	USA	Denver	1,4-Dichlorobenzene	0.051902174
North America	USA	Denver	17beta-Estradiol	225.6626506
North America	USA	Denver	17α-ethinylestradiol	0.431
North America	USA	Denver	5,5-Diphenylhydantoin	0.26779696
North America	USA	Denver	7-Acetyl-1,1,3,4,4,6-hexamethyltetraline	0.479792401
North America	USA	Denver	Acetophenone	0.002010048
North America	USA	Denver	Atenolol	0.067600989
North America	USA	Denver	Atrazine	1.493483333
North America	USA	Denver	Benzophenone	0.009730915
North America	USA	Denver	Bisphenol A	0.285866667
North America	USA	Denver	Bromacil	1.682736754
North America	USA	Denver	Butylated hydroxyanisole	0.018340122
North America	USA	Denver	Caffeine	7.679658544
North America	USA	Denver	Carbamazepine	0.035563987
North America	USA	Denver	Carbaryl	10.045

North America	USA	Denver	Cotinine	0.001616388
North America	USA	Denver	Cyclopenta[g]-2-benzopyran, 1,3,4,6,7,8-hexah	6.349401741
North America	USA	Denver	DEET	0.085610951
North America	USA	Denver	Diclofenac	0.584725458
North America	USA	Denver	Diuron	5.4565
North America	USA	Denver	Estrone	0.034384134
North America	USA	Denver	Gabapentin	0.043095526
North America	USA	Denver	Gemfibrozil	0.100777027
North America	USA	Denver	Hydrochlorothiazide	0.000680688
North America	USA	Denver	Imidacloprid	0.001063384
North America	USA	Denver	Lamotrigine	1.97415821
North America	USA	Denver	Levorphanol	0.087796491
North America	USA	Denver	Lidocaine	0.0303885
North America	USA	Denver	Meprobamate	0.001634677
North America	USA	Denver	Metformin	0.005023503
North America	USA	Denver	Metolachlor	10.40776458
North America	USA	Denver	Metoprolol	0.025075209
North America	USA	Denver	O-Desmethyl Venlafaxine	0.129815961
North America	USA	Denver	Oxcarbazepine	0.012643357
North America	USA	Denver	Oxycodone	0.003983687
North America	USA	Denver	Phenol	0.005125877
North America	USA	Denver	Pregabalin	0.002614205
North America	USA	Denver	Sotalol	0.000285725
North America	USA	Denver	Sulfamethoxazole	1.264166667
North America	USA	Denver	Temazepam	0.002516482
North America	USA	Denver	Tramadol	0.058324131
North America	USA	Denver	Triamterene	2.609385772
North America	USA	Denver	Tributyl phosphate	1.895385884
North America	USA	Denver	Triclopyr	0.112316289
North America	USA	Denver	Triclosan	0.220716418
North America	USA	Denver	Triethyl citrate	0.060373444
North America	USA	Denver	Trimethoprim	0.325291957
North America	USA	Denver	Triphenyl phosphate	0.214000059
North America	USA	Denver	Tris(1,3-dichloro-2-propyl) phosphate	0.721112305
North America	USA	Denver	Tris(2-butoxyethyl) phosphate	4.05977689
North America	USA	Denver	Tris(2-chloroethyl) phosphate	0.263217348
North America	USA	Denver	Venlafaxine	0.046292256
North America	USA	Detroit	1-(5,6,7,8-Tetrahydro-3,5,5,6,8,8-hexamethyl-2	0.046037052
North America	USA	Detroit	1,4-Dichlorobenzene	0.023550725
North America	USA	Detroit	1-Methylnaphthalene	0.00565371
North America	USA	Detroit	2,6-Dimethylnaphthalene	0.01
North America	USA	Detroit	2-Methylnaphthalene	0.016058091
North America	USA	Detroit	3,4-Dichlorophenyl isocyanate	0.029828281
North America	USA	Detroit	4-Cumylphenol	0.002722323
North America	USA	Detroit	4-Nonylphenol	10.48066667
North America	USA	Detroit	4-tert-Octylphenol	3
North America	USA	Detroit	5-Methyl-1H-benzotriazole	0.008984042
North America	USA	Detroit	Anthracene	1.276
North America	USA	Detroit	Anthraquinone	0.257457142
North America	USA	Detroit	Atrazine	14.11433333
North America	USA	Detroit	Benzo(a)pyrene	24.454

North America	USA	Detroit	Benzophenone	0.00367351
North America	USA	Detroit	beta-Sitosterol	3,352.80
North America	USA	Detroit	Bisphenol A	0.296366667
North America	USA	Detroit	Bromacil	0.344275996
North America	USA	Detroit	Bromoform	0.000882658
North America	USA	Detroit	Caffeine	1.455583691
North America	USA	Detroit	Camphor	0.023281249
North America	USA	Detroit	Carbaryl	20.92
North America	USA	Detroit	Carbazole	0.053201377
North America	USA	Detroit	Cholesterol	131.3818328
North America	USA	Detroit	Coprosterol	389.2533437
North America	USA	Detroit	Cotinine	0.000250167
North America	USA	Detroit	Cyclopenta[g]-2-benzopyran, 1,3,4,6,7,8-hexah	0.436089749
North America	USA	Detroit	DEET	0.023645533
North America	USA	Detroit	Dichlorvos	0.166946069
North America	USA	Detroit	Diethyl phthalate	0.024052478
North America	USA	Detroit	D-Limonene	0.065131879
North America	USA	Detroit	Fluoranthene	35.738
North America	USA	Detroit	Indole	0.002548169
North America	USA	Detroit	Isophorone	0.005301205
North America	USA	Detroit	Isoquinoline	0.00130719
North America	USA	Detroit	Menthol	0.006934813
North America	USA	Detroit	Metalaxyl	0.001373206
North America	USA	Detroit	Methyl salicylate	0.000725106
North America	USA	Detroit	Metolachlor	22.66504566
North America	USA	Detroit	Naphthalene	0.053166667
North America	USA	Detroit	p-Cresol	0.001010714
North America	USA	Detroit	Phenanthrene	0.423419362
North America	USA	Detroit	Prometon	0.014557759
North America	USA	Detroit	Pyrene	3.621506849
North America	USA	Detroit	Stigmastanol	1,699.90
North America	USA	Detroit	Tetrachloroethylene	0.056761064
North America	USA	Detroit	Tributyl phosphate	0.175564272
North America	USA	Detroit	Triclosan	0.134328358
North America	USA	Detroit	Triphenyl phosphate	0.094420296
North America	USA	Detroit	Tris(1,3-dichloro-2-propyl) phosphate	0.21903056
North America	USA	Detroit	Tris(2-butoxyethyl) phosphate	1.649453531
North America	USA	Detroit	Tris(2-chloroethyl) phosphate	0.352281828
North America	USA	Detroit	Triton X-100.2	0.040725462
North America	USA	DickinsonBayou	Acetaminophen	0.000203187
North America	USA	DickinsonBayou	Caffeine	0.143316685
North America	USA	DickinsonBayou	Carbamazepine	0.001415482
North America	USA	DickinsonBayou	Diclofenac	0.006855241
North America	USA	DickinsonBayou	Sucralose	1.89E-06
North America	USA	Dublin	Bifenthrin	1,059,288.83
North America	USA	Dublin	Dicamba	1.94E-05
North America	USA	Dublin	Diuron	0.0975
North America	USA	Dublin	Fipronil	0.000943144
North America	USA	Dublin	Triclopyr	1.02E-05
North America	USA	Folsom	Bifenthrin	1,261,058.13
North America	USA	Folsom	Dicamba	4.70E-06

North America	USA	Folsom	Diuron	0.00086
North America	USA	Folsom	Fipronil	0.001116881
North America	USA	Folsom	Triclopyr	6.00E-06
North America	USA	Laguna Niguel	Bifenthrin	2,377,995.33
North America	USA	Laguna Niguel	Dicamba	2.91E-05
North America	USA	Laguna Niguel	Diuron	0.0027
North America	USA	Laguna Niguel	Fipronil	0.005708502
North America	USA	Laguna Niguel	Imidacloprid	1.05E-06
North America	USA	Laguna Niguel	Triclopyr	1.71E-05
North America	USA	Los Angeles	7-Acetyl-1,1,3,4,4,6-hexamethyltetraline	0.450779467
North America	USA	Los Angeles	Acetaminophen	0.001313305
North America	USA	Los Angeles	Atrazine	0.027933333
North America	USA	Los Angeles	Bifenthrin	129.708836
North America	USA	Los Angeles	Carbamazepine	0.034221361
North America	USA	Los Angeles	Chlorpyrifos	4.626843382
North America	USA	Los Angeles	Cyclopenta[g]-2-benzopyran, 1,3,4,6,7,8-hexah	5.585686113
North America	USA	Los Angeles	DEET	0.023400576
North America	USA	Los Angeles	Diazepam	0.000757033
North America	USA	Los Angeles	Diclofenac	0.01985025
North America	USA	Los Angeles	Diphenylhydantoin sodium	0.544742856
North America	USA	Los Angeles	Fipronil	0.161079043
North America	USA	Los Angeles	Gemfibrozil	0.052516892
North America	USA	Los Angeles	Ibuprofen	0.0015197
North America	USA	Los Angeles	PBDE 47	0.007428571
North America	USA	Los Angeles	PBDE 99	0.012251219
North America	USA	Los Angeles	Permethrin	1.77205109
North America	USA	Los Angeles	Sulfamethoxazole	1.529666667
North America	USA	Los Angeles	Triclocarban	0.075234252
North America	USA	Los Angeles	Triclosan	0.007608955
North America	USA	Los Angeles	Trimethoprim	0.105179591
North America	USA	Los Angeles	Tris(1,3-dichloro-2-propyl) phosphate	1.042575864
North America	USA	Los Angeles	Tris(2-chloroethyl) phosphate	0.506686767
North America	USA	Los Angeles	Tris(2-chloroisopropyl)phosphate	2.369854152
North America	USA	Miami	Atrazine	0.0413
North America	USA	Miami	Bisphenol A	0.047533333
North America	USA	Miami	Caffeine	0.159184788
North America	USA	Miami	Chlorpyrifos	5.346574574
North America	USA	Miami	Cholesterol	464.6630418
North America	USA	Miami	Coprosterol	9.798940753
North America	USA	Miami	DEET	0.001752161
North America	USA	Miami	Deethylatrazine	0.000371738
North America	USA	Miami	Deisopropylatrazine	6.61E-05
North America	USA	Miami	Diazinon	35.0877689
North America	USA	Miami	Estrone	0.000941545
North America	USA	Miami	Malathion	0.002334971
North America	USA	Miami	Metolachlor	1.285515592
North America	USA	Miami	p,p'-DDE	0.449682809
North America	USA	Pensacola	Cadmium	184.875
North America	USA	Pensacola	Chromium	6.246153846
North America	USA	Pensacola	Copper	268.75
North America	USA	Pensacola	Nickel	39.5

