Health Risk Assessment of pharmaceuticals in drinking water from de facto water reuse in South Africa

And an investigation of the public's perception of de facto water reuse

Master's thesis in Infrastructure and Environmental Engineering

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ABSTRACT

In the last decades pharmaceuticals originating from wastewater have been detected in drinking water around the world. Consequently, a concern regarding human health risks due to long term exposure of pharmaceuticals in drinking water have been raised among water suppliers and consumers. In South Africa, in periods of drought, rivers that are used as raw water in drinking water treatment plants (DWTPs) have showed to contain up to 99% of treated wastewater, which is called de facto (unintendedly) water reuse. The occurrence of de facto water reuse might increase the concentration of pharmaceuticals in drinking water.

The aim of this study was to develop a model for Quantitative Chemical Risk Assessment (QCRA) of human health risks due to long-term exposure of carbamazepine, diclofenac, and sulfamethoxazole in drinking water in two DWTPs along Berg River, South Africa. A sensitivity analysis with different scenarios (conventional treatment and chlorination, no treatment, and conventional treatment and Granular activated carbon (GAC) filters) was performed in the QCRA-model for the population groups*:* infants, children, and adults. As a second part the public's perception of water reuse and the level of trust in safe water quality was investigated through an interview study.

Results showed that there is no human health risk for any of the population groups exposed to the pharmaceuticals studied via drinking water. Even with no treatment in the DWTPs no risk will occur with exposure of the pharmaceuticals studied. The result that was closest to a risk was exposure of diclofenac for infants that are formula fed. As a future scenario, if the concentrations of pharmaceuticals may increase, a suggestion would be to implement GAC filters, since the results shows a reduction of the risk, especially for diclofenac and carbamazepine.

The results from the interview study showed that the overall perception of water reuse is that most people seem to accept it as a water source, but the majority have doubts that it is safe to drink. To overcome this great barrier, higher public involvement and knowledge sharing actions are needed to increase the trust in that reused water is safe to drink.

Keywords: De facto water reuse, Risk assessment, Quantitative chemical risk assessment, Health risks, Sensitivity analysis, Toxicological effect, Water treatment, Berg River, South Africa

Hälsoriskanalys av läkemedelsrester i dricksvatten påverkat av avloppsvatten i Sydafrika samt en undersökning av befolkningens acceptans av oavsiktlig återanvändning

Masteruppsats inom programmet Infrastruktur och miljöteknik

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SAMMANFATTNING

Under de senaste decennierna har läkemedelsrester som härstammar från avloppsvatten detekterats i dricksvatten runt om i världen. Detta har föranlett en oro hos konsumenter och vattenleverantörer för potentiella hälsoeffekter och risker orsakade av långvarig exponering av läkemedel genom konsumtion av dricksvatten. I Sydafrika, särskilt under perioder av torka, har floder som används som råvatten för dricksvattenverk uppvisat ett innehåll på upp till 99% renat avloppsvatten, detta kallas för (oavsiktlig) återanvändning av vatten. Förekomsten av återanvändning av vatten kan komma att öka koncentrationen av läkemedelsrester i dricksvatten.

Syftet med denna studie var att utveckla en modell för kvantitativ kemisk riskbedömning för hälsorisker orsakade av långvarig exponering av karbamazepin, diklofenak och sulfametoxazol i dricksvatten. Studien gjordes på två vattenverk belägna längs floden Berg River, Sydafrika. För att inkludera osäkerheter och variationer i riskbedömningen utfördes en känslighetsanalys med olika scenarier (konventionell rening och klorering, ingen rening, konventionell rening och filter av granulärt aktivt kol, GAC) på olika befolkningsgrupper: spädbarn, barn och vuxna. Dessutom genomfördes en intervjustudie i syfte att undersöka allmänhetens uppfattning om konceptet återanvändning av vatten och om befolkningen känner tillit till att vattnet är tillräckligt rent.

Resultatet visade att det inte föreligger några hälsorisker för någon av befolkningsgrupperna som exponerades för någon av de läkemedel som studerades via dricksvatten. Resultaten visade inte heller på någon risk för läkemedelsrester helt utan rening i dricksvattenverken. Av de studerade grupperna och läkemedlen, var spädbarn med bröstmjölksersättning exponerade av diklofenak den grupp som befinner sig närmast att löpa hälsorisker. Om koncentrationerna av läkemedlen i dricksvatten skulle komma att öka är ett förslag att implementera GAC-filter, eftersom denna studie visade att det skulle reducera hälsorisken för exponering för särskilt diklofenak och karbamazepin.

Resultaten från intervjustudien visar att den övergripande uppfattningen om vattenåteranvändning är att de flesta accepterar det som en vattenresurs, men majoriteten tvivlar på om det är säkert att dricka. För att övervinna denna stora barriär krävs mer kunskapsspridning och involvering av befolkningen för att öka tilliten till att återanvänt vatten är säkert att dricka.

Nyckelord:
Oavsiktlig återanvändning av vatten, Riskbedömning, Kvantitativ kemisk riskbedömning, Hälsorisker, Känslighetsanalys, Toxikologiska effekter, Vattenrening, Berg River, Sydafrika

TABLE OF CONTENT

PREFACE AND ACKNOWLEDGEMENTS

This master thesis was performed as a cooperation between Chalmers University of Technology and Chris Swartz Water Utilization Engineers. It was planned to be performed as a field study in South Africa during spring 2021, but the field study was unfortunately cancelled due to Covid-19 pandemic. We would like to express gratitude to all those who made it possible to complete this study despite the prevailing circumstances.

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Emelie Andersson & Ellen Svärd

ABBRIEVIATIONS

ADI – Acceptable daily intake
BAC – Biological activated carbon
BW – Body weight
CMZ – Carbamazepine
DWS – Department of Water and Sanitation
DIC – Diclofenac
DWEL – Drinking water equivalent level
DWTP – Drinking water treatment plant
GAC – Granular activated carbon
GD – Green Drop
LOAEL – Lowest Observed Adverse Effect Level
LOEL – Lowest Observed Effect Level
MTD – Minimum therapeutic dose
NOAEL – No Observed Adverse Effect Level
NOEL – No Observed Effect Level
NRMMC – Natural Resource Management Ministerial Council
NSAID – Non-steroidal anti-Inflammatory drug
PAC – Powder activated carbon
PoD – Point of Departure
SMX – Sulfamethoxazole
QCRA – Quantitative chemical risk assessment
UF – Uncertainty factor
WR – Water reuse
WWTP – Wastewater treatment plant

1 INTRODUCTION

This chapter includes a background about de facto water reuse and public perception to present it in a broader context. The aim, research question and delimitations are presented.

1.1 Background

How to secure sufficient water supply is an increasing problem in many parts of the world because of drought, climate change and population growth (Fielding et al., 2019). South Africa is one country highly affected by water scarcity and the occurrence is frequently increasing (McKenzie et al., 2012). The country's water resources are extremely limited, and the groundwater and natural availability is poor, and they are therefore dependent on surface water as their main resource for drinking water supply (Smuts Basson & Senior Advisor, n.d.) According to (Swartz et al., 2019) the surface water quality has had a drastic deterioration due to an increase of treated wastewater discharge. Many municipalities and water services are dependent on the polluted surface water and de facto water reuse is occurring (Swartz et al., 2019). De facto, or unintendedly, water reuse refers to situations when water from a source is substantially composed of previously used water, mainly treated wastewater (US EPA, 2020). One common example of this is when surface water, such as rivers used for drinking water supply are affected by wastewater treatment plants (WWTPs) discharge upstream. In general people are open-minded towards water reuse for non-contact uses such as irrigation or firefighting, but studies show huge rejection for potable uses. The potential health risks together with the first feeling of disgust or so called “yuck”-factor associated with drinking water affected by wastewater impacts the rejection (Fielding et al., 2019). Overall microbial risks are widely researched, meanwhile there is a gap in the research for risks due to exposure of chemicals in drinking water (WHO, 2011b). In the last decades pharmaceuticals and other chemicals originating from wastewater have been detected in final drinking water which has raised the concern among different stakeholders such as governments, water suppliers and consumers (WHO, 2011b). Health impacts such as fertility reduction, cancer and birth defects have been linked to pollutants such as pharmaceuticals in fresh water (Archer et al., 2017a).

A project sponsored by the Water Research Commission has mapped out the extent of de facto water reuse in South Africa. One example is Berg River, north of Cape Town, that in 2017 during drought contained up to 99% of treated wastewater in certain section that had very low river base flow (Swartz et al., 2019). Above that, various pharmaceuticals have been detected (Swartz et al., 2019). Berg River is 285 km long and has a catchment area of 8,980 km^2 that mainly consists of agricultural land and natural vegetation (River Health Programme, 2004). Piketberg and Withoogte drinking water treatment plants (DWTPs) have their raw water intake in Berg River, respectively a dam in Berg River, downstream of five WWTPs discharges, and are therefore so-called de facto water reuse plants. See Figure 1 for Berg River and the location of all WWTPs and DWTPs along the river. Piketberg and Withoogte DWTPs serve drinking water to surrounding villages with design capacity of 2,400 m^3/day respectively 72,000 m^3/day. Both DWTPs are conventional and are not designed for the poor raw water quality caused by high treated wastewater content. Especially pharmaceuticals and other chemicals have been shown to have low removal efficiency in conventional treatment (Tröger et al., 2020). In this study, conventional treatment refers to the treatment steps combined: coagulation/flocculation, sedimentation, and sand filtration.

Figure 1 Berg River in blue, the direction of flow in blue arrows, WWTPs and DWTPs are shown in brown respectively green stars

1.2 Aim

The aim of the project was to conduct a model for Quantitative Chemical Risk Assessment (QCRA) to characterize the human health risks of exposure to the pharmaceuticals: carbamazepine, diclofenac and sulfamethoxazole in final drinking water from two de facto water reuse plants along Berg River. The emphasis has been on developing the QCRA-model including a sensitivity analysis using Monte Carlo simulations for different potential scenarios of treatment efficiencies. A second aim was to investigation the public's perception (acceptance or rejection) of the concept “de facto water reuse”, and to find potential factors influencing their perception.

1.3 Research questions

The following research questions will be answered to achieve the aim of the master thesis:

- At what level of concentration of the pharmaceutical studied in drinking water does it become a human health risk for long term exposure?

- Do the pharmaceuticals analysed pose a human health risk to the people drinking the final water after the conventional treatment in the Piketberg and Withoogte DWTPs?
    - Is there a risk if there is no treatment in the DWTPs?
    - Is the risk reduced if further treatment with Granular Activated Carbon (GAC) filters is used?

- What is the public's perception of using water from de facto (unintended) water reuse?
    - Is there an overall view of acceptance or rejection on the concept?
    - What would be suggested to do to improve the public's perception in the concept of water reuse?

1.4 Delimitations

The following statements was used to delimit the aim of the master thesis:

- The study only included the part of the water cycle from raw water to the final drinking water leaving the DWTPs. It did not take into consideration any risks or effects in the wastewater treatment plant or the distribution system.

- Assumptions was made by conditions and circumstances specific for the given place, the given river and the three specific pharmaceuticals.

- The study only investigated the human health impact risks due to the pharmaceuticals and no other type of health risks for any other kind of terrestrial or aquatic organisms.

- The study only considered pharmaceuticals apparent in WWTP discharge and do not consider other pollutants from industrial and agricultural effluents etc.

- The study only included Piketberg and Withoogte DWTPs and no other DWTP located along Berg River.

- Generalisation and assumptions to simplify the model is always a part of a risk assessment, also seen in this study. The assumptions have been chosen for different scenarios for potential risks.

- The planned field study in South Africa was cancelled, due to the ongoing Covid-19 pandemic, but the project was adjusted according to the situation by remote communication and support.

2 THEORETICAL BACKGROUND

2.1 De facto water reuse

Water reuse can occur in different forms, either intentionally or unintendedly. Intentionally water reuse occur when a wastewater treatment plant discharge goes direct into an engineered system with advanced treatment, in the aim to get water for potable uses (Weisman et al., 2019). Water reuse can also be unintended, which is called de facto water reuse. De facto water reuse is when treated wastewater is discharged into a surface water source such as a river upstream of a drinking water system. These drinking water systems draw raw water from the surface water contaminated with occasionally high content of treated wastewater from the WWTP upstream, see Figure 2 (Weisman et al., 2019). De facto water reuse is often expressed in percentage of how much of the raw water that is containing treated wastewater (Nguyen et al., 2018).