North America	USA	Pleasant Hill	Bifenthrin	1,044,876.73
North America	USA	Pleasant Hill	Dicamba	5.10E-06
North America	USA	Pleasant Hill	Diuron	0.0022
North America	USA	Pleasant Hill	Fipronil	0.005224521
North America	USA	Pleasant Hill	Triclopyr	0.000107939
North America	USA	Raleigh	17beta-Estradiol	0.53462798
North America	USA	Raleigh	Caffeine	0.03867022
North America	USA	Raleigh	Carbamazepine	0.000304986
North America	USA	Raleigh	Cotinine	0.000130785
North America	USA	Raleigh	DEET	0.001875665
North America	USA	Raleigh	Diphenhydramine	8.38E-05
North America	USA	Raleigh	Estrone	0.000257899
North America	USA	Raleigh	Fluoxetine	0.007419103
North America	USA	Raleigh	Gemfibrozil	0.032229221
North America	USA	Raleigh	Ibuprofen	3.43E-05
North America	USA	Raleigh	Lincomycin	0.062088208
North America	USA	Raleigh	Meprobamate	1.69E-05
North America	USA	Raleigh	Naproxen	0.000666085
North America	USA	Raleigh	Paraxantine	0.008192373
North America	USA	Raleigh	Paroxetine	0.000348415
North America	USA	Raleigh	Salicylic acid	9.73E-05
North America	USA	Raleigh	Sulfamethazine	3.94E-05
North America	USA	Raleigh	Sulfamethoxazole	0.00399606
North America	USA	Raleigh	Trimethoprim	0.008405536
North America	USA	Rochester	7,4'-Dihydroxyisoflavone	0.000205038
North America	USA	Rochester	Acetaminophen	0.000312188
North America	USA	Rochester	Acetochlor	1.296388417
North America	USA	Rochester	Atrazine	0.093333333
North America	USA	Rochester	Caffeine	0.334993305
North America	USA	Rochester	Carbamazepine	0.011032434
North America	USA	Rochester	Carbaryl	0.2
North America	USA	Rochester	Cotinine	1.91E-05
North America	USA	Rochester	DEET	0.002708934
North America	USA	Rochester	Erythromycin	1.92
North America	USA	Rochester	Genistein	0.003180439
North America	USA	Rochester	Metolachlor	0.794343627
North America	USA	Rochester	Sulfamethoxazole	2.058333333
North America	USA	Roseville	Bifenthrin	4,215,537.17
North America	USA	Roseville	Dicamba	7.81E-05
North America	USA	Roseville	Diuron	0.0452
North America	USA	Roseville	Fipronil	0.003288594
North America	USA	Roseville	Imidacloprid	5.21E-07
North America	USA	Roseville	Triclopyr	3.45E-05
North America	USA	Salt Lake city	Diphenhydramine	0.002884953
North America	USA	Salt Lake city	Fluoxetine	0.006586886
North America	USA	San diego	Amphetamine	0.002220387
North America	USA	San diego	Benzoylecgonine	0.001546197
North America	USA	San diego	Caffeine	25.87861061
North America	USA	San diego	Cocaine	0.001514508
North America	USA	San diego	Methamphetamine	0.072442293
North America	USA	San diego	Sucralose	1.13E-05

North America	USA	San Francisco	Atenolol	0.002403957
North America	USA	San Francisco	Bifenthrin	819.6877833
North America	USA	San Francisco	Caffeine	0.00755624
North America	USA	San Francisco	Carbadox	0.000101139
North America	USA	San Francisco	Carbamazepine	0.000759781
North America	USA	San Francisco	Estrone	0.000167015
North America	USA	San Francisco	Fenpropathrin	1.092928217
North America	USA	San Francisco	Gemfibrozil	0.014324324
North America	USA	San Francisco	Hydrochlorothiazide	1.27E-05
North America	USA	San Francisco	Ibuprofen	0.055061914
North America	USA	San Francisco	Oxytetracycline	0.008887095
North America	USA	San Francisco	Sulfadimethoxine	9.36E-05
North America	USA	San Francisco	Sulfamethazine	8.32E-05
North America	USA	San Francisco	Sulfamethoxazole	0.042733333
North America	USA	San Francisco	Triamterene	0.004179794
North America	USA	San Francisco	Triclosan	0.009104478
North America	USA	San Francisco	Trimethoprim	0.013623497
North America	USA	Washinghton DC	Bisphenol A	0.078633333
North America	USA	Washinghton DC	Ibuprofen	0.004210131
North America	USA	Washinghton DC	Triclosan	0.060865672
Oceania	Australia	Melbourne	Aminomethylphosphonic acid	6.23E-05
Oceania	Australia	Melbourne	Glyphosate	1.17E-05
South America	Argentina	Chascomús	17alpha-Hydroxyprogesterone	0.00030021
South America	Argentina	Chascomús	17beta-Estradiol	0.6
South America	Argentina	Chascomús	17α-ethinylestradiol	0.025365
South America	Argentina	Chascomús	5alpha-Dihydrotestosterone	0.001090509
South America	Argentina	Chascomús	Estriol	0.008946125
South America	Argentina	Chascomús	Estrone	0.007290188
South America	Argentina	Chascomús	Progesterone	0.001017615
South America	Argentina	Chascomús	Testosterone	0.000425
South America	Brazil	Manaus	Amitriptyline	0.018388048
South America	Brazil	Manaus	Benzoylecgonine	0.098893777
South America	Brazil	Manaus	Carbamazepine	0.042755885
South America	Brazil	Manaus	Citalopram	0.011498084
South America	Brazil	Manaus	Cocaine	0.177834395
South America	Brazil	Manaus	Diclofenac	0.104958403
South America	Brazil	Manaus	Metoprolol	0.001392758
South America	Brazil	Manaus	Propranolol	0.001907557
South America	Brazil	Paracombi	n-Nonylphenol	2.354321015
South America	Brazil	Porto Alegre	Azithromycin	2.466666667
South America	Brazil	Porto Alegre	Cephalexin	0.552380952
South America	Brazil	Porto Alegre	Ciprofloxacin	0.684888889
South America	Brazil	Porto Alegre	Clindamycin	0.916
South America	Brazil	Porto Alegre	Norfloxacin	0.012775
South America	Brazil	Porto Alegre	Sulfadiazine	0.008911686
South America	Brazil	Porto Alegre	Sulfamethoxazole	0.161666667
South America	Brazil	Porto Alegre	Trimethoprim	0.029909769
South America	Brazil	Rio Grande	Clomazone	0.795636555
South America	Brazil	Sao Paulo	17beta-Estradiol	0.49313253
South America	Brazil	Sao Paulo	17α-ethinylestradiol	0.00016
South America	Brazil	Sao Paulo	Acenaphthene	0.002479873

South America	Brazil	Sao Paulo	Acenaphthylene	0.005115156
South America	Brazil	Sao Paulo	Acetaminophen	0.530613441
South America	Brazil	Sao Paulo	Anthracene	0.26029
South America	Brazil	Sao Paulo	Atenolol	0.160305029
South America	Brazil	Sao Paulo	Benz(a)anthracene	0.097395522
South America	Brazil	Sao Paulo	Benzo(a)pyrene	0.92624
South America	Brazil	Sao Paulo	Benzo(b)fluoranthene	2.045766667
South America	Brazil	Sao Paulo	Benzo(g,h,i)perylene	9.102
South America	Brazil	Sao Paulo	Benzo(k)fluoranthene	0.607933333
South America	Brazil	Sao Paulo	Caffeine	104.6236985
South America	Brazil	Sao Paulo	Carbamazepine	0.016855685
South America	Brazil	Sao Paulo	Chrysene	0.050231081
South America	Brazil	Sao Paulo	Dibenz(a,h)anthracene	0.820999975
South America	Brazil	Sao Paulo	Diclofenac	0.033003328
South America	Brazil	Sao Paulo	Estrone	0.002336117
South America	Brazil	Sao Paulo	Fluoranthene	0.9912
South America	Brazil	Sao Paulo	Fluorine	0.001609527
South America	Brazil	Sao Paulo	Ibuprofen	0.016365854
South America	Brazil	Sao Paulo	Indeno(1,2,3-cd)pyrene	23.2865
South America	Brazil	Sao Paulo	Naphthalene	0.0511875
South America	Brazil	Sao Paulo	Naproxen	0.035012022
South America	Brazil	Sao Paulo	Phenanthrene	0.037910968
South America	Brazil	Sao Paulo	Propranolol	0.004875275
South America	Brazil	Sao Paulo	Pyrene	0.878667123
South America	Brazil	Sao Paulo	Triclosan	0.032674627
South America	Brazil	Sinos River	Benzoylecgonine	0.01397863
South America	Brazil	Sinos River	Caffeine	21.20735314
South America	Brazil	Sinos River	Cocaine	0.00158528
South America	Brazil	Vacacai	17beta-Estradiol	18.07228916
South America	Brazil	Vacacai	Acetaminophen	0.33435843
South America	Brazil	Vacacai	Diclofenac	0.009983361
South America	Brazil	Vacacai	Estriol	0.014177694
South America	Brazil	Vacacai	Estrone	0.03131524
South America	Brazil	Vacacai	Ethisterone	0.013207547
South America	Brazil	Vacacai	Ibuprofen	0.06739212
South America	Brazil	Vacacai	Megestrol	0.001367054
South America	Colombia	Medellin	Benzophenone	0.004843532
South America	Colombia	Medellin	Ibuprofen	0.003414634
South America	Colombia	Medellin	Methylparaben	0.00455
South America	Uruguay	Rocha	17beta-Estradiol	818.0722892
South America	Uruguay	Rocha	17α-ethinylestradiol	38.722
South America	Uruguay	Rocha	Amitraz	0.253515602
South America	Uruguay	Rocha	Atrazine	1.63
South America	Uruguay	Rocha	Atropine	0.000917782
South America	Uruguay	Rocha	Benzoylecgonine	0.038654934
South America	Uruguay	Rocha	Cadusafos	1.67297528
South America	Uruguay	Rocha	Caffeine	2.46837172
South America	Uruguay	Rocha	Carbamazepine	0.069941467
South America	Uruguay	Rocha	Carbofuran	0.072493836
South America	Uruguay	Rocha	DEET	0.004726225
South America	Uruguay	Rocha	Diclofenac	0.372712146