De facto water reuse is not officially acknowledged but is occurring in several places around the world (Chaudhry et al., 2017; Weisman et al., 2019). In the US, half of all the drinking water treatment plants serving more than 10,000 people each are affected by at least one treated wastewater discharge upstream (Nguyen et al., 2018). In countries where there are seasons of drought and the natural water flow is low, the rivers can consist primarily of treated wastewater from upstream WWTPs making the raw water source for DWTPs highly polluted, with up to 100% treated wastewater sometimes (Chaudhry et al., 2017). In Sweden there are surface waters that have a DWTP downstream of a WWTP discharge (Tröger et al., 2018), however it is not officially acknowledged as de facto water reuse. De facto water reuse is mainly pronounced in dry periods when the natural water flow is low and the percentage of treated wastewater in the raw water is high (The National Academics of Sciences Engineering Medicine, 2012).

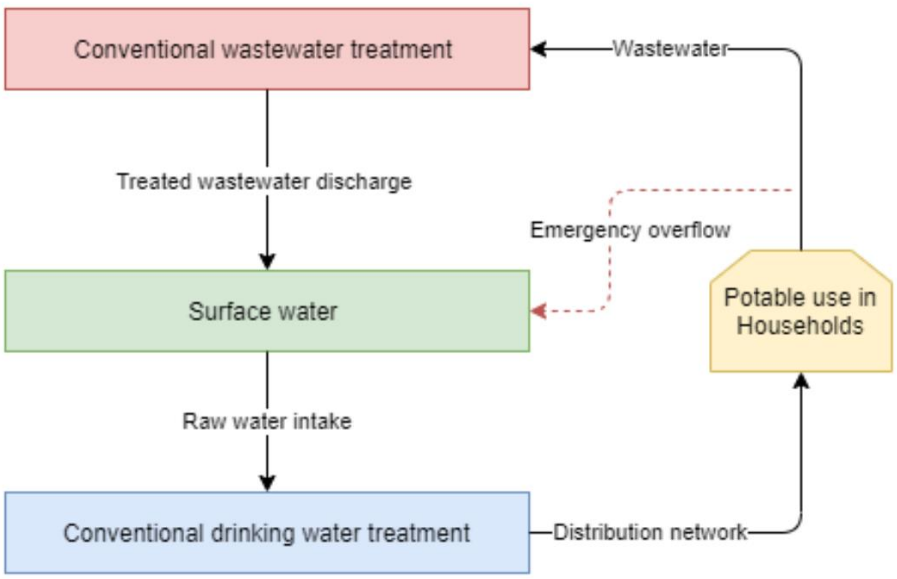

Figure 2 Cycle of de facto water reuse based on Chaudhry et al. (2017)

2.2 Wastewater treatment plants

Conventional wastewater treatment purpose is to remove nitrogen, phosphorus, and organic matter (BOD/COD) i.e., prevent eutrophication and spreading of hazardous compounds into the environment (SEPA, 2008). The conventional plants are not designed for removal of chemicals such as pharmaceuticals and therefore there is a high risk of harmful pharmaceuticals to be expected to be detected in rivers (Archer et al., 2017a). In Sweden for example, there are no restrictions regarding treatment of pharmaceuticals in WWTPs, which makes the discharge of pharmaceutical from WWTPs of a more significant concern than the discharge from pharmaceutical production, since it is strictly regulated in Sweden (Glimstedt et al., 2016). Generally, conventional WWTPs including activated sludge processes or other forms of biological treatment have shown to have an insufficient pharmaceutical removal efficiency ranging from less than 20% to greater than 90% (WHO, 2011b). The variation depends of sludge age, activated sludge tank temperature and hydraulic retention time (WHO, 2011b). Another main reason for inefficient wastewater treatment is inadequate human resources for maintenance and operation of the plants, which have been seen lacking in South Africa (Archer et al., 2017a). In 2008 South African Department of Water and Sanitation (DWS) launched a Green Drop (GD) certification program to evaluate the performance of the country´s wastewater works. If a WWTP fulfill all DWS criteria's regarding design capacity, operational flow relative to plant capacity, compliance/non-compliance of effluent quality being discharged into receiving waters, and compliance/non-compliance of technical skills utilized at the WWTP it will be awarded with green drop status (Archer et al., 2017a). In 2012, 39% of the WWTPs did not meet the DWS criteria, and 18-26% received a critical and high-risk rating. The high amount of WWTPs not meeting the criteria's regarding non-compliance with water quality and service delivery criteria means a risk of harmful chemicals, such as pharmaceuticals, discharging into the environment (Archer et al., 2017a).

2.3 Drinking water treatment plants

Due to insufficient wastewater treatment, pollutants such as pharmaceuticals can reach DWTPs through the surface water when de facto water reuse is occurring. Treatment processes in DWTPs are normally conventional and not specifically designed for pharmaceutical removal, however some treatment may occur (WHO, 2011b). Conventional drinking water plants often consist of mainly two types of processes: separation and disinfection, as showed in Figure 3. According to US EPA (2010) DWTPs typically use coagulation or flocculation and granular filtration to remove colloidal and suspended solids. After solids removal, treated drinking water is disinfected to inactivate pathogens. The removal of pharmaceuticals varies in DWTPs depending on type and structure of the pharmaceutical and the type of drinking water treatment processes used (US EPA, 2010).

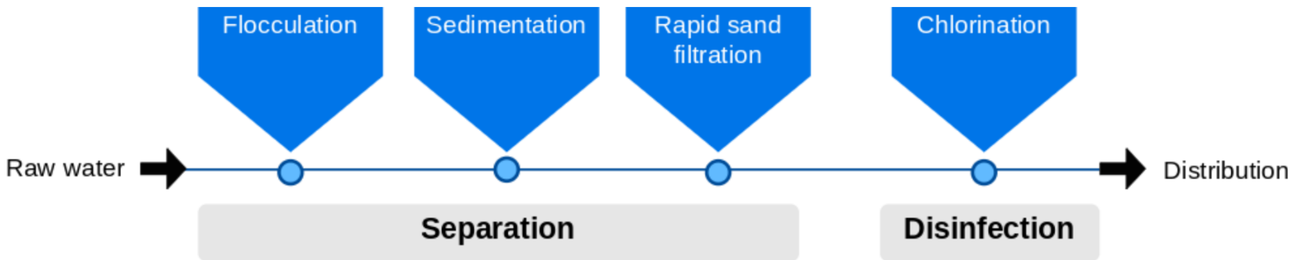

Figure 3 Conventional drinking water treatment processes

2.3.1 Separation in DWTP

Coagulation/flocculation, sedimentation, and filtration

Conventional separation processes in DWTPs is normally coagulation/flocculation, sedimentation and filtration, and occurs to remove pathogens and biological particles (Snyder et al., 2003). Typically, alum, ferric, chloride, and or synthetic polymers is used for coagulation allowing the compounds in the water to precipitate (Snyder et al., 2003). Aggregate particles are called flocculation and improves settling characteristics (Snyder et al., 2003). Conventional treatment plants using coagulation, flocculation and precipitation show a high reduction of pathogens and biological particles (Snyder et al., 2003) but it has been showed to be ineffective of removing pharmaceuticals (Borrull et al., 2021). Depending on the physical and chemical properties of the pharmaceutical some removal may occur through sorption to particles in the separation process (WHO, 2011b). The level of hydrophobicity that is described by octanol-water partition coefficient (log K_{ow}) is highly important. The more hydrophobic the compound is, e.g., the higher log $K_{ow,}$ the higher removal with coagulation (Snyder et al., 2007). However, only the pharmaceuticals with a log K_{ow} higher than five will be removed to a noticeable degree (Vieno et al., 2007). Since the pharmaceuticals generally are ionic, they may in theory adsorb to particles removed in coagulation and sedimentation by electrostatic interactions, though the removal rate is most often negligible (Snyder et al., 2007; Vieno et al., 2007).

Activated carbon

Activated carbon is also a separation process that can be used in DWTPs (US EPA, 2010). Powder activated carbon (PAC), Granular activated carbon (GAC) are different forms of activated carbon and removes contaminants through adsorption (US EPA, 2010). GAC that has biological activity on its surface is referred to as biological active carbon (BAC) and does efficiently remove dissolved organic compounds (DOC) trough degradation (Yapsakli & Çeçen, 2010). BAC filters are known to reduce odour and taste compounds and does not efficiently remove pharmaceuticals (Ullberg et al., 2021a). PAC is mostly added to the raw water before the coagulation, sedimentation and filtration (Snyder et al., 2003) and has a contact time of 1-3 hours before it settles in the sedimentation tank where it is removed (WHO, 2011b). PAC is mainly used to remove pesticides and to improve taste and odour (WHO, 2011b) but has been seen to remove pharmaceuticals if the dose and contact time of PAC is optimised (Snyder et al., 2007). GAC is on the other hand operating as a stationary packed bed or as filters with continuous water flow, contact time of less than 30 minutes and operates for months to years (Snyder et al., 2003). By chemical and physical bounds, dissolved materials are held to the activated carbon surface (US EPA, 2010). GAC has a high removal efficiency of micropollutants for the first's weeks or months, but after that new strong adsorbents can replace the old less strong adsorbed compounds and makes it less efficient. From a study in Sweden it showed that DWTPs with GAC filter had an average removal of 60% of organic micro pollutants (OMP), such as pharmaceuticals, meanwhile DWTPs without GAC filters only reduced 38% of OMPs (Tröger et al., 2020). The older the GAC filter where, the lower removal efficiency occurred: a 12 month old filter or less had up to 92% removal of OMPs, meanwhile an 71 month-old filter only showed removals of 34% of the OMPs (Tröger et al., 2020).

The removal efficiency with activated carbon depends on the properties of the activated carbon such as surface area, pore size distribution and oxygen content (Snyder et al., 2003). Also, the property of the contaminant is important such as the shape, molecular size, charge and hydrophobicity. The hydrophobicity of the compound is the most important mechanism for the removal efficiency, and activated carbon does efficiently remove nonpolar organic compounds (hydrophobic compounds) with a log K_{ow} higher than 2 (Snyder et al., 2003). Polar compounds can be removed depending on the strength of the polar interactions, and ion exchange, but that is hard to predict (Snyder et al., 2003). Large molecule has been seen to have lower removal (Snyder et al., 2007). Overall, the contact time and water quality is essential to achieve efficient removal capacity (Snyder et al., 2007). Natural organic matter (NOM) is also adsorbed to activated carbon and will therefore compete with pharmaceuticals for adsorption, and high content of NOM in the raw water will reduce the removal efficiency of pharmaceuticals (Snyder et al., 2003). Moreover, Snyder et al., (2007) claims that it is critical that the activated carbon not is exhausted since that will result in ineffective removal.

2.3.2 Disinfection in DWTP

As a last step in DWTPs disinfection by chlorine/chloramines or ozonation are commonly used, ozonation is more practiced in Europe and chlorine in the United States and South Africa (Snyder et al., 2003). Another, often used disinfection method is ultraviolet light (UV) (Government of Western Australia, 2016). Ozonation and UV will not be further described since the DWTPs studied only use chlorination as disinfection step. Disinfection with chlorine is a treatment step that is used to inactivate pathogens (US EPA, 2010). Chlorine gas in water is either hypochlorite (OCl-) or hypochlorous acid (HOCl) and occur as “free available” chlorine. Different types and structure are used in DWTPs such as chlorine, chlorate, chloramine and chlorine dioxide (WHO, 2016). Chlorination is an oxidation process, and can therefore also transform organic chemicals, such as pharmaceuticals (Snyder et al., 2009). However, there is a risk that the organic chemicals are transformed into harmful disinfection biproducts (DBP) (US EPA, 2010). It has raised a health concern about the these biproducts since it has carcinogenic effects and other health impacts. DBPs such as Trihalomethanes (THMs) and Halo acetic acid (HAA) are correlated to the influence of de facto water reuse, since the high content of organic matter in wastewater impact the amount of biproducts (Weisman et al., 2019). By lowering the contact time between the organic chemicals and the chlorine can help reduce the transformation of harmful biproducts. The contact time can be reduced by having a coagulant before the chlorination, or reduce the chlorine dose (WHO, 2011a). However, it is a risk of reducing the contact time because the removal of bacteria will be affected. Chlorination can achieve a high removal for some pharmaceuticals depending on chemical structure and treatment conditions such as the oxidant dose and the pH in the water (WHO, 2011b). However, the treatment processes in DWTPs with conventional treatment and chlorination may not remove the pharmaceutical below the detection limit and therefore it might end up in the final drinking water (WHO, 2011b).

2.4 Pharmaceuticals in drinking water

Pharmaceuticals are used for pharmacological effects in both human and veterinary drugs. They can be synthetic or natural chemical and can be found in prescription medicines as well as in over-the-counter drugs (WHO, 2011b). Pharmaceuticals have been detected in the environment for more than 30 years (WHO, 2011b). Human consumption is an important contributor for pharmaceutical to end up in the urban water cycle e.g., wastewater, treated wastewater discharge, surface water and drinking water, and the higher usage, the higher excretion levels, and improper disposal of pharmaceuticals in sewage occurs (WHO, 2011b). One study in the United Kingdom showed that 11.5% of the unwanted pharmaceuticals were flushed down in the sewage, and in Germany a study showed that in total 364 tons of pharmaceuticals were flushed away every year (WHO, 2011b). What type of pharmaceutical that is most detected in water sources depends on and differ from regions because of differences in social, cultural, technical and agricultural factors impacting the surface water (WHO, 2011b). Some studies, mostly on rats and mice have shown reduction in fertility, increasing in the incidence of several cancers, birth defects, embryo disruptions, spontaneous abortions and other physiological disorders have been linked to contaminants in the surface water later used for drinking water (Archer et al., 2017a; Soto & Sonnenschein, 2010).

Pharmaceuticals can enter the environment either as the original substance or as its metabolite, they are often found in trace concentrations since the compounds have gone through metabolism and degradation through natural processes and in wastewater and drinking water treatment processes (WHO, 2011b). Depending on the hydrophobicity, temperature and biodegradability the attenuation of the compound will vary (WHO, 2011b).

The presence of pharmaceuticals in water is not well known since most countries does not have any monitoring programs, and the information available originates from targeted research projects (WHO, 2011b). In developing countries such as South Africa the information is especially lacking (Archer et al., 2017a). However, the usage of pharmaceutical indicate that many pharmaceutical compounds can be detected in the surface waters.

2.4.1 Usage, occurrence, therapeutic and toxicological effects of pharmaceuticals

In this part the usage of carbamazepine, diclofenac and sulfamethoxazole will be presented. Also presented are physical parameters, the therapeutic and toxicological effects as well as the occurrence in water.

Carbamazepine

Carbamazepine is an anticonvulsant medication or drug used to mitigate the amount of electrical signal spread in the brain that causes elliptical seizures (Snyder et al., 2009; The Swedish Association of the Pharmaceuticals Industry, 2020c) Carbamazepine is typically used as one of the most common active substance in treatment of epilepsy and neuropathic pain (The Swedish Association of the Pharmaceuticals Industry, 2020c). It is also used for trigeminal neuralgia, episodes of mania and bipolar 1 disorder, depression, restless legs syndrome and posttraumatic stress disorder (U.S. National Library of Medicine, n.d.). Carbamazepine is a generic medication, listed on WHO's "Essential medicines", and is the 176th most prescribed drug in US 2017 and is prescribed more than three million times (www.clincalc.com).

The treatment with carbamazepine is often chronic medication (The Swedish Association of the Pharmaceuticals Industry, 2020c). The treatment begins with that the patient start with a lower dose, 200 mg per day and extend the dose to the desired therapeutic effect are achieved up to 1200 mg/day for adults, lower doses are recommended for children and infants. About 3% of carbamazepine is excreted unmetabolized from the body (WHO, 2011b). A study in 2017 summarized the detected pharmaceuticals in South African surface waters that was known to the authors, and carbamazepine was detected in levels between 0.1-3.2 µg/l (Archer et al., 2017a). Carbamazepine was shown in drinking water as well at levels of 0.01-0.3 µg/l (Archer et al., 2017a). Comparing the concentration of carbamazepine found in South Africa drinking water and surface water with Swedish water, the concentrations in South Africa is significantly higher, see Table 1 (Karki et al., 2020; Ullberg et al., 2021). Carbamazepine is relatively persistent in the environment (Kumar et al., 2016) and half-life time varies depending on environmental conditions influencing the biodegradation (Bu et al., 2016). The half-life time was 63 days in a lake in Switzerland and 1200 days in a lake in Sweden (Bu et al., 2016). Carbamazepine has a log K_{ow} of 2.45, and the removal during conventional separation process is generally negligible. However, a full scale study of a conventional treatment plant with coagulation, sedimentation and sand filter showed an reduction of -10% to 30% (Ullberg et al., 2021b). The negative removal indicates an desorption of carbamazepine that previously been adsorbed (Ullberg et al., 2021a). Chlorine removes carbamazepine less efficient than other pharmaceuticals, an average of 49% is removed and the removal is highly dependent on the pH (US EPA, 2010). It has been seen that a higher removal occurred when the pH was at 5.5 compared to ambient pH's for carbamazepine, a pH of 7.9-8.5 decreased the removal rate significantly for the compound (Snyder et al., 2007). Reduction of carbamazepine with GAC was reported to be 60-85% (US EPA, 2010), and with PAC 50-80% according to Natural Resource Management Ministerial Council of Australia (NRMMC, 2008).

Several studies have shown developmental and reproductive effects on the fetus both in human and in animals (Bruce et al., 2010; Kumar & Xagoraraki, 2010; USEPA, 2010; Snyder, 2008). According to The Swedish Association of the Pharmaceuticals Industry (2020c) all antileptic medicines prove that the incidents of fetal malformations in women taking the drug are three times higher than in the general populations. Studies on mice, rats and rabbits have shown an embryonic mortality at doses 10-20 times the recommended human dose (www.rxlist.com; The Swedish Association of the Pharmaceuticals Industry 2020c). Evidence of carcinogenicity has been seen in studies on rodents (Bruce et al., 2010). A two-year study on rats exposed of carbamazepine showed an increased incident of tumors but the study did not show any evidence on that his should be connected to the therapeutic dose used for humans (The Swedish Association of the Pharmaceuticals Industry, 2020c).Toxic doses have shown defects and growth inhibition on rats, and another study on mice proved defects of cerebral ventricles during toxic doses from 40 mg/kg (The Swedish Association of the Pharmaceuticals Industry, 2020c).

Diclofenac
Diclofenac is a non-steroidal anti-inflammatory drug (NSAID) most common to treat inflammatory diseases and pain and to lower fever (Snyder et al., 2009; The Swedish Association of the Pharmaceuticals Industry (2020b). Diclofenac is a generic medication and was in United States 2018 the 72th most common prescribed medication with over 11 million prescriptions (www.clincalc.com). Diclofenac is also used as a veterinary drug in cattle and swine (EMEA, 2004). Diclofenac is often used to treat different types of arthritis such as rheumatoid arthritis (The Swedish Association of the Pharmaceuticals Industry, 2020b). It is also used for mild to moderate postoperative or post-traumatic pain, especially when inflammatory also is present, but also used for chronic pain associated with cancer etc. Diclofenac can be combined with other medicines (The Swedish Association of the Pharmaceuticals Industry, 2020b). According to Corrêa et al. (2021) diclofenac was one of the pharmaceuticals included in the first European Union watch list in accordance with Directive 39 of the European Parliament and the Council of the European Union regarding substances in the field of water to have special check and regulations on. The treatment of diclofenac is often taken either for chronic treatment or occasionally when needed (The Swedish Association of the Pharmaceuticals Industry, 2020b). The treatment is recommended to begin with the lowest expected effective dose (therapeutic dose) and is adjusted for chronic treatment to the received effect or potential side effects. The recommended dose for adults are 75-150 mg per day and diclofenac should not be given to children under 18 years according to The Swedish Association of the Pharmaceuticals Industry, (2020b). The treatment should not exceed 12 weeks for the recommended doses. For chronic and long-term treatment, a lower dose per day is recommended (The Swedish Association of the Pharmaceuticals Industry, 2020b). Further, there is of importance of being careful with elderly persons or persons with low body weight, since they have a higher risk of side effects of NSAID and higher possibility to have impaired kidney, heart, or lever function and therefore they should have a lower dose per day. According to Webb et al., (2003) the therapeutic dose for diclofenac is 25 mg/day.

About 15% of the compound diclofenac is excreted from the body (WHO, 2011b). Diclofenac is not as persistent as carbamazepine since it showed low half-life (Bu et al., 2016). The half-life varies from 3 hours in summer temperature and up to 2 days in winter locations (Kumar et al., 2016). Photolysis is the major degradation pathway (Kumar et al., 2016). Diclofenac does not easily attach to particles since it is ionized and is not readily volatilized (Kumar et al., 2016). Another concern is that diclofenac metabolites and their metabolites may have a higher toxicity than the parent compound (Scheurell et al., 2009). In a study from US diclofenac compared to many other pharmaceuticals show results of having a lower frequency of detection in surface water (Corrêa et al., 2021). Overall diclofenac shows a very spread range of concentrations levels found in surface water, a study from 2017 summarizing the pharmaceuticals in South African surface water shows concentrations of 0.3 to 15.6 µg/l (Archer et al., 2017a). Comparing the concentration of diclofenac found in South Africa drinking water and surface water with Swedish waters, the concentration in South Africa is significantly higher, see Table 1 (Archer et al., 2017a; Tröger et al., 2018). Diclofenac has a log-K_{ow} of 4.51 and the removal during conventional treatment may generally be negligible (Vieno et al., 2007;Tröger et al., 2018). Removal of diclofenac in a pilot study with coagulation, flocculation, sedimentation and sand filtration showed a reduction of up to 37% (McKie et al., 2016). Diclofenac is not much reported in drinking water treatment plants for disinfection with chlorine, but treated wastewater effluent diclofenac is treated with an average of 61% in the chlorination process (US EPA, 2010). Diclofenac has been seen to have a high reactivity with chlorine independently of the pH (Snyder et al., 2007). Reduction of diclofenac with GAC was reported to be 69% (Snyder et al., 2007).

According to several studies on animals exposed of diclofenac has shown developmental toxicity effects (Bruce et al., 2010; Snyder, 2008; Pfitzer, 2018). Also, The Swedish Association of the Pharmaceuticals Industry (2020b) show that high exposure of diclofenac impacts the inhibition of prostaglandin that in turn may adversely affect pregnancy or embryonal of fetal development, such as miscarriage, gastroschisis and heart malformation during early pregnancy. Hence, the pharmaceutical is not recommended to pregnant women, especially not in late pregnancy (www.rxlist.com). The study show that the risk increases with increased dose and duration of treatment. Another study of The Swedish Association of the Pharmaceuticals Industry (2020b) in epidemiological data show that high doses (150mg/day) together with long duration of treatment increase the risk of arterial thrombotic events such as myocardial infarction or stroke.

Sulfamethoxazole
Sulfamethoxazole is an antibacterial sulfa drug (antibiotic) used for bacterial infections (Schwab et al., 2005). The pharmaceutical is used as a human and veterinary drug (Kumari & Kumar, 2020). One of the most common usage are to treat urinary tract infections, bronchitis and prostatitis and the antibiotic are also effective on different bacteria such as E.coli (www.go.drugbank.com). The drug is often used in combination with trimethoprim (The Swedish Association of the Pharmaceuticals Industry, 2020a) and the combination is on the WHO’s list of “Essential medicines” as a first choice for treatment for urinary tract infections (Friesen, 2003). The combination of sulfamethoxazole and trimethoprim was prescribed more than 11 million times in US 2015 (www.clincalc.com).