South America	Uruguay	Rocha	Enrofloxacin	1.507853403
South America	Uruguay	Rocha	Ethoxyquin	0.720624966
South America	Uruguay	Rocha	Fenazaquin	0.334462503
South America	Uruguay	Rocha	Fluazifop	0.000102939
South America	Uruguay	Rocha	Fluazifop-P-butyl	0.236675772
South America	Uruguay	Rocha	Flufenamic acid	1.00754717
South America	Uruguay	Rocha	Ibuprofen	0.011257036
South America	Uruguay	Rocha	Indoxacarb	0.059402593
South America	Uruguay	Rocha	Lomefloxacin	3.47E-06
South America	Uruguay	Rocha	Metolachlor	203.7855547
South America	Uruguay	Rocha	Miconazole	6.8864122
South America	Uruguay	Rocha	Neburon	0.051191501
South America	Uruguay	Rocha	Nicotine	0.006013966
South America	Uruguay	Rocha	Norfloxacin	0.0025
South America	Uruguay	Rocha	Penconazole	0.680917625
South America	Uruguay	Rocha	Pendimethalin	7.522977981
South America	Uruguay	Rocha	Propranolol	0.021129861
South America	Uruguay	Rocha	Prosulfocarb	0.030634846
South America	Uruguay	Rocha	Pymetrozine	0.00414737
South America	Uruguay	Rocha	Pyraclostrobin	0.303393555
South America	Uruguay	Rocha	Pyrazophos	7.890275507
South America	Uruguay	Rocha	Pyridaben	20
South America	Uruguay	Rocha	Tamoxifen	14.64379909
South America	Uruguay	Rocha	Terbutaline	0.011136515
South America	Uruguay	Rocha	Thiabendazole	0.031503469
South America	Uruguay	Rocha	Trifloxystrobin	0.339001683
South America	Uruguay	Rocha	Trimethoprim	0.035916493

Annexe 4.1: Experts' feedback results for identification of key drivers of antidepressants emissions in freshwater

		Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Expert 9	
SSP drivers	SSP sub-drivers	Do you consider this driver a **high, low or uncertain priority** to study antidepressant emissions scenario in fresh water bodies for the year 2050 et Europeen scale?									**Do 70% of experts define this driver as high priority ?**
Demographics	*Age*	Low	High	Uncertain	Uncertain	High	High	High	Medium	High	No
	Gender	Low	High	Low	High	High	High	Low	Low	Low	No
	Population Migration	High	High	High	Uncertain	Uncertain	Low	Low	Low	Uncertain	No
	Population Growth	High	High	x	High	High	High	High	Medium	High	**Yes**
	Population mortality	Uncertain	High	High	High	Uncertain	Low	x	Low	Low	No
Economy and lifestyle	*Inequality*	Uncertain	High	High	High	Uncertain	High	High	Uncertain	High	**Yes**
	Culture/Belief	High	High	Uncertain	High	High	Low	High	x	High	**Yes**
	Ethnics	Uncertain	Uncertain	High	Low		Low	Low	x	High	No
	Gender equity	Low	High	Low	Low	Uncertain	High	Low	Low	Low	No
	Globalization	Uncertain	Uncertain	Uncertain	High	Low	Low	High	Medium	Uncertain	No
	Growth (per capita)	Uncertain	High	Uncertain	Uncertain	Uncertain	Low	High	x	Low	No
	Consumption and diet	High	Uncertain	High	High	High	High	Low	Low	Low	No
	International trade	Low	Uncertain		High	Low	Uncertain	Uncertain	Low	Uncertain	No
Environment and natural ressources	*Environment*	High	Uncertain	High	High	High	Low	Uncertain	Medium	Low	No
	Urbanization	High	Uncertain	High	High	High	High	Low	Low	High	**Yes**
	Climate change	Low	Uncertain	Uncertain	High	High	Low	Low	Low	Low	No
	Fossil constraints	Low	Low	Uncertain	Uncertain	Low	Low	Low	Low	Uncertain	No
	Land-use	Uncertain	Low	High	High	Low	Low	Low	Low	High	No
	Agriculture	Uncertain	Low	Uncertain	Uncertain	Low	Low	Low	Low	Low	No
Human development	*Economy*	High	High	High	High	Uncertain	High	High	Medium	High	**Yes**
	Education	High	High	Uncertain	High	Uncertain	High	High	Uncertain	High	**Yes**
	Social participation	High	High	High	Uncertain	High	Low	High	Uncertain	High	**Yes**
	Social cohesion	High	Low	High	High	High	Uncertain	High	Medium	High	**Yes**
	Healthcare	High	High	High	High	High	High	High	Medium	High	**Yes**
	Healthcare access	High	High	High	High	High	High	High	Medium	High	**Yes**
	Gender equality	Low	High	Low	Uncertain	Low	High	Uncertain	Low	Low	No
Policies and institutions	*Policies orientation*	Low	Low	Uncertain	High	Uncertain	Uncertain	High	Medium	Low	No
	Environmental Policy	Uncertain	High	High	High	Uncertain	Uncertain	Low	Low	Low	No
	Institutions	Uncertain	Uncertain	Low	Low	Uncertain	Uncertain	High	Low	Uncertain	No
	International Cooperation	Low	Uncertain	Low	Uncertain	Uncertain	Uncertain	Low	Low	Uncertain	No
Technology	*Development*	High	Uncertain	High	High	Uncertain	High	High	Low	High	**Yes**
	Energy Intensity	Uncertain	Low	Low	Uncertain	Uncertain	Uncertain	Low	Low	Uncertain	No
	Energy Tech Change	Uncertain	Low	Low	Uncertain	Uncertain	Uncertain	Low	Low	Uncertain	No
	Transfer	High	Low	x	Uncertain	Uncertain	Uncertain	Low	Low	Uncertain	No
	Carbon Intensity	Low	Low	Low	Uncertain	Uncertain	Uncertain	Low	Low	Uncertain	No
Climate change	*Floodings*	High	Low	High	High	High	Uncertain	High	Medium	High	**Yes**
	Droughts	High	High	High	High	High	High	High	Medium	High	**Yes**
	Temperature	Uncertain	High	Uncertain	Uncertain	Uncertain	Low	High	x	Low	No
	Rainfall	High	Uncertain	High	High	High	High	Low	Low	Low	No

Annexe 4.2: Experts' feedback results for identification of key drivers of insecticides emissions in freshwater

		Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Expert 9	Expert 10	
SSP drivers	SSP sub-drivers	Do you consider this driver a **high, low or uncertain priority** to study antidepressant emissions scenario in fresh water bodies for the year 2050 et Europeen scale?										**Do 70% of experts define this driver as high priority ?**
Demographics	*Population growth*	High	High	High	High	High	Low	High	High	Medium	High	Yes
	Urbanization	Uncertain	High	Low	High	Uncertain	Uncertain	High	Low	Low	High	No
Human Devlopment	*Education*	High	High	Uncertain	Low	High	High	High	High	Low	High	Yes
Economy and Lifestyle	*Consumption and diet*	High	High	High	High	High	High	Low	Low	Medium	High	Yes
	International trade	Uncertain	High	High	High	Low	High	Uncertain	High	Medium	High	No
	Growth (per capita)	Uncertain	High	Uncertain	Uncertain	Low	Uncertain	Uncertain	Low	Medium	High	No
Environment and Natural Resources	*Land-use*	High	High	High	High	High	High	Low	High	Medium	High	Yes
	Agriculture	High	High	High	High	High	High	Low	High	High	High	Yes
Policies and Institutions	*Policy orientation*	High	High	High	High	High	High	High	Low	High	Low	Yes
	Institutions	Low	High	Low	Low	High	Uncertain	Low	High	x	Low	No
	International Cooperation	Low	High	High	Uncertain	Low	High	Low	High	Low	High	No
Technology	*Development*	High	Uncertain	High	High	High	High	High	High	High	High	Yes
	Carbon Intensity	Low	Uncertain	Low	Uncertain	Low	High	Uncertain	Low	Low	Uncertain	No
Climate Change	*Temperature*	High	High	Uncertain	High	High	High	High	High	Low	High	Yes
	Rainfall	High	High	Low	High	High	High	High	High	Low	High	Yes
	Extreme events	High	High	Uncertain	High	High	High	High	High	Low	High	Yes
	Pest pressure	High	High	Uncertain	High	High	High	High	High	Low	High	Yes

Annexe 5.1 - Part 1: Tables send to antibiotics experts to option their opinions on impacts of future Eur-SSP1, Eur-SSP4 and Eur-SSP5 socio-economics and climate drivers to antibiotics emissions

Step 1 : Read the first European SSPs storyline (Eur-SSP1)

Eur-SSP1 developped by Kok et al., 2019	**European-shared socio-economic pathway 1 (Eur-SSP1)—We are the World** There is a high commitment to achieve sustainable development goals through effective governments and global cooper- ation, ultimately resulting in less inequality and less resource- intensive lifestyles. The interplay of financial, environmental, and economic crises fuel the feeling that behaviour has to change away from an unregulated market-driven economy to a sustainable development path. This puts governments under pressure to take ambitious measures, including stimulating an energy transition towards renewables and facilitating innovative research, accompanied by investments in health, education, and social support. A decrease in conflicts in Europe's southern and eastern border regions leads to higher political stability and moderate but steady economic growth in an increasingly equitable Europe. The European Union expands further and participates in new global governance initiatives. Advances in green technologies are further stimulated by international competition leading to a CO2 neutral society by 2050. By 2100, Europe is characterised by a high level of sustainability-oriented political and societal awareness, focusing on renewable energy and low-material growth in a strongly regulated but effective multi-level.

Annexe 5.1 - Part 2: Tables send to antibiotics experts to option their opinions on impacts of future Eur-SSP1, Eur-SSP4 and Eur-SSP5 socio-economics and climate drivers to antibiotics emissions

Step 2: **Based on Eur-SSP1 story and driver's assumption, complete the following table with your interpretation of the driver's impact on future antibiotics emissions in Europeans Freshwatrersystems in 2050? Consider one driver at a time and ignore the interlinkages of drivers within a society**

Table A1

Key drivers category	Key drivers of antibiotics emissions in freshwater systems	Assumption on how the driver will change under Eur-SSP1	--- (High decrease)	-- (Medium decrease)	-- (Low decrease)	+ (Low increase)	++ (Medium increase)	+++ (High increase)	Cannot say
Climate Change	Precipitation	Relatively small increase in Northerm Europe and mall decrease in Southern Europe					*ex:* ***X***		
	Floods	Increase in Western Europe, decrease in Eastern Europe						*ex:* ***X***	
	Temperature	around 1.5°C above pre-industrial levels by 2050							
	Extreme Weather Events RCP2.6	Increase frequency and duration							
Demographic Change	Population Growth	Relatively low growth							
Human Development Change	Education	High investments							
	Health Investment	High investments							
	Access to health facilities, water, sanitary	High investments							
Policies and Institutions chang	Environmental Policies	High environmental investments							
	Regulations and quality of governance	High quality with focus on sustainability							
Technology development	Development	High, but not pervasive							

Annexe 5.1 - Part 2: Tables send to antibiotics experts to option their opinions on impacts of future Eur-SSP1, Eur-SSP4 and Eur-SSP5 socio-economics and climate drivers to antibiotics emissions

Step 3: Give your level of confidence to provide an answer for each driver (1: low confidence; 5: high confidence)	**Step 4:** If any, please provide a comment

Level of confidence	Comments	Source
ex: ***4***		IPCC_AR6_WGI
ex: ***3***		IPCC_AR6_WGI
		IPCC_AR6_WGI
		IPCC_AR6_WGI
		O'Neil at al., 2017
		Kok et al., 2017
		Kok et al., 2017
		Kok et al., 2017
		Kok et al., 2017
		Kok et al., 2017
		Kok et al., 2017

Annexe 6 – Manuscript in preparation: Environmental Management Cycles for Chemicals and Climate Change, EMC^4: A new conceptual framework contextualizing climate and chemical risk assessment and management

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Abstract

The Environmental Management Cycle for Chemicals and Climate Change (EMC4) is a suggested conceptual framework for integrating climate change aspects into chemicals risk management. The interaction of climate change and chemical risk brings together complex systems that are imperfectly understood by science. Making management decisions in this context is therefore difficult and often exacerbated by a lack of data. The consequences of poor decision making can be significant for both environmental and human health. This paper reflects on the ways in which existing chemicals management systems consider climate change and proposes a conceptual framework that acts as a tool for decision makers operating at different spatial scales. This tool highlights key questions to help the decision maker identify chemical risks from climate change, management options and, importantly, the different types of actors that are instrumental in managing that risk. Case studies showing decision making at different spatial scales are presented highlighting the conceptual framework's applicability to multiple scales. With the United Nations Environmental Programme's current development of an intergovernmental Science Policy Panel on Chemicals and Waste, the opportunity has been presented to action the inclusion of research highlighting the environmental and health impacts of chemicals and climate change interlinkages,

Key Points

- **The chemicals and climate change nexus need to be mainstreamed into chemical risk management strategies and polices nationally, regionally and internationally.**
- **Explain in one sentence EMC^4!**
- **A key requirement of chemical management strategies is the conceptualization of differences between actors regarding their capacity, within an actor network, to perform actions both in the chemicals and climate communities.**
- **UNEP's new intergovernmental Science Policy Panel on Chemicals and Waste needs to prioritize research and data gaps on the impact of climate change and chemicals interlinkages.**

1. Introduction

In 2021, it was estimated that the value of global production, shipping and trade in chemicals was US$ 4.7 trillion, with Asia Pacific, Europe and North America accounting for the bulk of this figure (ACC, 2022). While the chemicals industry has brought large benefits to modern lives (e.g. advances in the development of medicines, detergents, lubricant and cosmetics), the use of chemicals has the potential to negatively impact the natural environment and human health. Examples of known negative impacts include: persistent perfluorinated compounds accumulating in animal tissue and in turn entering human blood, tissue and breast milk (Houde et al., 2011; Jian et al., 2017); toxic pesticides contributing to global insect declines (Forister et al., 2019; Sánchez-Bayo & Wyckhuys, 2019); endocrine disruptors (e.g. oral contraceptive pills, bisphenol A) causing feminization and potential infertility of fish populations, even in sites far from urban areas (Jarque et al., 2015); anti-inflammatory pharmaceuticals devastating populations of vulture species in areas of India and Pakistan (Oaks et al., 2004); and non-point source agricultural pollution, contributing to eutrophication of water bodies (EEA, 2018; Grizzetti et al., 2017). A recent risk analysis highlighted that current chemical uses transgress safe operating space of the planetary boundary for chemical pollution and threatens ecosystems and human viability (Diamond et al., 2015). It is therefore key that systems are in place to manage chemical risks.

Landscape of chemicals managements systems

To limit and manage chemical pollution multiple chemical management systems exist, including regulatory, policy and voluntary systems. At the world scale, the Inter-Organization Programme for the Sound Management of Chemicals (IOMC) strengthens international cooperation on chemicals issues and supports national decision making through the IOMC toolkit; the Stockholm Convention regulates Persistent Organic Pollutants (POPs), the Rotterdam Convention promotes prior informed consent for exporting listed chemicals and the Minamata Convention regulates mercury. At regional scale the European Union Registration, Evaluation and Authorization of Chemicals (REACH) legislation and in the United States,-the Toxic Substances Control Act (TSCA), legislate the manufacture, import, distribution, use, and disposal of various types of chemicals. Systems are also in place for specific types of substances and pollution issues on national scale, for example, a series of UK contaminated land regulations identify and remediate chemicals on land in the UK. Through voluntary mechanisms various branch organizations and company groups establish agreements and systems to control manufacture and use of chemicals, for example, the Antimicrobial Resistance (AMR) Industry Alliance, has a promotes responsible antibiotic manufacture ain order to reduce environmental contamination from these substances and help supress the selection of antimicrobial resistance.

These are a few examples from the complex landscape of chemicals management approaches that have been developed over the last century (Löggren, 1992; Christensen et al., 2011; Teran et al., 2012). Table 1 gives a non-exhaustive list of these systems, providing examples at different ranges of legal coverage, chemicals targeted and geographic reach, all aimed at meeting their respective protection goals vis-à-vis potential effects of chemicals.

Depending on the protection goals of each management system or framework, chemicals are evaluated, characterized, and handled in different ways. The evaluation process usually relies on existing information regarding chemical characteristics, toxicity, and exposure data. If research suggests a substance's risk will affect the protection goal of a system, then the environmental risks or hazards of the substance will be managed in some way. There is, however, a circumstantial factor of growing importance that is largely ignored within these chemical management systems and that affects the management and impacts of chemicals at every stage of a products lifecycle, namely climate change.

Impacts of climate change on chemicals

Climate change and chemicals emissions are tightly intertwined. Climate change, to cite a few, alters temperature, ocean acidification and water systems which, in turn, change chemical efficiency, usage, demand and concentrations in environmental matrices (Redshaw et al., 2013; Goodenough et al., 2018; Hooper et al., 2013; Zouboulis & Tolkou, 2015). Similarly, chemicals technology development, production, usage and consumption increase ozone depletion, carbon dioxide emissions and alter environmental services (McKenzie et al., 2011; Naidu et al., 2021; Thonemann, 2020). The interactions between climate change and chemicals emission are further explained in section 2.

Lack of climate change inclusion in chemicals management systems.

Even though concerns over the links between climate change and chemical risk have been highlighted, conventions and strategic initiatives around climate and chemicals take a siloed approach. For example, the UN Framework Convention on Climate Change tends to ignore implications for chemical pollution while the voluntary Strategic Approach to International Chemicals Management (SAICM) overlooks the impacts of climate on chemical risks. The same is true for the sixth and most recent Intergovernmental Panel on Climate Change assessment report and its predecessors (IPCC et al., 2021). If we are to continue to benefit from the use of chemicals under a changing climate while not harming the natural environment, there need to be changes in the the management of the risks in each area, addressing theimpacts of the interlinkages.

Aim of this article

The aim of this paper is to explore the implications of climate change for different chemicals management practices and to provide recommendations on how these practices could and should be adapted moving forwards to ensure sustainable use of chemicals into the future. We present a discussion on how climate change impacts can be incorporated into chemicals management. A conceptual framework is presented to guide the reader through understanding the causal pathway integrations with risk assessment and risk management. This paper also provides three case studies of where a changing climate will impact the stated goals of chemicals management frameworks. It also offers a structure to help decision-makers incorporate climate science into their decision-making. Where tools and techniques exist to support this process, these are highlighted. Where gaps exist in the tools needed to support decision-makers these are similarly highlighted, along with suggestions on how these could be filled.

This paper is part of a series (cite the 5 other manuscripts here) produced at a Society of Environmental Toxicology and Chemistry (SETAC) Pellston® workshop in June 2022. The goal of the workshop and more specifically this paper was to address the concern that potential environmental and ecological impacts associated with a changing climate were not being considered in national or international chemicals management processes.

Table 15. Curated list of chemical management scenarios and corresponding compliance characteristics.