The treatment of sulfamethoxazole is often prescribed over a short time and are recommended to cease after 2 days of no symptoms and the usage should not extended for more than 7 days (The Swedish Association of the Pharmaceuticals Industry, 2020a). According to Webb et al., 2003 the minimum therapeutic dose is 800 mg/day. A lower dose is recommended to patients with impaired kidney functions and sulfamethoxazole should not be given to infant below 6 weeks (The Swedish Association of the Pharmaceuticals Industry, 2020a). Further, the use of high doses or for extended periods of time may cause bone marrow depression. About 15-25% of sulfamethoxazole is excreted unchanged from the human body (Patrolecco et al., 2018). Sulfamethoxazole have been found in high levels and this may be because of it is strongly resistance to biodegradation in WWTPs (Pérez et al., 2005). The half-life is 10 hours according to (Kumari & Kumar, 2020). Exposure of antibiotics in the environment can worsen the situation and challenges with antibiotic resistance (WHO, 2014). A study summarized 2017 detected pharmaceuticals in South African surface waters, and sulfamethoxazole was detected in a spread range from 0.6 to 5.3 µg/l (Archer et al., 2017a). Comparing the concentration of sulfamethoxazole found in South Africa drinking water and surface water with Swedish water, the concentrations in South Africa is significantly higher, see table 1 (Paíga et al., 2016). Sulfamethoxazole has a low log-K_{ow} of 0.89 and therefore a polar compound (Snyder et al., 2009). For coagulation/flocculation poor removal of sulfamethoxazole was seen, with up to 20% removal (Snyder et al., 2007). On the other hand, disinfection with chlorine show to remove sulfamethoxazole on an average of 69% (US EPA, 2010). Sulfamethoxazole is a polar compound and is therefore expected to be less efficiently removed by GAC than carbamazepine and diclofenac, from a study it showed to be reduced with average eof 42% (Snyder et al., 2009; US EPA, 2010). RxList (www.rxlist.com) present that sulfamethoxazole have shown teratological effects on rats, which means that the development of a fetus is disturb (at a dosage of 533 mg/kg body weight) and cleft palates in rats (at doses of 512 mg/kg body weight). Further, studies on rabbits show increased maternal mortality on rabbits at a dose of 150mg/kg/day. Some studies on rats show cancerogenic effects such as thyroid tumors caused by of sulfamethoxazole (Pfitzer, 2018; Schriks et al., 2010; Schwab et al., 2005; Swarm et al., 1973).

Table 1 Pharmaceutical’s properties, usage, effects and occurrence

Parameters	Carbamazepine	Diclofenac	Sulfamethoxazole
Drug class	Anticonvulsants	NSAID	Antibiotic
Molecule	$C_{15}H_{12}N_2O$	$C_{14}H_{11}Cl_2NO_2$	$C_{10}H_{11}N_3O_3S$
Pharmacological use	Epilepsy, neuropathic pain, trigeminal neuralgia, episodes of mania, bipolar 1 disorder, depression, restless legs syndrome, posttraumatic stress disorder (*; (U.S. National Library of Medicine, n.d.)	Inflammatory diseases and pain, lower fever, different types of arthritis, post-traumatic pain, chronic pain **	Urinary tract infections, bronchitis and prostatitis and effective to different bacteria such as E.coli ***
Consumer age	All ages*	Not under 18**	Not under 6 weeks***
Generic medication	Yes	Yes	Yes

Veterinary drug	No (NRMMC, 2008)	Yes (EMEA, 2004)	Yes (EMEA, 1997)
Period of treatment	Often chronic usage *	When needed, or lower dose for chronic use **	When needed, Up to 7 days for treatment ***
Minimum therapeutic dose	200 mg/day *	25 mg/day (Webb et al., 2003)	800 mg/day (Webb et al., 2003)
Health effects			
Toxic effects	Developmental, cancerogenic (Bruce et al., 2010)	Developmental (Bruce et al., 2010)	Developmental, (Bruce et al., 2010) cancerogenic (Swarm et al., 1973)
Physical parameters			
log K_{ow}	2.45 (Snyder et.al., 2009)	4.51 (Snyder et.al., 2009)	0.89 (Snyder et.al., 2009)
ion mode	+ (Tröger et.al.,2018)	- (Tröger et.al.,2018)	+ (Tröger et.al.,2018)
Half-life	63-1200 days (Bu et al., 2016)	3 hours – 2 days (Kumar et al., 2016)	10 hours (Kumari & Kumar, 2020)
Excretion level	3% (WHO, 2011b)	15% (WHO, 2011b)	15-25% (Patrolecco et al., 2018)
Occurrence level			
Concentration in surface water in South Africa	0.1-3.2 µg/l (Archer et.al., 2017a)	0.3-15.6 µg/l (Archer et.al., 2017a)	0.6-5.3 µg/l (Archer et.al., 2017a)
Concentration in final drinking water in South Africa	0.01-0.3 µg/l (Archer et.al., 2017a)	Not found	Not found
Concentration in surface raw water in Sweden or Portugal	0.00008-0.008 µg/l in 12 raw water intakes in Sweden (Karki et al., 2020); 0.0056-0.0093 µg/l in Görvälvn DWTPs raw water (Ullberg et al., 2021a). 0.0018 µg/l intake in Göta älv (Tröger et.al.,2018)	0.0083 µg/l by DWTP intake in Göta älv, Sweden (along Göta älv the concentration was 0.0073-0.037 µg/l) (Tröger et.al.,2018)	0.043 µg/l in Lis River, Portugal (Paíga et al., 2016)
Concentration in final drinking water using surface water in Sweden	0.0002-0.0075 µg/l (median=0.0006 µg/l (Karki et al., 2020)	0.0098-0.01 µg/l (Tröger et.al.,2018)	Not found

*(The Swedish Association of the Pharmaceuticals Industry, 2020c)
**(The Swedish Association of the Pharmaceuticals Industry, 2020b)
***(The Swedish Association of the Pharmaceuticals Industry, 2020a)

2.5 Human health risks of exposure to pharmaceuticals in drinking water

In this part earlier studies on human health risk due to exposure of pharmaceuticals in drinking water will be presented. Different approaches of risk assessments and analysis on pharmaceutical toxicological and therapeutic effects from Germany, the US and Australia will be presented.

There is a concern regarding pharmaceuticals that have been detected in water sources used for drinking water and what potential health-related risks and impact it might have, not only among the citizens but also among the drinking water regulators, government agencies and water suppliers (Kumari & Kumar, 2020). According to US EPA (2010) the knowledge about long-term effects and potential risk of chronic exposure over a time is poor. The risk of long-term exposure of pharmaceuticals is not fully regularly investigated or monitored and therefore, the fate and the human toxicological effects are in many cases still unknown (Parlapiano et al., 2021). Some pharmaceuticals that potentially could cause harm in the environment and human body are according to USEPA (2010) and Corrêa et al., (2021) often on a so-called "watch lists" in the aim to regulate their usage and monitor the frequency of occurrence, toxicity, and potential harmful effects on human and other organisms. The main challenges in pharmaceutical risks in drinking water is the limited occurrence data that is available, the huge range in pharmaceutical used, variation in individual usage between countries and the technical limitations to assess risk of chronic exposure to low-dose of pharmaceuticals and mixtures (WHO, 2011b). However, there are a few scientific risk assessments conducted of exposure to pharmaceuticals in drinking water and their results will be presented below (WHO, 2011b). First, common approaches of health risk assessments will be presented.

2.5.1 Common approach of health risk assessment

A quantitative health risk assessment is often divided in four steps according to Natural Resource Management Ministerial Council, Australia (NRMMC, 2008). The four steps are: hazard identification, exposure assessment, dose-response determination and risk characterizations. Exposure assessment consider the exposure routes (through drinking water or via food for example) and the exposed population. The third step, dose-response determination considers the level where there is a response, or effect in the population exposed is determined, and finally, the risk characterization where the risk is characterized, which can vary depending on the type of hazards (NRMMC, 2008). A quantitative risk assessment means that it is based on models for combining and structuring events and gives an estimation of risk levels (Rosén et al., 2008). The four steps are further presented below.

Hazard identification
The first step of a health risk assessment is to recognize what hazards that do exist and define the hazards characteristics (NRMMC, 2008). A common method to identify potential hazards are through brainstorming (group members contribute with ideas of hazards spontaneously), experience from the past e.g., detected pharmaceuticals in drinking water that have been shown in the past and that is known to have toxicological effect on humans and animals can be identified as hazards (Rosén et al., 2008). Also "what if" analysis is method for hazard identification which also is a brainstorming method where the team asks for example, "what if the pump inlet pipe is blocked?" and from that, hazards can be identified, or a method for identifying risks is to do a checklist e.g., a list of items that can cause a hazard, or scenarios that can cause a hazard such as failure in the technical system, power failure or sabotage (Rosén et al., 2008).

Exposure assessment
The exposure assessment is the estimation of the magnitude of for example, pharmaceuticals exposed to a certain population by a specific exposure route e.g., through drinking water and to a specific population (NRMMC, 2008). Data on concentration of pharmaceuticals in final drinking water can be insufficient, and Schwab et.al. (2005) assumed that the detected levels in surface water was equal to the concentrations in drinking water, e.g., no removal or degradation of the pharmaceuticals was assumed to occur, meanwhile Snyder (2008) used the maximum detected levels of pharmaceuticals in finished drinking water in the United States in the exposure assessment. Depending on the exposed population, the ingestion of drinking water varies per body weight, and that in turn leads to that the consumption of pharmaceutical will vary e.g., the more a person drink the more it will be exposed to the hazard. In US EPA exposure handbook ingestion rates are presented for all ages in the USA which can be used in the exposure assessment (US EPA, 2019). Also default values can be used in the exposure handbook recommended by WHO (2011a) assuming adults weighing 60kg and drinking 2 l/day.

Dose-response determination
The dose-response determination for a chemical, such as a pharmaceutical, is done by establish a daily acceptable daily intake (ADI) of a pharmaceutical per kilogram body weight (WHO, 2011b). ADI of a pharmaceutical compound is the amount of acceptable intake where no adverse health effects occur in the studied population, including sensitive sub-populations (Schwab et al., 2005). The ADI is calculated by applying uncertainty factors to a chosen Point of Departure (PoD) level from animal or human toxicological

studies (Schwab et al., 2005). The chosen PoD for a pharmaceutical is preferable the highest dose exposed to an animal or human resulting in no observed effects (no observed effect level, NOEL), or the highest dose resulting in no adverse observed effect (no observed adverse level, NOAEL) (Schwab et al., 2005). Human studies are limited and the most frequently studies used are laboratory studies on animals (NRMMC, 2008). Though, for many pharmaceuticals there is no NOEL or NOAEL and therefore the lowest dose where there is an observable effect is chosen (lowest observed effect level, LOEL), or the lowest dose where there is an observable adverse effect (lowest observed adverse effect level, LOAEL) (Schwab et al., 2005). ADI can also be calculated by applying uncertainty factors to the minimum therapeutic dose (MTD) on humans (NRMMC, 2008; Schwab et al., 2005; Webb et al., 2003). The minimum therapeutic dose, are often significantly lower than the dose that can, in very few cases, cause unacceptable adverse effect (WHO, 2011b).

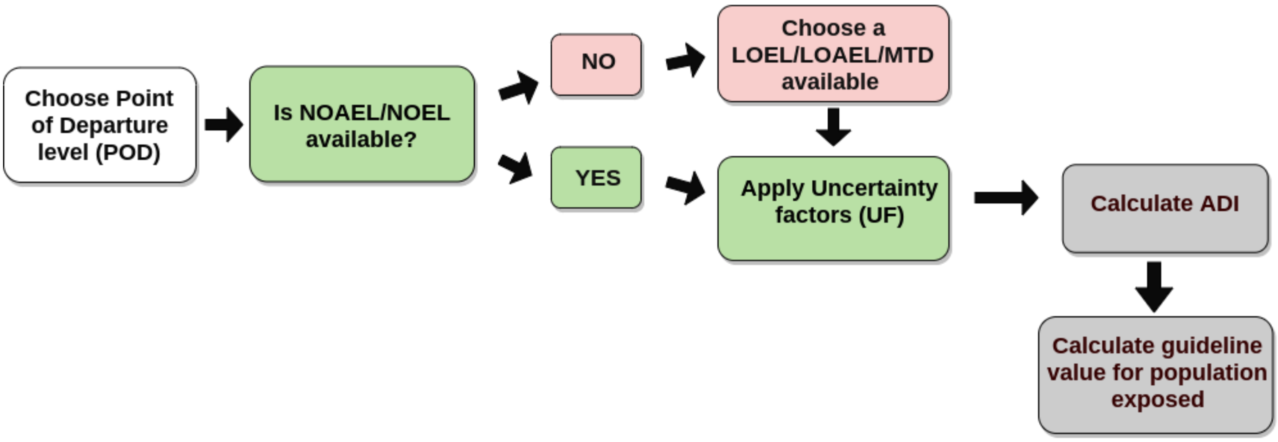

Figure 4 Schematic figure for the process of establishing an ADI and guideline value for pharmaceuticals

When calculating ADI different uncertainty factor guidance are available. Uncertainty factors are generally applied to take into account variations in interspecies and intra-species, limited experimental data, restricted period of experiments, and if NOAEL/NOEL is available or not (Schwab et al., 2005). Uncertainty factor are applied to the PoD to reduce the dose to a level where there is reasonable certainty that there will not be an effect in humans (Schwab et al., 2005). A study by Schwab et.al. (2005) applied uncertainty factors to the minimum therapeutic dose for 26 pharmaceuticals varying from 9 to 200. Another uncertainty factor guidance is for minimum therapeutic doses, with conservative uncertainty factors of 1000 taking account for interspecies variation, protection of subgroups and the minimum therapeutic dose not being a no effect level (NRMMC, 2008)

See Figure 4 for the procedure described above in a schematic figure. ADIs established in different studies (Bruce et al., 2010; EMEA, 2004; NRMMC, 2008; Schwab et al., 2005; Snyder, 2008) varies depending on the toxicological or therapeutic study used for PoD, it can be a therapeutic study e.g., using minimum therapeutic dose or LOEL (NRMMC, 2008; EMEA, 2004), or a study with cancerogenic end point (Snyder, 2008; Schwab et.al., 2005; Kumar & Kumari, 2020) as well as a study with fetal effects e.g., developmental end point (Bruce et al., 2010; EMEA, 2004; Snyder, 2008). Also, the uncertainty factors chosen to apply to the PoD varies between studies which affects the ADI (Bruce et al., 2010; EMEA, 2004; NRMMC, 2008; Schwab et al., 2005; Snyder, 2008).