Management Scenarios	Management Systems	Responsible Agency	Compliance Commitment	Chemicals/pollutants Covered	Protection Goal and Approach	Implementation Scale
Management of global chemical pollution	Stockholm Convention	UNEP	Regulatory/legally binding	Persistent Organic Pollutants (POPs)	Reduce global pollution of persistent organic chemicals by helping parties to phase-out production and products with POPs	Global scale
	Basel Convention	UNEP	Regulatory/legally binding	Hazardous chemicals and hazardous waste	Control on trades of hazardous chemicals between countries and the promotion of environmental-friendly chemicals	Global scale
	Rotterdam Convention	UNEP	Advisory and facilitation service/legally binding	Pesticides and industrial chemicals that have been banned or severely restricted	Facilitate government decision-making with the promotion of information exchange (Prior Informed Consent) for listed hazardous chemicals	Global scale
	Minamata Convention	UNEP	Regulatory/legally binding	Mercury	Places controls on or bans all uses of mercury during production, use & disposal	Global scale
	SAICM/Beyond 2020 Framework	UNEP	Advisory and facilitation service/voluntary	POP, plastics pollutants, metals, emerging policy issues, chemicals of concern, highly	Agrees targets and provides guidance for signatories to minimize harm from chemicals during production, use & disposal	Global scale

				hazardous pesticides, etc.		
	Chemicals Road Map	WHO	Advisory/roadmap guidance	All chemicals and waste	Provides road map of actions where the health sector plays a role in the multi-sector management of chemicals	Global and multi scale
	International Code of Conduct on Pesticide Management	FAO and WHO	Advisory guidelines/ voluntary	Pesticides	Provides guidelines (including criteria for identifying highly hazardous pesticides) for governments, industry, and civil society on best practices to reduce health and environmental impacts around a life-cycle approach.	Global scale
	Inter-Organization Programme for the Sound Management of Chemicals (IOMC)	rotating agency lead	Advisory/roadmap guidance	All chemicals and waste	A nine United Nations Agency that provides facilitating, coordinating, and capacity building on the sound management of chemicals.	Global scale
	GAAPL	UNEP	Legislation	Air pollutants	Provides recommendations to strengthen air quality governance as well as guides countries to effectively address air pollution	Global scale

	WHO global air quality guidelines	WHO	Legislation	Air pollutants	To provide guidance to help reduce levels of air pollutants (quantitative health-based recommendations for air quality management, expressed as long- or short-term concentrations for a number of key air pollutants)	Global scale
Management of regional pollution	MAP	UNEP	Advisory and facilitation service	Harmful chemicals and waste	Protect the Mediterranean sea from pollution and obtain a clean and sustainable Mediterranean sea environment.	Mediterranean countries
	REACH	EU member countries competent authorities (and Third countries responsible departments)	Legislation	Industrials chemicals	To protect human health and the environment by the registration, evaluation, authorization, and restriction of chemicals prior to entering the market	EU countries
	TSCA	FDA	Legislation	Multiple types of chemicals	To protect the public from unreasonable risk of injury to health or the environment by the regulation of the manufacture, import, distribution, use, and	USA

					disposal of new and existing chemicals in U.S. commerce	
	FIFRA	USDA	Legislation	Insecticide, Fungicide, and Rodenticide	To ensure that pesticides will not cause unreasonable risk to human health or the environment by the governance of the registration, distribution, sale, and use of pesticides	USA
	CERCLA/RCRA	EPA	Legislation	Solid waste and hazardous waste, and remediation of contaminated sites	For the proper management of hazardous and non-hazardous solid waste by law and by waste management program, and remediation of contaminated sites	USA
	ECHA	EU commission	Regulatory	Multiple types of chemicals	For the safe use of chemicals to benefit human health, the environment and innovation and competitiveness in Europe by legislation	EU countries
	OSPAR	OSPAR commission	Legislation	Hazardous substances	To protect the marine environment of the North-East Atlantic by the adoption of decisions, which are legally binding on the Contracting	Marine Environment of the North-East Atlantic

					Parties, recommendations, and other agreements	
	EU Ambient Air Quality Directives	EU commission	Legislation	Air pollutants	To protect human health and the environment from the harmful effects of air pollution	EU countries
Management of local pollution	EU Water framework directive	EU commission	Legislation	Multiple types of chemicals (in total 45 priority chemicals)	To achieve good status for all water bodies. This comprises the objectives of good ecological and chemical status for surface waters and good quantitative and chemical status for groundwater.	EU countries
Management of contaminated sites (Domestic and regional regulations)	UK Contaminated land regulations	Environmental Protection Act 1990	Regulatory / Advisory	Organics, inorganics, metalloids	Regulations made provision for the identification and remediation of contaminated land.	UK
	EU Soil Thematic Strategy	EU commission	Legislation	All chemicals and waste	To protect and sustain use of soil by preventing further soil degradation, preserving its functions, and restoring degraded soils to a level of functionality consistent at least with current and intended use, thus also considering the cost implications of the restoration of soil.	EU countries

Management of water quality in a catchment	Domestic and regional regulations (e.g. EU Water Framework Directive)	EU commission	Legislation	Currently 45 chemicals (metals, pesticides, pharmaceuticals)	To ensure good ecological status of aquatic systems by regulatory controls and the development of divers programs for river restoration for the removal of barriers to fish migration or for the reduction of diffuse pollution.	EU countries
Environmental impact assessment / Strategic Environmental Assessment of new developments	EU EIA and SEA Directives	EU commission	Legislation	Certain public and private projects (airports, nuclear installations, railways, roads, waste disposal installations, wastewater treatment plants, etc.)	To ensure that projects that are likely to have a significant impact on the environment are identified and assessed, within an appraisal process, before these projects proceed to development.	EU countries
Management strategies by Industry (Industry-dependent)	AMR industry alliance safe manufacturing framework	AMR industry alliance	Advisory	Antibiotics, pesticides, industrial chemicals	To promote responsible antibiotic manufacturing.	industry
Management of Agricultural pollution	Nitrate directive	EU commission	Legislation	Nitrate	To reduce nitrate used in agriculture by establishing codes of good agricultural practices and developing	EU countries

					measures to prevent and reduce water pollution	

Implications of Climate Change for Chemical Management

Climate change and associated adaptation approaches will affect how chemicals are emitted to and behave in the environment as well as the characteristics of receiving environments and the sensitivity of receptors to exposures. These effects have been reviewed in detail in a range of publications (e.g. Boxall *et al.*, 2009; Noyes *et al.*, 2009; Balbus *et al.*, 2012; Gouin *et al.*, 2012; Halder et al., 2022).

Some positive impacts of chemical risks can be foreseen. For example, a move away from fossil fuels, in response to climate change, will result in a reduction in emissions of hydrocarbons from spills and combustion processes. The associated decline in the availability of oil-based feedstocks is already resulting in a move towards more biologically-based chemicals in products produced by different sectors which may be less toxic to receptors. Increases in temperature will reduce the persistence of chemicals within the environment.

Most changes, however, will have a negative impact on chemical risk. In terms of chemical use, a number of scenarios can be foreseen. For example, increases in plant, animal and human disease pressures, will require increased use of pesticides, veterinary medicines and pharmaceuticals (e.g. Boxall et al., 2009; Redshaw et al., 2013). Increasing dry and hot periods will result in increased emissions of chemicals used in sunscreens and other home-use products (REF).

Flooding events, sea level rise and increased erosion will mobilize contaminants, such as metals and persistent organic compounds contained in dump sites and other contaminated sites. In turn, establishing new pathways by which they can affect biological receptors (Brand *et al.*, 2018). Existing wastewater treatment infrastructure will not be able to cope with the large volumes of surface runoff from extreme rainfall events resulting in an increase in untreated emissions from combined sewer overflows (Esteve-Selma *et al.*, 2016).

During hot dry periods, which are predicted to increase under climate change (IPCC, 2021), the dilution of effluents and runoff will be reduced thus increasing chemical concentrations; while increase of precipitation and/or intensity of rainfall events in some regions could provide higher nutrients loadings in certain catchment areas, which together with an increase of temperature could trigger eutrophication processes. In forested areas, increases in fires will result in an increase in PAH, PCB, HCB, HCH and dioxin emissions (Fong and Wang, 2021) and the use of fire suppression chemicals such as foams and wetting agents. Increases in temperature will alter the bioaccumulation, persistence and volatility of chemicals (Bailey, 2004; Tao et al., 2017). These alterations will have important implications for chemical risk managers working at the global, national, local, and site-specific scales. In Table 2, we take a selection of the chemical management scenarios described in the previous section and highlight some of the climate-driven changes that are likely to be relevant for that scenario. We also consider the potential implications of a selection of adaptive and mitigation responses to climate and explore the impacts of these on chemical risks in the environment. The take home message from Table 2 is that, if we are to protect ecological and human health in the future:

1. those responsible for chemical risk management need to incorporate climate change into their assessment frameworks and ask the question ‘Will climate change alter the use, emissions, fate, exposure and effects of chemicals in the system I am managing?’; and
2. those responsible for policies to mitigate and adapt to climate change need to consider chemical risk in their decision-making processes and ask the question ‘will the mitigation/adaptation approach that I am evaluating or proposing have any unforeseen consequences in terms of chemical risks to the environment?’
3. both groups need to consider the fundamental material connections between petroleum exploitation for use in the energy system and the use of petroleum derived products as feedstock for the production of chemicals, including polymers. The extent and diversity of this use in human societies combines into a huge challenge, posing questions of system dynamic feedbacks (Dixon-Declève et al., 2022) and possible ways for addressing both climate change and chemicals management, given limited possibilities of material substitution using biobased feedstocks, which connects into land-use.

Both chemical policy developers and climate policy developers need to work in a more coordinated way to optimize the co-benefits of any adaptation or mitigation approaches in the two areas and to ensure that there are no disbenefits for the other sector. In the next section, we propose an overarching framework that risk managers could use to consider climate change andchemical interactions for different management scenarios and illustrate the approach using three contrasting scenarios covering a range of scales and both a chemicals management scenario and a climate change mitigation scenario.

Table 16. The implications of climate change for global through to highly localized environmental management scenarios from a chemical impacts perspective.

Management scenarios	Scale	Approach used	Implications of CC from a chemical impact perspective	References
Minamata Convention	Global	● **Ban on new mercury mines, the phase-out of existing ones, the phase out and phase down of mercury use in a number of products and processes** ● **Emissions to air, land and water are controlled** ● **Regulations of artisanal and small-scale gold mining.** ● **Considers interim storage and disposal of mercury and sites contaminated by mercury**	● **The speciation of mercury at a site will be altered due to increases in the incidence of flood events and sea level rise** ● **The connectivity of key ecological and human receptors to sources of mercury will alter due to extreme events**	WHO, 2021.
Development of a contaminated land register for a country	National	● **Data on previous site use, used to identify whether a site is potentially contaminated** ● **Monitoring of sites performed to determine level of contamination and these data compared to threshold values or to assess risks to controlled waters**	● **Increase in frequency and magnitude of flood events or sea level rise, resulting from climate change, could create new pathways to aquatic systems and require classification of sites to be reconsidered**	

Development of a national policy to move away from fossil fuels towards renewable source of energy	National	**Driven by national targets on greenhouse gas emissions as well as air quality targets and political drivers (e.g., Ukraine)** **Country typically sets targets to reduce use within certain timescales** **A range of options employed, including move towards renewables** **Other than traditional air quality indicators, chemicals not considered**	**Move away from oil results in fewer hydrocarbon emissions from spills and combustion** **Move towards plant-based industrial feedstocks results in new chemistries in household and other products** **Replacement sources of energy, such as photovoltaics, nuclear, wind and biofuels results in new sources of chemical emissions and increases the emissions of some chemical types** **Electrification of vehicles increases the emissions of metals and tyre particles in local low emission zones**	European Commission, 2021.
Evaluation of a new pesticide as part of the marketing authorization process	National	**Data on application rate, use characteristics and environmental fate used in models alongside scenarios of weather, soil characteristics to estimate exposure concentrations** **Data from ecotoxicity studies used alongside safety factors to establish a ‘safe’ concentration for the pesticide (e.g. a PNEC)** **Exposure concentrations are compared with ‘safe’ concentrations to assess whether use is acceptable or not**	**Scenarios for weather, soil properties and soil parameters will be different from current scenarios** **Climate change will alter the fate characteristics (e.g. biodegradation rate) of the pesticide** **Transport pathways not currently considered, e.g. flooding, will become more important** **Sensitivity of receptors to the pesticide will be altered due to changes in temperature**	

Meeting the requirements of the nitrates directive	National	● **Identifying waterbodies affected by nitrates pollution from agricultural origin.** ● **Monitoring nitrate concentration in those waterbodies.** ● **Designating as vulnerable those areas which drainage leads to nitrate pollution.** ● **Developing action measures regarding agricultural activities, e.g. applying regulations regarding fertilizer application, including manure from livestock.**	● **Nitrate loads/concentrations might increase: waterbodies ecological status and water quality for consumption threatened** ● **Vulnerable areas might change and hence the exposure** ● **Uncertainty about future fertilizer use, which will ultimately depend on the socio-economic pathway followed: might increase (marked driven agriculture) or decrease (agriculture for nature)**	OJEC, 1991. Molina-Navarro *et al.*, 2018.
Development of a river basin management plan to achieve good status/potential in waterbodies as part of the WFD	Catch-ment	● **Monitoring of biological, hydromorphological and chemical indicators to determine status** ● **Identification of pressures and mitigation approaches to achieve good status** ● **Implementation of measures**	● **Changes in land use and chemical use in response to climate change will affect chemical emissions into the catchment** ● **Changes in temperature and hydrology will affect the transport and fate of chemicals in the catchment and hence the exposure** ● **Changes in community structure will affect the sensitivity of the catchment to chemicals exposure** ● **Interactions of chemicals with co-stressors will become more important** ● **Changes in water demand for multiple uses will affect the chemical processes**	OJEC, 2000. EEA, 2018. Molina-Navarro *et al.*, 2014. Mack *et al.*, 2019 Molina-Navarro *et al.*, 2020.

			in the catchment and the exposure of ecosystems and human targets	
Development of city policy to meet zero carbon	Local	- **Multiple options, such as a move to renewable energy sources, electrification of transport and insulation of buildings.**	- **Emissions of polycyclic hydrocarbons, NOx, particulates reduced in the city** - **Increase in traffic, due to electrification of vehicles, in areas currently designated as low emission zones will result in higher emissions of tire particles and metals** - **Lithium mining to produce vehicle batteries, will cause wider impacts in areas not currently affected by pollution**	
Selection of treatment methods for antibiotics emissions from a factory as part of AMRIA good management practice	Site specific	- **Target values are set for an antibiotic based on tests with bacteria and cyanobacteria** - **Information on production volumes, cleaning etc. used to calculate emissions to the environment which are then combined with flow data to estimate exposure** - **Results are used to inform mitigation options**	- **Changes in flow resulting from climate change will alter exposure concentrations** - **Changes in environmental conditions could affect the sensitivity of microbes to antibiotics**	
Performance of an EIA procedure for	Site specific	- **Data on ecology, hydrology, hydrogeology, pedology, geomorphology and current and**	- **Increase in frequency and magnitude of flood events or sea level rise,**	OJEU, 2012. OJEU, 2014.

a new municipal landfill		**future receptors (humans, ecosystems, crops and livestock, heritage) used to assess whether the proposed site is likely to cause impacts or not.** ● **Impact mitigation measures proposal and designing of a monitoring program to prevent/correct eventual pollution events.**	**resulting from climate change, could increase exposure of receptors** ● **Human receptors could become more sensitive to the chemical exposure due to interactions with other stressors (e.g. temperature)** ● **Sensitivity of ecological receptors could be altered due to changes in temperature**	Granero Castro *et al.*, 2015.

2. Conceptualization of and Framing Chemical and Climate Change Management/Implementation

Decision and Implementation Deficit

Both the climate and the way in which society uses chemicals are changing rapidly, thus the addressing of climate and chemical issues needs to be flexible. Chemical management performed within a multi-level governance understanding (Geels *et al.*), in addition to the combined challenges of climate and increasing production and resulting emissions, exposures, and effects of chemicals, requires management systems that can adapt to the challenges presented by changing ecosystems and societal structures. All these management frameworks and strategies exist (e.g. Table 15), why are they not working? Where is action needed? Previous research highlights the lack of identification of actors (e.g., Persson *et al.*). To address the impacts of climate change on chemicals management and chemicals on climate change, we need to move beyond decision-makers initiating actions such as strategies, policies, and standards to the identification and appointment of "doer's" who will implement the identified mechanisms, and follow-up on outcomes of actions taken.

Conceptual Framing for Change and Action Implementation

A conceptual framework was developed to guide chemical and climate change decision-makers on the implications of climate change for the current chemicals management strategies summarized in Table 15. This framework, Environmental Management Cycles for Chemicals and Climate Change (EMC^4), illustrates the flow of information and interactions between components of the assessment, management, and implementation processes (Figure 20) and builds on following existing management (non-analytical) approaches:

- **Driver-Pressure-State-Impact-Response (DPSIR, environment focus; EEA, 1999; Maxim *et al.* 2016),**
- **the Driving force-Pressure-State-Exposure-Effect-Action (DPSEEA, environmental health focus; Corvalan *et al.*, 1999, Edokpolo *et al.* 2019),**
- **and the Adaptive Management Framework (van den Brink *et al.* 2016; Cains and Henshel 2021)**

To strengthen and emphasize the monitoring and implementation needed to improve on current chemicals management, while highlighting the key chemicals and climate change actors (e.g., decision makers), it is key to identify which actors are in a position to give the directive for developing and initiating strategies and laws as well as the actors physically implementing said strategies and laws. The purpose of this conceptual framework (Figure 1) is to provide a tool to identify actors and options for chemicals management. Furthermore, it can lead to recommendations for different actors on how to incorporate monitoring and adaptive management approaches for sustainable design, production, use, and disposal of chemicals in the context of climate change. The conceptual framework considers the different levels of chemicals management (local, regional, national, global), and is therefore scalable and adaptable, and the actors (e.g., intergovernmental organizations, governments, non-governmental organizations, industry, academia) within these policy arenas.

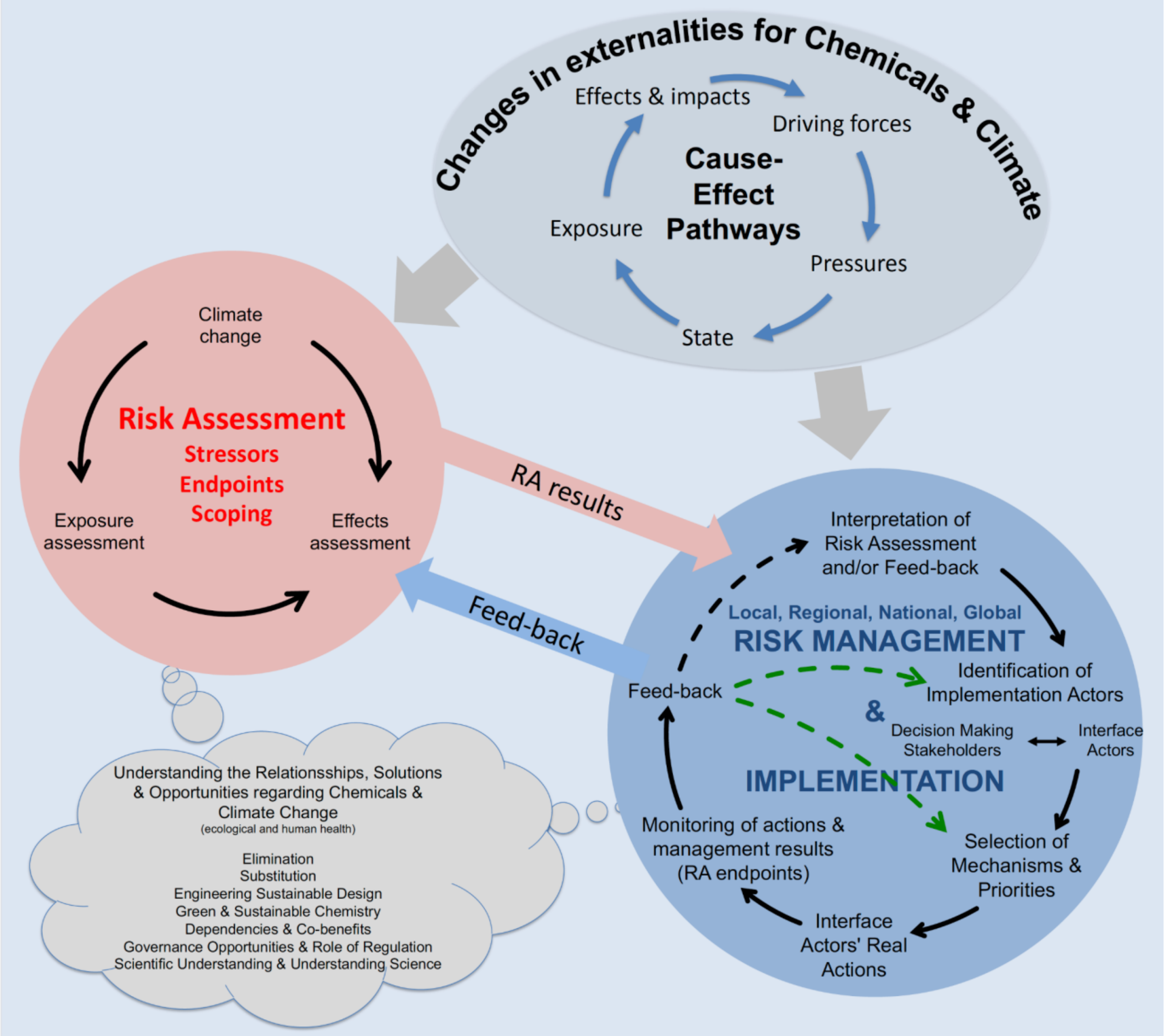

Figure 20. Environmental Management Cycles for Chemicals and Climate Change (EMC^4) The framework includes several feedback cycles, and linkages between and within subsystems, since learning and adaptation are key processes for the actors involved.