The ADI established can thereafter be used to calculate a provisional guideline value by taking body weight and liter of water consumed per day per person in the exposed population into consideration (Kumar & Xagoraraki, 2010). The guideline value is lower for children since they consume more water per kilogram body weight (Schwab et al., 2005).

Risk characterization
For chemicals such as pharmaceuticals there is not sufficient data to quantify the impact of the illness caused by the substance in for example Disability-Adjusted life years (DALY), so instead the quantitative health risk assessment is often a comparison between the calculated guideline value and the pharmaceutical exposure dose (NRMMC, 2008). Hazard quotient is one way of presenting the risk (also denoted as margin of exposure), which is the ratio between the exposure dose and the calculated guideline value (Snyder, 2008). Hazard quotient exceeding one (1) indicate that the exposure concentration can pose a risk to human health. However, the pharmaceuticals commonly used in the society need a significant margin of safety (WHO, 2011b).

2.5.2 Results from earlier health risk assessments of carbamazepine, diclofenac, and sulfamethoxazole

In this part, earlier health risk assessments and their results will be presented. In general, no human health risk due to exposure of carbamazepine, diclofenac or sulfamethoxazole have showed a human health risk in any of the studies that have been found.

Snyder (2008) did a human health risk assessment on carbamazepine, diclofenac and sulfamethoxazole among other pharmaceuticals. Snyder (2008) used a Point of Departure (PoD) that caused cancerogenic and developmental end points on rats giving a guideline value (denoted as drinking water equivalent level, DWEL) of carbamazepine, diclofenac and sulfamethoxazole of 10 µg/l, 48 µg/l respectively 8,400 µg/l. These levels were well above the maximum detected concentrations in final drinking water of 0.018 µg/l, 0.00025 µg/l respectively 0.003 µg/l, and concluded that there is unlikely that pharmaceutical pose a significant threat towards human health through exposure via drinking water. The margin of exposure was 0.0018 for carbamazepine, $52 \cdot 10^{-7}$ for diclofenac respectively $3.6 \cdot 10^{-7}$ for sulfamethoxazole (Snyder, 2008).

Schwab et.al. (2005) did a human health risk assessment on sulfamethoxazole among other pharmaceuticals. Schwab et.al. (2005) used a PoD for the calculation of a guideline value for sulfamethoxazole, that caused thyroid tumor as the toxicological end point. From the PoD a guideline value was developed (denoted as predicted no effect concentration, PNEC which also took account for 350 days per year of exposure to the pharmaceutical during 30 years for adults and 6 years for children) in drinking water. PNEC for children was calculated to 1,900 µg/l in the study. The exposure concentration of sulfamethoxazole was assumed to be equal to the maximum concentration in surface water of 1.9 µg/l, which gave a margin of exposure (denoted as drinking water ratio) of 0.003 indicating no human health risk for the exposed population in the US (Schwab et al., 2005). Further, the same study also predicted a concentration in drinking water through a model and assumed a low flow in the river causing a higher predicted concentration of 8.5 µg/l in final drinking water, which gave a margin of exposure of 0.0045.

Natural Resource Management Ministerial (NRMMC) established guideline values for carbamazepine based on therapeutic doses to be 100 µg/l, for diclofenac based on animal studies to be 1.8 µg/l and for sulfamethoxazole based the lowest ADI for sulfonamides to be 35 µg/l (NRMMC, 2008). There was no risk for human health impact seen, when assuming the concentrations that the population was exposed to was equal to the concentrations detected in secondary treated sewage of 27 µg/l for carbamazepine, 0.81 µg/l for diclofenac respectively 1.9 µg/l for sulfamethoxazole (NRMMC, 2008). The margin of exposure was 0.27 for carbamazepine, 0.45 for diclofenac and 0.05 for sulfamethoxazole (NRMMC, 2008).

Schwab et.al. (2005) state that quantity of pharmaceutical found in the surface waters is highly correlated to its potency. If higher dose is required for therapeutic effect, higher volumes of the pharmaceutical will be found in the water, but it will not reach the therapeutic doses. This means that when the ADI is based on the therapeutic effect, the ADI is also correlated to the quantity in the water, meaning that the higher volumes found in the water, the higher ADI is established which leads to that the concentration of a pharmaceutical found in water will most likely not be a risk for human health (Schwab et al., 2005).

2.5.3 Sensitivity analysis of health risk assessment

Kumar & Xagoraraki (2010) and Kumar et.al. (2020) have conducted sensitivity analyses of carbamazepine respectively sulfamethoxazole. They used variations of ADI and guidelines values calculated in different studies, using different uncertainty factors applied and different PoD levels from animal, studies either toxicological studies or therapeutic studies chosen. The sensitivity analysis of the hazard quotient of carbamazepine, showed that ADI was the main contributor to the variance in the result of the hazard quotient. The guideline value used for carbamazepine (denoted as ADI-equivalent drinking water level) was 350-3333 µg/l. The study concluded that further research needs to be done to standardize use of ADI values to reduce the variation of result in risk assessment (Kumar & Xagoraraki, 2010). However, no health risk was seen of exposure of carbamazepine, with a hazard quotient (99th percentile) for both children and adults to be $1.23 \cdot 10^{-4}$ (Kumar & Xagoraraki, 2010). The risk assessment on sulfamethoxazole showed that the concentration was the main contributor to the variation of the hazard quotient, and ADI came on second place (Kumari & Kumar, 2020). For sulfamethoxazole no human health risk was seen, and resulted in a hazard quotient (95th percentile) of $1.09 \cdot 10^{-2}$ for children and $2.28 \cdot 10^{-4}$ for adults (Kumari & Kumar, 2020).

2.5.4 Comparing exposure dose with minimum therapeutic dose

Another approach of risk assessment is to compare the exposure dose of pharmaceuticals via drinking water to the recommended therapeutic dose, or the minimum therapeutic dose (MTD) which has been done by Webb et.al. (2003). The MTD is normally below the dose where an adverse effect has been observed in animals or humans (WHO, 2011b). The study was conducted in Germany analysing the exposure of diclofenac, carbamazepine and sulfamethoxazole among other pharmaceuticals, during a lifetime (25 550 days) for a person of 70 kg, consuming 2 l/day (Webb et al., 2003). The study used the maximum detected concentration in drinking water, 0.06 µg/l for carbamazepine, 0.006 µg/ l for diclofenac, and 0.040 µg/l for sulfamethoxazole and the daily intake was at least 1,000,000 times lower than the therapeutic dose for the three compounds. The total ingested concentration of diclofenac, carbamazepine and sulfamethoxazole during a lifetime was only 0.13%-1.23% of the recommended therapeutic dose (Webb et al., 2003).

2.6 Perception of de facto water reuse among people

In the following section a wider background of literature on public perception of water reuse will be presented. Different factors impacting the acceptance or rejection of the concept have been explored.

2.6.1 Disgust and "yuck"-factor

When implementing water reuse programs and projects or implementing water reclamation plants a rejection among the public for the proposed action have been showed (Garcia-Cuerva et al., 2016). The perception of water reuse, and not least the "yuck"-factor is a major barrier for implementation. The yuck factor is a psychological variable, and it describes the first feeling of instinctive disgust associated with getting in contact with treated and recycled sewage (Garcia-Cuerva et al., 2016). Further, Garcia-Cuerva et al., (2016) describes that in a psychological approach, this disgustness in associated drinking water treated from sewage could lead to relieving a feeling of fear of exposure and contact with contaminated and unsafe water. According to (Fielding et al., 2019) disgusting object could also be linked and associated with contagions. Studies of Rozin et al. (1986) have been doing research and defined contagion as the idea that everything that get in contact with something contaminated will also be contaminated.

Several studies (Fielding et al., 2019; Garcia-Cuerva et al., 2016; Swartz et al., 2018) referring to and reporting similar results among water reuse associated with disgust. One specific study in Australia points out that recycled and reused water is judged as disgusting and repugnant by almost a third of the citizen (Dolnicar & Schäfer, 2009). The authors (Fielding et al., 2019; Garcia-Cuerva et al., 2016; Swartz et al., 2018) claims that one significant potentially explanation of people's rejection towards water reuse is this yuck-factor and the associated disgust of getting in contact or drink reused water. Overall, this perception and feeling of disgust are a huge barrier towards water reuse projects (Snyder, 2008).

2.6.2 Non-contact or contact uses and potable use

The use of the final water (irrigation, toilet flushing, potable usage etc.) have been discussed in the research about the public's acceptance of water reuse as an option for water scarcity. The research points out different approaches and perceptions towards water reuse when people have been asked if they could accept water reuse as an alternative water source (Garcia-Cuerva et al., 2016). Overall, people's acceptance and support of non-contactable uses such firefighting, use in industry, car washing, sidewalk etc. was showed to be supported widely (Friedler et al., 2006).

Several studies have proved that the uses of final water that involve high human exposure and contact have typically less acceptance than the use that involve less or low levels of human contact (Alhumoud & Madzikanda, 2010; Chen et al., 2015; Garcia-Cuerva et al., 2016; Haldar et al., 2021; S. Dolnicar & Hurlimann, 2009) In the survey of Friedler et al., (2006) acceptance of different types of uses was investigated, from non-contactable (firefighting etc.), low-contact (toilet flushing etc.), medium-contactable (shower etc.) and high-contact e.g., potable use. About 40 studies have showed that acceptance of recycled wastewater drops with increasing human contact (Fielding et al., 2019). Overall, any human contact or indirect contact, such as gardening, irrigation, agriculture with reused water showed a lower acceptance and bigger rejection, and potable use had the lowest acceptance. In the 40 studies people were also asked if they would accept reused water for potable uses, with a result that differed between total 3.6% to 72%. Further, low acceptance of water reuse for potable uses could be a huge barrier and need to be taking into consideration when implementing water reuse projects, campaigns and programs (Snyder, 2008).

2.6.3 Health risk perceptions and public knowledge of risks

Awareness and the concern about health impact caused by contaminated drinking water is one of the most important factors connected to water reuse, according to several studies (Alhumoud & Madzikanda, 2010; Chen et al., 2015; Friedler et al., 2006; Garcia-Cuerva et al., 2016). If the safety of clean drinking water could be guaranteed, the acceptance of water reuse would be spread and most people would accept water reuse as an option for drinking water (Fielding et al., 2019; Jeffrey & Jefferson, 2003). Fielding et al. (2019) mentioned studies proving that health risk perception is a major source of concern and that it is a link between social acceptance of drinking reused water and some studies shows up to 92% of people concerned of health-related risks. Alhumoud & Madzikanda (2010) state that only 10% of the people asked in a survey only used tap water for drinking water due to the fear of health risks, most of the people used a mix of bottle water and tap water, and 34 % only used bottle water for drinking water. Upon this Dolnicar & Schäfer (2009) and Water research commission (2018) describes that many people express that they miss information and available research from scientist that the water is safe to drink.

General risk perceptions, trust, fairness, social norms and influence together with science and technology and knowledge on the topic have been showed to be important factors. Chen et al., (2015) points out that risk control is essential in the implementation and management of water reuse programs in the aim to get all stakeholders involved, in the aim to overcome the public health and environmental pollution risks associated with reused water. Also, Fielding et al. (2019) claims that stakeholder analysis is of high importance to get a range and understanding of what health risks associated with contaminated drinking water and other concerns that have appeared among the public. Stakeholders get information from different sources such as water suppliers, academic researchers, regulators and general information from different communities. These different sources spreading information about potential risks and heath impact is a major factor influencing people's acceptance or rejection of water reuse. Garcia-Cuerva et al. (2016) mentioned that the lack of knowledge of the public can be a reason for people's resistance associated with health hazards. According to Fielding & Roiko (2014) it could be advantage and effective in water reuse programs to try to spread short information about water reuse and the health concern in water reuse in the aim to tackle the worst health prejudices.

2.6.4 Knowledge sharing and trust in authorities and technologies

One barrier of water reuse project and reclamation programs are the lack of knowledge and information sharing among the people (Fielding et al., 2019). The information about the concept of a technology and issues regarding the technologies will result in a higher acceptance influenced of the "information-deficit approach" (public scepticism and hostility based on lack of understanding, as a result of lack of information). Hence, several studies prove that publics knowledge and information regarding water reuse and treatment technologies are very low (Chen et al., 2015; Fielding et al., 2019; Haldar et al., 2021). Also, Rice et al. (2016) confirm this and highlights that a respondent with knowledge of the concept water reuse are 10 times more likely to accept using reused water for potable uses. It has also been shown that many people express a need of knowledge and understanding about water reuse, and the public's involvement are essential to take into considerations in implementations programs for water reuse projects (Chen et al., 2015; Fielding & Roiko, 2014). Further, Fielding et al. (2019) describe that especially a desire of information needed of water treatment processes are required to support water reuse. On the other hand, in Windhoek, Namibia a survey on their reclamation plant was conducted, and the majority of the drinking water consumers were very satisfied with their drinking water but only a minority knew that it ordinates from reused water (Fielding et al., 2019). Further Chen et al. (2015) present results on the publics knowledge of the concept water reuse, 12% "have no idea", 31% "have heard of it" and 51% "know a little". Several studies have investigated the potential link and relationship between self-reported knowledge of water reuse and acceptance and Dolnicar & Hurlimann (2009) raised an interesting and maybe provocative question: Is it better to avoid public consultation in introducing water from alternative sources?

The level of information and knowledge among people could affect the level of trust in science and technologies as well as in trust in authorities (Fielding et al., 2019). Trust or distrust for authorities working with water such as municipalities or other water suppliers together with the government play an important role of acceptance (Haldar et al., 2021). Moreover, trust have been proved to be an issue in one survey of Dolnicar et al. (2014) describing that more than 40% of the respondents are unsure that providers can be trusted to ensure drinking water from water reuse of safe quality. According to another study showing similar results, Dolnicar & Hurlimann (2009) mean that many citizens lack scientific evidence that the water is safe to drink. On the same topic, Haldar et al. (2021) investigate institutional challenges and stakeholder's perception and claim that trust in authorities and their ability to manage risks is a critical factor connected to acceptance of water reuse.

Further, Fielding et al. (2019) describes the awareness of reliability of technology and the management of the schemes. Potential issues and failures such as system break down together with the concern about the risk arising from human error are also mentioned as important factors. Also, the maintenance and operations of wastewater treatment are of highly importance, according to Haldar et al. (2021) rules and regulations on wastewater discharge are only partially enforced and overall, the governments organisations and intuitions sometimes lack of proper operations together with very low citizens involvement. Upon this, Chaudhry et al. (2017) highlight the concern about reliability on pathogen removal in water reuse systems as critical. People's overall perception and belief and comfort in science and technology may increase the acceptance of water reuse for potable uses (Fielding et al., 2019). According to Water research commission, (2018) the most of peoples concern on water reuse and health related risks are based on different factors such as their owns lack of knowledge, lack of capacity and trust to municipalities and operations together with helplessness in that there is no other available water resource.

2.6.5 Socio-economic and demographic links

Overall, social norms, behaviours and what is accepted in the society influence other group members attitude, approaches, and behaviour (Fielding et al., 2019). One example of this is that people tend to be more open for reused water if they read or are aware of the others who use it (Chen et al., 2015). According to Fielding et al. (2019) some studies state that the perceptions of others levels of support of water reuse often was based on or reflected in their own level of support, those who are supportive think that other also are supportive, and those who do reject it think that others would also reject it. The authors describe those opponents of water reuse could belief that others in the region share their perception even if it not the actual case, if data is checked. One explanation of this could be the cognitive bias, so called false consensus effect, when people tend to use their own opinions to draw conclusions of others perception and behaviours (Fielding et al., 2019).

Dolnicar & Hurlimann (2009) present that friends and family are more likely to influence the level of support and the overall behaviour, much more than expert or scientist etc, which could be a great barrier for water reuse. Many studies have researched the area of potential links between socio-economic and demographic background with acceptance of water reuse, showing conflicting results (Haldar et al., 2021). In many studies the effects of sociodemographic variables put in relation to the findings show no significant effect across the studies, on the same time, other studies present same factors studied impacting on a large scale. Haldar et al. (2021) express a potential explanation that the socio-demographic variables are often investigated in isolation and need to be put in a social, cultural and geographic context in the aim to conduct appropriate findings. On the other hand, Dolnicar & Hurlimann (2009) describe in their study that the most frequently found factor to be associated with acceptance of water reuse was education level. These results were strengthened of Haldar et al. (2021) showing that education together with socio-economic standard such as family income, house structure type etc play an important role in level of acceptance. Chen et al. (2015) study also state that occupation and education are significant factors impacting the perception of water reuse and the overall result prove that their perception was influenced by these social-economic attributes. Also, Garcia-Cuerva et al. (2016) claims that income and education influence the level of acceptance of water reuse significantly, but also claims that race and ethnicity was correlated to the support of reused water.

2.6.6 Positive perception and motivation for water reuse

Acceptance and positive perception have been seen to be higher in regions experiencing water shortage (Garcia-Cuerva et al., 2016). The authors present that people living in regions with widely spread drought and increasing water issues the acceptance of reused water may be influenced and underpinned of a motivation to deal with the critical water situation. Studies have investigated the accept of reused water if no other source is available and showed that people may feel inevitability or a belief that it can support or solve the water scarcity and therefore, they are more willing to drink reused water (Dolnicar & Hurlimann, 2009). Hence, the motivation or acceptance of water reuse have a higher support in this proposition. The study of Dolnicar & Hurlimann (2009) presented the opposite a typical result of many other studies on the acceptance of water reuse as drinking water, that the majority of all respondents was willing to drink water from alternative sources such as water reuse, if necessary, when no other sources are available.

According to many people showing support in the environment gain of saving water and express motivation in doing something environmentally friendly. Interviews have proved that many people express feelings of understanding of the increasing water scarcity situation worldwide (Haldar et al., 2021). People could therefore tend to be motivated to save water and therefore also more open to use and accept alternative sources for drinking water to overcome the water scarcity in their region (Alhumoud & Madzikanda, 2010; Dolnicar & Schäfer, 2009). This could lead to a great support in implementation programs for water reuse projects. According to Alhumoud & Madzikanda (2010) many people showing support in the environmental gain of saving water and express motivation in doing something environmentally friendly.

3 MATERIAL AND METHOD

The chapter consists of two parts: Part 1 – case study of Berg River creating a QCRA-model including hazard identification, exposure assessment, dose-response and risk characterisation and, Part 2 - interview study of the perception among the public using de facto water reuse.

3.1 Case study: The Berg River

This part describes the drinking water plants with treatment processes operating along Berg River as well as the wastewater plants affecting the raw water quality in the Berg River. The focus will be on two drinking water treatment plants, Withoogte and Piketberg that will be presented more in detail.

3.1.1 Raw water quality in Berg River

Berg River in Western Cape is experiencing a severe drought that affects the quality and quantity of the water (Swartz et al., 2019). Berg River is affected by five WWTP discharge upstream the three DWTP's raw water intake, see Figure 5. The WWTPs together have a design capacity of 55 000 m^3/day (55 ML/day) which means that Berg River is receiving up to 55 000 m^3 of wastewater per day (Swartz et al., 2019). Above that, there is two WWTP of a design capacity of about 4 ML/day discharging into tributaries to Berg River upstream the DWTPs. In 2017 there was a severe drought in South Africa causing a low natural flow in Berg River. At that time, the river water at the raw water intakes to Withoogte and Piketberg contained up to 99% treated wastewater in certain sections of the river at its worst case in 2017 (during the middle of the severe droughts). The wastewater content in Berg River has been measured between 2016-2018, and in 2016 the highest wastewater content was 46% and in 2018 it was 51% (Swartz et al., 2019). Raw water from Berg River used in DWTPs by Berg River is therefore unintendedly reusing wastewater (de facto water reuse) due to the high content of treated wastewater during dry periods. During one of the sampling campaigns, some pharmaceuticals was detected in the Berg River (Swartz et al., 2019). During the sampling periods the effluent from WWTPs discharging to Berg River ranged between: 0.2 µg/l – 2.1 µg/l of carbamazepine, 0.06 µg/l – 0.5 µg/l of diclofenac and 0.02 µg/l – 6.4 µg/l of sulfamethoxazole. Overall, the WWTPs along Berg River are mainly conventional WWTPs (C. Swartz, personal communication, April 09, 2021).

Berg River is compared to many other rivers in South Africa slightly polluted, there are many other rivers that are in a more critical stage (C. Swartz, personal communication, April 09, 2021). Also, different programs and initiatives in the aim to keep the river clean, such as Berg River Improvement Plan (BRIP) have been developed (Horn, 2020).

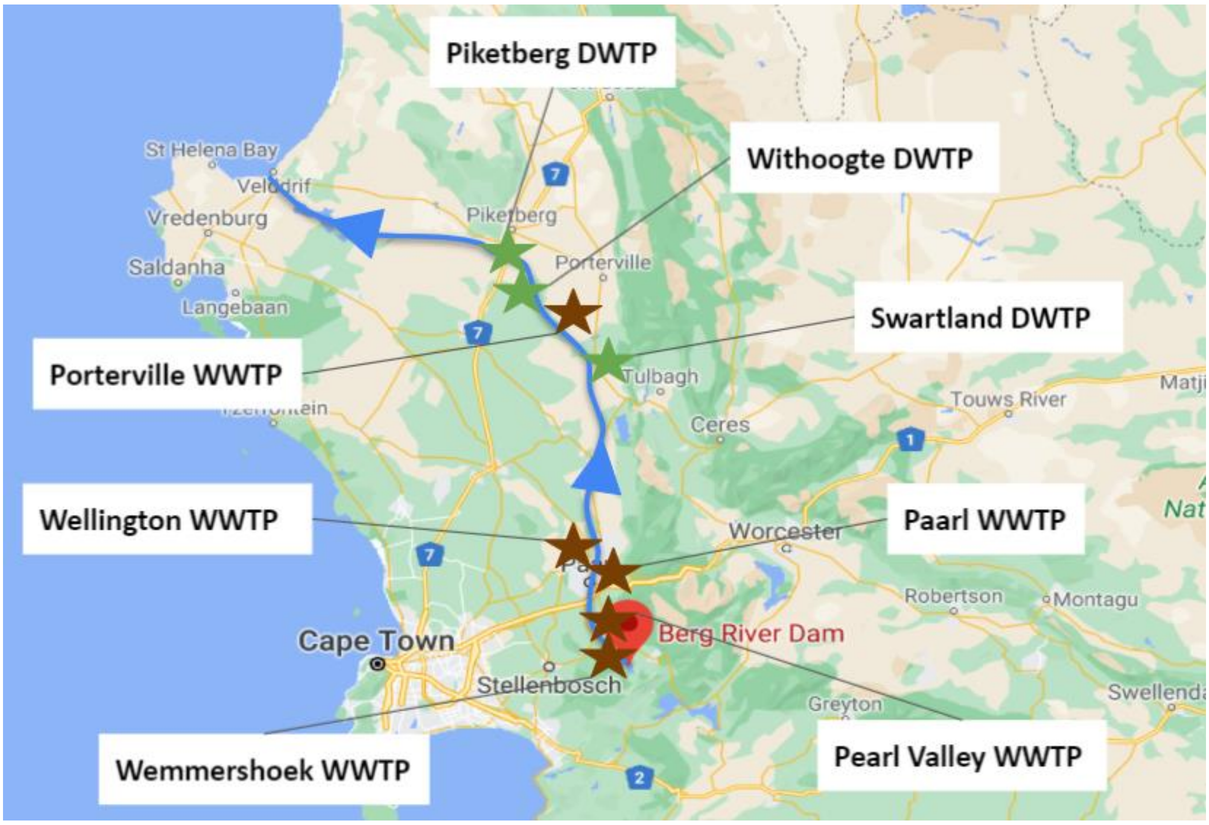

Figure 5 Berg river, DWTPs (green stars) and WWTPs (brown stars) along the river

3.1.2 Withoogte drinking water treatment plant

The Withoogte drinking water treatment plant is located more or less in the middle of the length of the Berg River, downstream Swartland DWTP, and upstream Piketberg DWTP, see Figure 5. The plant is owned and operated by the West Coast District Municipality (Swartz, 2011). The plants design capacity is 72,000 m^3/day and they are using Berg River (mostly from Misverstrand Dam that is in Berg River) as their raw water source, the system pumping the water to a storage reservoir before entering the water treatment plant by gravity (Swartz et al., 2019). See Figure 6 for a schematic of the DWTP.