1 *Changes in Externalities*

From the perspective of an adaptive management cycle, externalities (i.e., contexts) are properties and characteristics of a system that are beyond the purview or scope of the decision makers' or managers' governance. Some things cannot be changed or are perceived as being constant. For example, climate change is an external factor to the scope of impact for city-level governance; the sustainability management practices of one city or one chemical facility cannot directly affect climate change on a global scale, but only provide a small contribution towards mitigation and adaptation. Thus, climate change is an externality of the environmental management cycle for any single actor. Building from the DPSEEA and DPSIR models, climate change is both an impact and driving force producing causes and giving effects that need considerations for chemical risk management strategies. Driving forces of climate change include, but are not limited to, emissions, technology, lifestyles, economics, social issues, political contexts, and institutional structures.

2 Risk Assessment (RA)

For chemicals risk management the tightest connections are between the risk assessment and risk management. The process of risk assessment can help decision makers and managers understand how externalities and driving forces are affecting their system of interest (e.g., chemical manufacturing, watershed, species in ecosystems). The problem formulation and scoping step of risk is foundational in establishing the scope, context, stressors, and criteria specific to the decision makers and risk managers' decision space (Cains and Henshel, 2020; Suter *et al*., 2003). Traditionally, risk assessments have focused on a single stressor, e.g., a chemical of interest (NRC, 1983; NRC, 2009), however such an approach limits the ability to understand the interaction between chemicals and climate change. Given that climate change is a "threat multiplier" (Goodman and Baudu, 2023), a multi-stressor risk assessment approach is suggested to characterize the multi-faceted ways that physical stressors caused by climate change can and have affected the physical, chemical, and toxicological characteristics of chemicals in the environment (e.g. Hering *et al*., 2015). In addition to interactions between climate change impacts and chemical properties, both types of stressors have the ability to increase the vulnerability of susceptible endpoints. For example, honeybee research has theorized increased susceptibility to compounding stressors due to climate change (Le Conte and Navajas, 2005). Research has found that some pesticides reduce colony survival, which can be further compounded by reduced queen bee fertility caused by temperature extremes (Cunningham, *et al*., 2022).

3 Risk Management and Implementation

Risk management requires decision makers and managers to interpret risk assessment results and transform them into actional management strategies. Risk management also needs to follow-up on earlier actions and learn from experiences in a feed-back loop. The translation from assessment to management furthermore needs to be able to identify options and actors/stakeholders in detail at each level. Such a process should identify various types of actors, together with their motivations and possibilities to act during various steps of implementation. The suggested conceptual framework distinguishes between "implementation actors", "decision making stakeholders" and "interface actors" and their possible actions. A key requirement of management strategies is the conceptualization of differences between actors regarding their capacity, within an actor network, to perform actions. That is, actions that influence changes of relevance regarding the material flows leading to emissions, and exposures. Not all actors can *de facto* change the material flow of concern. The ones who can do it, we call "interface actors". They are the actors that do have a combination of motivation and means, to change, or reduce, the particular material flow(s) that is concerned. It can be a question of closing a valve, buying, and using a chemical to substitute a troublesome substance or to use less in a particular situation. We motivate the use of "interface actors" (following Wallin, 2014) by distinguishing specific actors that do have the capacity to take specific decisions that affect *the material's flow over the interface between the socio-technical and ecological subsystems*. A reason for thinking in terms of an interface between these two subsystems is that as long as substances and materials are within the socio-technical subsystem they can potentially be controlled by human actions, e.g. by circular material handling systems. When substances are emitted into the environment this control is mostly completely lost, or at least drastically reduced. An example in particular is contaminated soil where earlier ways of disposal, like burrowing materials in the ground, or a sloppy use of substances at a site, have given slow and long-time dispersal of contaminants into surrounding areas. These contaminations are sometimes possible, but difficult and costly, to retake control over.

Activities on various governmental, or corporate, levels do not directly change material flows, but are intended to influence other actors, in an, often incomplete, chain of actors/activities, to reduce or in other ways change material flows with the final aim of reducing emissions and exposures foregoing unwanted impacts on human health and the environment.

"Implementation actors" are hardly able to take decisions that directly influence a material flow, but they might have possibilities to incentivize (or disincentivize) other actors within their own organization or adjoining. Since human organizations mostly are hierarchical several levels of organization may need to be involved in order to stepwise move information, motivations, and responsibilities, the whole way from implementation to interface actors. We foresee a rather detailed analysis to identify interface actors, together with mechanisms to influence their behavior. In conjunction to the implementation and interface actors a wider set of "decision-making stakeholders" can be identified. In this group of actors, we may find industrial branch organizations, NGO's and media. In some cases, ordinary households occur also in this group, while they often can be regarded as "interface actors" having the direct influence over the release of substances into the environment.

Interface actors can occur at different levels in the organizations operating in product chains handling chemical substances, chemical mixtures, materials, and products that might find their ways into the environment. Often concerted actions within organizations are needed in order to change material flows and reduce emissions of particular substances. Furthermore, long-term activities (e.g. product design, design of industrial production systems and the construction of supply chains) are of importance, but indirectly, to achieve substantial emission reductions.

A large set of background information regarding the relations between actors is of importance together with an extensive understanding of the relationships, solutions and opportunities that exist regarding chemicals management and climate change. Basically, underlying material links between different steps in the material flows need a deeper consideration. Chemical production is reliant on feedstocks emanating from petroleum, which is the common source also for fossil fuels. Larger changes related to elimination, substitution or changes regarding fuel production and feedstocks will have repercussions in the chemical industries and likewise application of various engineering solutions, new greener and sustainable chemistry insights will lead to changes of material flows and emissions. Various dependencies and possible co-benefits from changes need consideration, will most likely, influence what management options are seen as acceptable. The role of governance, and perceived opportunities for chemicals management, may also need a more holistic approach in order to make possible the larger changes in material flows that are needed in order to meet climate challenges.

Furthermore, a scientific understanding of various steps, and information needs, in designing effective chemicals management is crucial, and so is also the interplay between science and management. The further development of the panel is therefore of specific interest.

3. Case Study Application of EMC^4

We developed eight guiding assessment and management questions that risk assessors and risk managers should ask themselves to better understand how climate change will affect the assessment and management of environmental chemical risks (see Table 17). The three case studies of varying scale (e.g., global, regional, and local) are used to answer the eight questions and illustrate how the Environmental Management Cycle for Chemicals and Climate Change (EMC^4; in Figure 20) can be used by risk assessors and risk managers to frame the integration of climate change into environmental risk assessments. These case studies provide contrasting scenarios to show how there is no one answer or management solution that fits all.

For the "changes in externalities" and "risk assessment" component of EMC^4, the following questions should be addressed:

1. **Driving Forces: What are the current chemical risks associated with your case study or context?**
2. **Pressures: How is the climate changing within the area/region of concern?**
3. **State: How will the physical stressors (e.g., precipitation extremes) induced by climate change affect the fate, transportation, and toxicity of the chemical, or the susceptibility of the exposed ecosystem/humans?**
4. **Exposure: How will climate change affect the use/release/toxicity of the chemicals of interest?**
5. **Effects and Impacts: Is there evidence and data available to understand the relationship between the chemical risks and climate change impacts?**

For the "risk management and implementation" component of the EMC4, the following questions should be addressed:

6. **What actors need to be involved in the assessment and management of these risks?**
7. **How can change of actors' behavior be motivated and how can it occur in ways to mitigate greenhouse gas emissions, chemical emissions, and climate change impacts at the same time?**

8. **What policy options (e.g., “carrots or sticks”) are available to affect change while taking into consideration the pros and cons of each option?**

Global case study: Integrating climate change into SAICM

The Strategic Approach to International Chemicals Management (SAICM) is a global chemicals management framework adopted by the United Nations in 2006. One of SAICM’s stated functions is to identify and call for action on global Emerging Policy Issues, such as the product lifecycle of textiles. More than 1900 chemicals are used in the production of clothing; the EU classifies 165 as hazardous to health or the environment (EPRS, 2019). To understand how the externalities driving chemical risks in this system may change in the face of climate change it is necessary to characterize the risks as they currently stand. The UNEP Chemicals Branch (2011) identified several risks, including:

- **pesticides used in the growing of natural fibers, and any dyes used in their formulation;**
- **effluent from the manufacture of dyes and colorants (e.g., dye baths); and**
- **effluent from the tanning and treatment of leather products.**

China represents over 35% of global textile exports (Leal Filho et al., 2020) and its future climate has been modelled using the IPCC’s SRES B2 Scenario (Xu et al., 2006). If by the 2080s air temperatures significantly increase and there is an overall increase in precipitation and flooding, there would then be significant precipitation decreases in specific regions in winter and summer. Increased temperatures and drought are associated with increased pests in cotton crops in China (Huang and Hao, 2018) and therefore increased pesticide use. Organophosphate pesticides have been found in flood sediments across China (Qian, *et al*., 2020. Linxi Yuan, *et al.*, 2013) and transportation of chemicals applied to soils or deposited in freshwater through this route is likely to increase. Further examples of how climate change can impact the risks from chemicals due to the textile industry in China are provided below in Table 3.

In terms of the risk management and implementation component of EMC[4], a chemical pressure such as that resulting from textile manufacture, use and disposal is global in nature due to the nature of the supply chains involved. Without a global response the impacts of chemical pollution may simply be transferred to a weaker, and therefore cheaper, regulatory regime. Since 2006, SAICM has been one of the primary actors in coordinating global action on chemical management. The question is whether the new framework emanating from the SAICM Beyond 2020 process can incentivize governments to ask the questions listed above. Particularly for a better understanding ofhe changes in externalities climate change presents and the impact it will likely have on chemicals risk management and implementation within countries. Secondly, UNEP is currently developing a Science Policy Panel which is intended to bridge the information gap between governments and current scientific research on chemical and waste risks. The Science Policy Panel is ideally placed to collate and communicate existing knowledge of the likely impact of climate change on chemicals risk assessment, in addition to taking steps to understand, prioritize, and close evidence gaps. A remaining gap is a process to identify the different actors necessary for the designing of stringent management mechanisms to tackle the issue and the follow up actions to ensure the risk is managed.

Regional case study: Nutrient pollution in European catchments

The European Union (EU) water policy, highlighted by the European Water Framework Directive (WFD; OJEC, 2000), aims at achieving a good ecological status in all surface waterbodies by 2027. This ecological status is determined with several indicators, including the nutrients concentrations. In fact, nutrients pollution, mainly in the form of diffuse pollution from agriculture, has been a concern in Europe for several decades now, and particularly since the proclamation of the Nitrates Directive in 1991 (OJEC, 1991). However, despite all the efforts done, nutrients pollution is still one of the main environmental problems in Europe, and one of the most important threats for aquatic ecosystems (EEA, 2018; Grizzetti *et al.*, 2017). The impact of global change on the fate and transport on nutrients in Europe is uncertain and a deep analysis of current findings is needed to plan adequate management strategies to cope with this problem, and particularly to reduce the risk of eutrophication. Also, the on-going war, and potential food security issues in its wake, influence the European handling of the issues.

Table 17 provides a brief overview of how global change (climate change and their associated changes in the society) might affect nutrient pollution in European catchments, which tools are available to investigate this problem and who is playing a role in the matter (e.g. actors, policy options). Nutrients pollution management will not be an easy task in the next few decades in Europe since the impacts might be different depending on the region: climate will change differently (e.g., increasing precipitation in the north, decreasing in the south) and the social changes will take different directions too (e.g. Mack *et al.*, 2019; Molina-Navarro *et al.*, 2020). However, actions are being taken to address this problem, including coping with the WFD and the Nutrients Directive requirements, a sustainable food system pursued in the implementation of the Green Deal or the imminent Integrated Nutrient Management Action Plan (https://agriculture.ec.europa.eu/farming/organic-farming/organic-action-plan_en; https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12899-Nutrients-action-plan-for-better-management_en).

Local case study: Legacy and active contamination of the South River, VA, USA

We describe the South River, Virginia site as an example of considering climate change in ecological risk and remedial decision-making at a local / site scale Table 17. The explicit inclusion of climate change as a compounding stressor produced a suite of prospective risk assessments that facilitated a risk management and implementation process producing management actions tailored to both the exposure and impact of chemical and climate change-induced stressors. More than 20 years of investigation culminated in a plan for remediating legacy mercury at this site (Stahl, Kain *et al.* 2014, Stahl Jr 2022). This included specific evaluation of ecological risks coupled with climate change (Johns, Graham *et al.* 2017, Landis, Ayre *et al.* 2017). Results of the ecological risk assessments were incorporated into an adaptive management (AM) framework (Foran, Baker *et al.* 2015), designed to evaluate the effectiveness of remedial actions. Restoration actions were also coupled with the remedial actions and were driven by considerations described elsewhere (Kapustka, Bowers *et al.* 2015, Hooper, Glomb *et al.* 2016). All work was conducted under the Resource Conservation and Recovery Act, Corrective Action program (RCRA-CA), overseen by the Commonwealth of Virginia, and the U.S.

Environmental Protection Agency. Additional information can be found at www.southriverwatershed.org

Table 17. Guiding assessment and management questions for integrating climate change into environmental risk assessment. Three case studies (e.g., global, regional, local) provide example applications of these questions.

Guiding assessment and management questions:	Global: Integrating climate change into SAICM regarding textiles	Regional: Nutrients pollution in a European catchment	Local: Mercury contamination in South River, WV, USA
1. What are the current chemical risks associated with your case study?	Pesticide usage, effluent of dyes, treatments, coatings & detergents, microplastic release	Nutrients diffuse pollution from agriculture, point sources pollution, eutrophication.	Methyl mercury (MeHg), PAHs, organochlorine pesticides
2. How is the climate changing within the area/region of concern?	Textiles a global industry, however increased flooding, weakening of the monsoon, increased air temp and reduced precipitation expected in textile growing/manufacturing areas	Changes will be different across Europe: Temperature will increase, while precipitation might increase in the north but decrease in the south.	Increased river temperature; Increased inland flooding
3. How will the physical stressors induced by climate change affect the fate, transportation, or the susceptibility of the exposed system?	Lower dilution capacity for pollutants, increased run-off into fresh and marine water, increased deposition and into new areas, change in transformation of metabolites	Lower dilution capacity for nutrients, increased erosion and thus nutrients transport, higher risk of eutrophication (increased nutrients availability and temperature)	Habitat alteration for aquatic species; Release/resuspension of contaminated soil into river; Increased suspended solids
4. How will climate change affect the use/release/toxicity of the chemicals of interest in the exposed system?	Increased and changed pesticide & fertilizer usage, increased and changed use of textile treatments (e.g. anti-mold),	Uncertainty about fertilizer use: changing crop distribution, population growing, green	Legacy MeHg contamination; Increasing population and land development, increases PAHs;

	likely change in the way society uses & washes textiles,	policies, etc. Changes in the water demand for multiple uses.	Increasing population and agricultural production increases organochlorine pesticides, suspended solids
5. Is there evidence and data available to understand the relationship between the chemical risks and climate change?	The impact of climate change on the types of chemical pollution caused by textiles is increasingly well evidenced. The impact of climate change on textiles as a source of chemical risk is not well understood.	EU member states have a strong monitoring network to cope with the WFD requirements, registering nutrient concentrations (among other parameters) in every continental and transitional waterbody. Availability of hydrological and ecological models incorporating climate change scenarios provided by downscaled regional climate models.	Historical record of assessed stressors and monitored assessment endpoints; Multi-year feasibility study of each management options; Downscaled regional climate change projects specific to South River
6. What actors need to be involved in the assessment and management of these risks?	International Governments, UNEP, IOMC, industry bodies, new global science/policy panel	EU administration, Ministries of Environment, River Basin Authorities, farmers and/or regional administrations.	South River Science team (consortium of academics, consultants, government personnel, NGOs)
7. How can human behavior be modified in a way to mitigate greenhouse gas emissions, chemical emissions, and climate change impacts at the same time?	Consume less clothing and fabric-based products, preferentially buy sustainable fabrics, wash clothes less often, avoid fabrics with applied treatments, improve	Decreasing fertilizer use, working towards a sustainable and high-tech agriculture; implementing nature-based solutions to improve water quality through nutrient uptake,	Adaptive management to monitor and assess efficacy of: riverbank stabilization;

		carbon sequestration and biodiversity conservation.	adding riparian vegetation and trees; agricultural best management practices
8. What actions or policy options (e.g., carrot or stick) are available to affect change while taking into consideration the pros and cons of each option?	Harsher regulation of emissions, incentivize integrated pest management, incentivize improvement in manufacturing and detergent technology, improved collection for re-use, repair & recycling, improved transparency/labelling, consumer awareness campaigns	Water Framework Directive, Nitrates Directive, European Green Deal, EU's Common Agricultural Policy. Definition and implementation of specific catchment adaptation plans, nested in the national and regional adaptation strategies.	Collaborative assessment and management process driven by diverse knowledge and experience needed to ensure successful long-term bank stabilization by working with the existing old-growth trees along the bank.

4. Implications and Path Forward

In contrast to the other papers in this series, our task was to determine if and how any new approaches for incorporating climate change projections into ecological risk assessment could become a standard practice in chemical management programs and policies. While the case studies provided by the other work groups in this workshop (cite the Yakima River, GBR, and pesticides manuscripts) focused on spatial and temporal scales suitable for ecological risk assessment, our focus was on chemical management at multiple geographic scales. Particulary as as management occurs across scales. This was the backdrop for developing the EMC4 conceptual framework.

In the Introduction and Section 2 we touched on how climate change can influence the fate and effects of chemicals, and potential barriers to address this in chemical management programs. Nations first cooperated to address climate change in 1992 (Rio Convention), and the first specific climate change convention was celebrated in 1995 (COP1, Berlin), yet in 2022 when the most recent convention was held (Paris), measurable progress to achieve the goals nations set for themselves remains elusive. It appears also to be the case with SAICM that nations desire to participate and make progress, but that progress has been slow (SAICM, Independent Evaluation of the Strategic Approach, 2019). Yet this presents the risk management and policy community with an opportunity since SAICM is under review and changes are likely. Thus, with the acknowledgment of a need, consideration of climate change could be incorporated into the SAICM Beyond 2020 framework/approach. Given that many frameworks rely on pre-existing knowledge and research for evidence based chemical decision making (e.g., Stockholm), there is a need for a coordinated effort to understand and explain the relationship between chemicals and climate change on a global scale to stimulate an evaluation of the data that exist (e.g., SPI, IOMC).

In this series of papers, case studies have been provided for chinook salmon (Landis et al. This series) in the U.S. Pacific Northwest, the Great Barrier Reef in Australia (Jenny / Sophie et al., this series), pesticides in Norway (Jannicke / Rik / Sophie, this series), and have shown the methodology for incorporating climate change projections into a wide variety of ecological risk assessments, at various spatial scales, and for differing environmental situations. These methods could be operationalized in the near future as there appear to be little, if any, technical barriers to preclude their use for ecological risk assessments. The next logical step would be to incorporate them into chemical management programs worldwide and to require that they are used in future industry data submissions for new chemicals, and for new uses of existing chemicals. The consequences of not incorporating climate change considerations into chemical management programs range from increased pesticide susceptibility of nontarget species, to approving widespread use of a new chemical that will, perhaps, exhibit the same harmful, environmental profile as ozone-depleting chemicals of the 1950s-1970s. The latter is something we should endeavor to avoid.

Since many chemical management programs and frameworks rely on pre-existing knowledge and additional research on chemical management decision making (e.g Stockholm) the use of the EMC4 Framework would enhance incorporating climate change. Thus, it makes sense to develop a scientific expert process to evaluate chemical fate and effects data that exist, and the implications that may result due to climate change (e.g. SPI, IOMC). With the development of the UNEPs new Chemical and Waste Science Policy Panel, the opportunity is there, key is that those setting up the

IPCC, IPBES and IRC type of panel include this focus during the horizon scanning and other prioritization mechanisms put in place. Key would be for the new Science Policy Panel to interact with the IPCC to discuss uncertainties in the analyses, and whether there is a need to fill data gaps. While the new panel's focus is "policy relevant, not policy prescriptive", it could also suggest approaches and tools that might be useful to decision makers in the governmental and business communities involved with chemical manufacture and management.

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