The treatment processes are shown in Figure 6 with the first treatment process of stabilization by adding lime. This first step aims to increase the pH and to improve the coagulation process that is the next step. In this precipitation process raw water is mixed with flocculant and flocs are formed, thereafter the water leads to the sedimentation tanks followed by rapid gravity sand filtration to remove the flocs. The last step of treatment process disinfection with chlorine before entering the distribution network (Chris Swartz, 2011). The distribution network system provides the cities of Langebaan, Hopefield, Vredenburg (Jacobs Bay & Paternoster), Saldanha, St Helena Bay, Moorreesburg, Koringberg, Velddrifand Dwarskersbos with municipal drinking water.

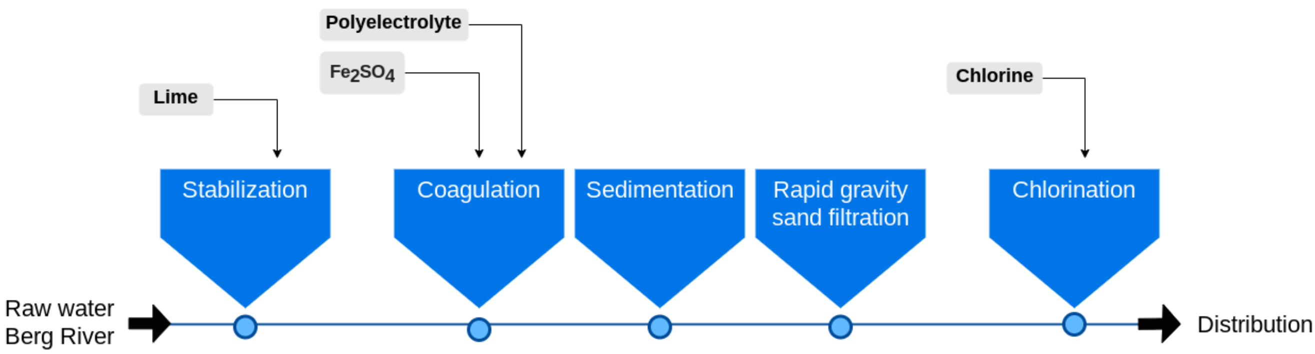

Figure 6 The treatment processes in Withoogte DWTP

3.1.3 Piketberg drinking water treatment plant

The Piketberg drinking water treatment plant is the plant located furthest downstream in the Berg River, see Figure 5. Piketberg DWTP was established in 1963 and is one of the oldest DWTPs and is operated by Berg River Municipality, using Berg River as their raw water resource. Design capacity is 2,400 m^3 /day (2.4 ML/day) and is designed to produce drinking water for a population of 10,000 people (Swartz, 2017), See Figure 7 for a picture of the DWTP.

The treatment processes in Piketberg DWTP are all conventional and are described in the Figure 7 below. In the first step, coagulant is added to the raw water and as a second optional step PAC can be added to the water for adsorption. PAC is used to reduce taste and odor of the water. However, the PAC adsorption process have not been operated the last couples of years in Piketberg DWTP (W. Burger, personal communication, April 06, 2021). As the third step thereafter flocculated water flows into two different setting tanks for sedimentation followed by five different rapid sand filters. In the last step, the treated water is stabilized with lime and thereafter chlorine is dosed for disinfection (Swartz, 2017). Later the water is stored in two reservoirs before pumped into the distribution network systems to reach the consumers living in Piketberg area.

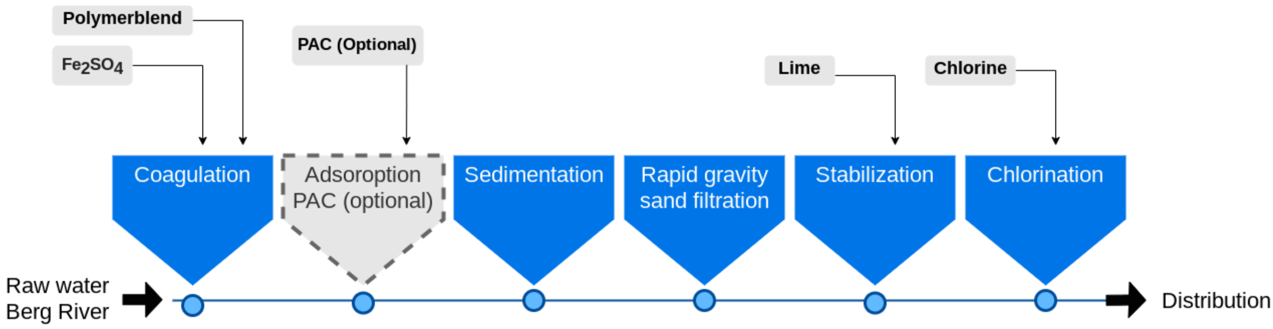

Figure 7 Treatment processes in Piketberg DWTP

3.2 Creating a model for QCRA

In this part the method for creating a model for Quantitative Chemical Risk Analysis will presented, including the method of a sensitivity analysis with Monte Carlo simulations.

The health risk assessment was divided into four steps: hazard identification, exposure assessment, dose response determination and risk characterization, an approach developed by NRMMC (2008). The QCRA-model that is developed in this study have been inspired by NRMMC (2008) but is further divided into more sub-steps see Figure 8, where steps 1-3 are part of the exposure assessment, steps 4-5 are part of the dose-response determination and step 6 is a part of the risk characterization. As a very first step three pharmaceuticals were identified to be potential hazards in the drinking water using raw water from Berg River.

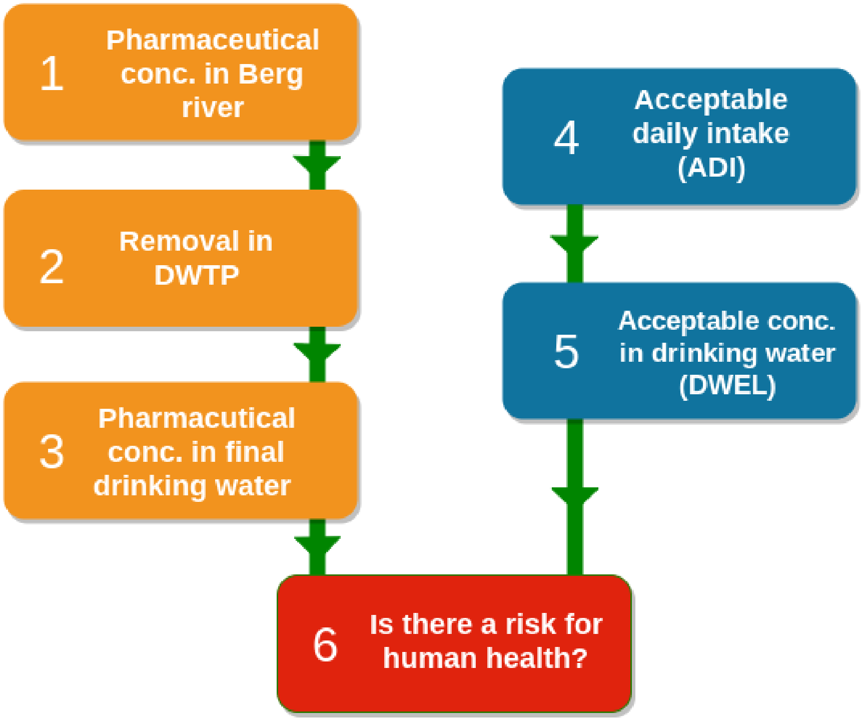

Figure 8 QCRA-model step 1-6

3.2.1 Sensitivity analysis

The method of the QCRA was done through a sensitivity analysis using Monte Carlo simulations. The Monte Carlo simulation was done in a spreadsheet software, MS Excel add-in @risk (Palisade, n.d.) and 10,000 simulations was performed, where 10,000 random values of the input values were used in the calculations giving results within a range of possible values. @Risk also gives the possibility to see the "*Inputs ranked by Effect on Output Mean"* which was done in order to see what input that is affecting the mean value the most. The sensitivity analysis will address both variability and uncertainty that will increase the likelihood that the results of the assessment are used in an appropriate manner (US EPA, 2011). By performing a risk assessment with variability means that the risk assessment accounts for the variation of the population exposed. Further, by including uncertainty means that the risk assessment considers gaps in knowledge, meanwhile variability accounts for heterogeneity across people, places or time (US EPA, 2011).

3.2.2 Hazard identification

Carbamazepine (anticonvulsants), diclofenac (NSAID), and sulfamethoxazole (antibiotic) were pharmaceutical compounds identified as hazards since they have been detected in Berg River as well as in both surface water and drinking water in other parts of the world, they are persistent in the environment and have shown toxicological effects of long-term exposure of pharmaceuticals in animal studies, as described in the theoretical background. The pharmaceuticals have different medication purposes, and the occurrence, removal and dose response information were available for each pharmaceutical in the literature. In dialogue with experts these three pharmaceuticals have been chosen with the aim to reach a wide range of properties and usage: one anticonvulsant, one anti-inflammatory and one antibiotic.

3.2.3 Exposure assessment

This part describes the exposure assessment from pharmaceutical concentration in the final drinking water, i.e., to understand how exposed the population are of the pharmaceuticals from their drinking water. This study was based on sample analyses from the raw water intakes of Withoogte and Piketberg DWTPs (conducted by Chris Swarts Water Utilization Engineering). Also, data from the literature was used in the exposure assessment to validate the reliability of the result from Withoogte and Piketberg DWTPs. These raw water concentration values were then reduced applying the pharmaceutical removal efficiency from the DWTPs collected from literature review. The exposure assessment considered the uncertainties in raw water concentration and in the removal efficiency. The exposure rout only included exposure through intentionally ingestion of drinking water.

Pharmaceutical concentration in Berg River

The pharmaceutical concentration in Berg River was measured in the raw water intake before entering Withoogte DWTP and Piketberg DWTP. The consulting company, Chris Swartz Water Utilization Engineers collected 10 samples for each DWTP during 5 weeks in March and April. During the time of sampling there were not any flow data available in Berg River but looking at the rain data during the time of sampling and comparing to the past, Berg River was considered having normal flow (C. Lourens, personal communication, June 03, 2021). Mean and standard deviation was calculated and used as input for a log normal distribution in the Monte Carlo simulation. Log-normal distribution was assumed since it has been shown to describe the concentration of pharmaceuticals well in the environment in previous studies (Kumar & Xagoraraki, 2010). For comparison, another river case data (Sesmylspruit River in Gauteng Province, South Africa) was used and tested in the QCRA-model. Using these raw water concentrations from Sesmylspruit River exemplifies a worst-case scenario, since it has higher raw water concentrations of the pharmaceuticals than in Withoogte and Piketberg DWTP. These samples were taken in a river 3.5 km from a WWTP (Archer et al., 2017b). See Table 2 for the raw water concentrations, where the two first columns are sample data from Withoogte and Piketberg DWTP and the third column is concentrations used for comparison, retrieved from Archer et al. (2017b).

Table 2 Pharmaceutical concentration in raw water intake to Withoogte DWTP, Piketberg DWTP and from a Sesmylspruit River, South Africa

Pharmaceuticals	Withoogte DWTP intake Distribution*	Piketberg DWTP intake Distribution*	Sesmylspruit River for comparison Distribution*
Carbamazepine [µg/l]	Lognormal (0.010, 0.0019)	Lognormal (0.010, 0.004)	Lognormal (0.280, 0.024)[a]
Diclofenac [µg/l]	Lognormal (0.019, 0.0008)	Lognormal (0.019, 0.001)	Lognormal (1.462, 0.509)[a]
Sulfamethoxazole [µg/l]	ND	ND	Lognormal (1.013, 0.294)[a]

*Distribution, (mean, standard deviation)

a. (Archer et al., 2017b)

ND=Not detected

Pharmaceutical removal in DWTP

It was assumed that the treatment processes and treatment efficiency for both Withoogte and Piketberg DWTP were equal. The treatment efficiency for coagulation/flocculation, sedimentation and rapid gravity sand filtration was combined in the QCRA, followed by treatment efficiency by chlorination. The treatment efficiencies were based on values from the literature, see Table 3. A literature review was conducted and treatment efficiencies from both pilot scale and full scale were of interest, but the studies on full scale was preferred to be used if available. Ullberg et al. (2021b) did a full-scale study in Sweden on Görväln DWTP for carbamazepine for the combination of coagulation/flocculation, sedimentation and rapid sand filtration and it was used in the model simulations. Removal of diclofenac in the coagulation/flocculation, sedimentation and sand filtration process was only found for pilot scale, and since only the maximum efficiency was presented, the minimum efficiency was assumed to be zero (McKie et al., 2016). The removal of sulfamethoxazole with coagulation/flocculation, sedimentation and sand filtration was not found, only the removal in coagulation/flocculation and sedimentation which was chosen to be used in the model simulations (Snyder et al., 2007), and since only the maximum efficiency was presented, the minimum efficiency was assumed to be zero. In an American study a literature review of full-scale treatment with chlorination and GAC filters among other treatment steps was carried out (USEPA, 2010). For diclofenac, the treatment efficiency for chlorination in DWTPs was not reported and therefore the treatment efficiency on treated wastewater effluent was chosen to be used. Removal efficiency of diclofenac in GAC filters was not reported in the USEPA (2010) but a full-scale test of treatment with GAC filters in another study in a water reuse system was found and therefore used (Snyder et al., 2007). In Table 3 the assumed probability distribution used in the QCRA-model is presented as well as the treatment efficiencies.

Table 3 Removal efficiencies of carbamazepine, diclofenac, and sulfamethoxazole for different treatment steps

Pharmaceuticals	Coagulation, flocculation, sedimentation, and rapid sand filtration [%]	Chlorination [%]	GAC filters [%]
Carbamazepine	Uniform (-11, 30)[a]	Triangular (2.6, 49, 85)[b]	Triangular (60, 72, 85)[b]
Diclofenac	Uniform (0, 37)[c]	Triangular (41, 61, 82)[b]	Point value (69)[d]
Sulfamethoxazole	Uniform (0, 20)[d]	Triangular (13, 69, 98)[b]	Triangular (17, 42, 67)[b]

Uniform (min, max); Triangular(min, mean, max)

a. (Ullberg et al., 2021b)

b. (US EPA, 2010)

c. (McKie et al., 2016)

d. (Snyder et al., 2007)

Scenarios for the exposure assessment in the QCRA

The exposure assessment in the QCRA was done with three different scenarios for three different raw water intakes: Withoogte DWTP, Piketberg DWTP and Sesmylspruit River (see Table 2 for the raw water concentrations). See Table 4 for explanations of the three scenarios. The first scenario includes treatment through coagulation, flocculation, sedimentation, sand filtration followed by chlorination with treatment efficiencies according to Table 3. The second scenario was assuming technical/human failure leading to no treatment (zero removal). The third scenario was assumed to be a future scenario where GAC filter is applied to the DWTPs with treatment efficiency according to Table 3. For scenario 1 PAC were not included in the treatment processes at Piketberg DWTP since it has not been used the last couple of years (W. Burger, personal communication, April 06, 2021).

Table 4 Scenarios in the risk assessment using three different raw water intakes (Withoogte DWTP, Piketberg DWTP and from Sesmylspruit River)

Scenario	DWTP treatment	Referred as
1	Treatment with coagulation, flocculation, sedimentation, sand filtration and chlorination with efficiencies according to literature review.	*conventional treatment + chlorination*
2	Assuming technical/human failure leading to no treatment.	*no treatment*
3	Future scenario where GAC filters is applied to the DWTPs with treatment efficiency according to literature.	*conventional treatment + chlorination + GAC filter*

Exposure concentration in the final drinking water

The final exposure concentration (for the drinking water consumers) of carbamazepine, diclofenac and sulfamethoxazole in the final drinking water was calculated using Equation 1. $C_{final\ DW}$ is the concentration in final drinking water in µg/l, while $C_{raw\ water}$ is the concentration in the raw water, and TE is the treatment efficiency in % for each process used. For scenario 2 there were no treatment, therefore the concentration in the final water were equal to the concentration in the raw water.

Equation 1 Final concentration in drinking water after treatment in DWTP

$$C_{final\ DW} = C_{raw\ water} \cdot \left(1 - \frac{TE_1}{100}\right) \cdot \left(1 - \frac{TE_2}{100}\right) \cdot \left(1 - \frac{TE_3}{100}\right)$$

3.2.4 Dose-response function development

The dose-response function development was to first establish an acceptable daily intake (ADI) for the studied pharmaceuticals, which is in the unit µg/kg bodyweight (bw)/day. The ADI was then used to calculate the dose (µg/l) where it is safe to say that no response or effect will occur in the human body. The ADI used in different studies were varying depending on what Point of Departure (PoD) that has been chosen, what type of toxicological or therapeutic end point (such as cancer, fetal effects etc.) and what type of study (animal or human, duration of the study, how many humans/animals tested etc.). PoD is the level of exposure of a certain pharmaceutical where there is a response or no response in a human/animal. This study has therefore performed a thorough literature review of ADIs already established, but also calculated own ADIs based on different PoD levels that was found in mainly animal studies. In the studies: No Observed Adverse Effect Level (NOAEL), No Observed Effect Level (NOEL), Lowest Observed Adverse Effect Level, Lowest Observed Effect Level (LOEL), or the minimum therapeutic dose (MTD) in humans was used to calculate the ADIs, see Figure 9 to follow the different steps. Uncertainty factors (UF) applied to PoD levels from toxicological studies on animals was based on guidance from Schwab et.al., (2005). When MTD was used as the PoD value, two different uncertainty factors guidance/method was followed, where the NRMMC (2008)'s approach is more conservative compared to Schwab et al. (2005). All steps in Figure 9 is further explained below.

In the dose-response development, calculation of a provisional guideline value was made, denoted as a drinking water equivalent level (DWEL) representing the concentration where there is a reasonable certainty that there will not be an effect in humans during long-term exposure of the pharmaceutical residuals, which also is further explained below.

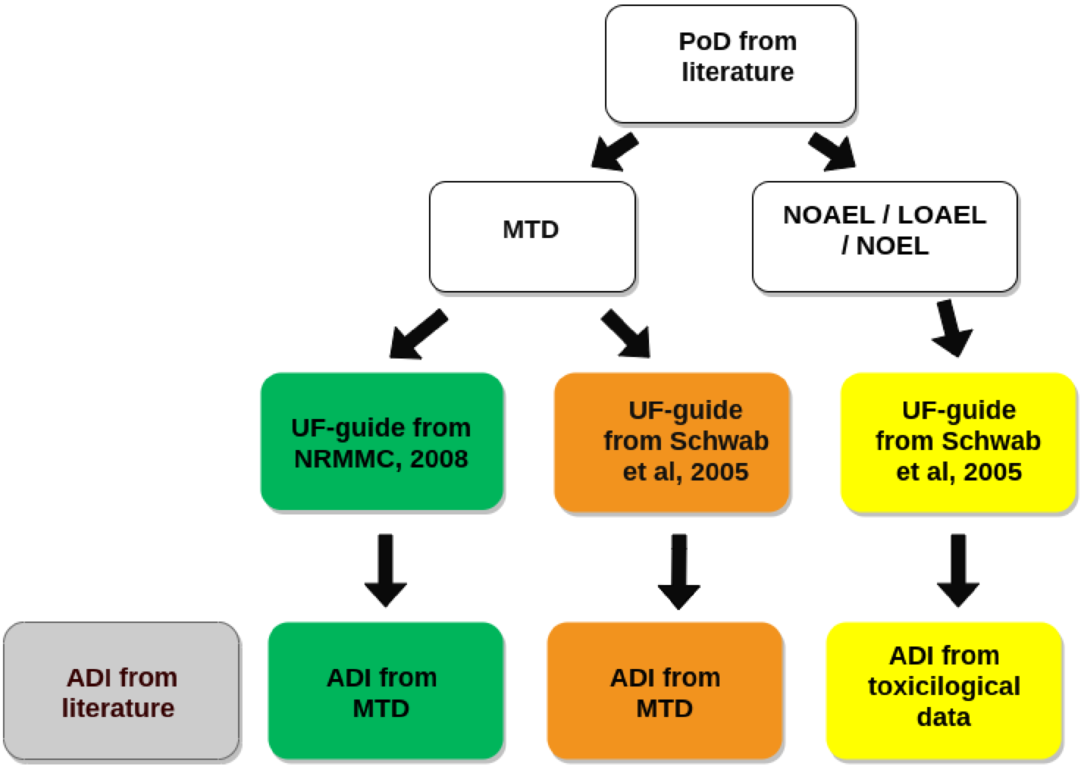

Figure 9 Method of establishing ADI

ADI from the literature

As a first step ADI already established in the literature was found, see Table 5. The ADI ranged from 0.34 to 2.8 (µg/kg body weight/day) for carbamazepine, 0.5 to 67 (µg/kg body weight/day) for diclofenac and 10 to 510 (µg/kg body weight/day) for sulfamethoxazole. The ADIs established by NRMMC (2008) are from *Australian guidelines for water recycling* and is established by a committee of scientists and professions. ADIs established by the European Agency for the Evolution of Medicine (EMEA) by a committee for veterinary medicinal products was also found (EMEA, 2004). The other ADIs found were from scientific articles.

Table 5 ADI established in the literature

ADI (µg/kg bw/day)	Based on	Source
Carbamazepine		
0.34	Cancerogenic endpoint, study on rats, maximum tolerated dose (MTD) of 25,000 µg/kg/day, uncertainty factor 700,000	Snyder (2008); Bruce et.al., (2010)
2.8	MTD using NRMMC uncertainty factor guidance	NRMMC (2008)
Diclofenac		
0.5	Based on LOEL 100 µg/kg/d (fetal effects and therapeutic effect in rats), and safety factor of 200	EMEA, (2004); NRMMC, 2008
1.6	Developmental end point in mouse	Snyder (2008)

67	Based on NOAEL of 20,000 µg/kg/d (developmental end point and UF=300)	Bruce et.al., (2010)
Sulfamethoxazole		
10	Based on NOEL 1000 µg/kg/d with a uncertainty factor of 100	NRMMC (2008)
130	Thyroid tumor after 60 week of duration (PoD of 25,000 µg/kg/d) and uncertainty factor of 200	Schwab et.al., (2005)
280	Developmental end point on rats	Snyder (2008)
510	Developmental end point on rats, based on NOAEL 512,000 µg/kg/d and uncertainty factor of 1,000	Bruce et.al., (2010)

bw = body weight

Calculating ADI from PoD

The first step was to find different PoD levels for carbamazepine, diclofenac and sulfamethoxazole. Different levels of PoD was found, such as NOAEL, LOAEL, NOEL and MTD levels. Uncertainty factors of a value of 1 or 3 (i.e., approximately a half log) or 10 were applied to the PoD values according to the guidance of Schwab et.al., (2005). The five uncertainty factors (UFs) consider five parameters: if the PoD was a NOAEL/NOEL or LOAEL/LOEL, duration of exposure, interspecies variation, intra individual susceptibility and data quality. Schwab et. al., (2005) used an approach and points out that the UFs should be chosen with scientific judgment and that is not a single default approach. This study's justifications to each UF are described in Table 6, and shown to vary between 300 and 3,000. However, the UF for data quality was always set to 1 since a conservative uncertainty factor value was set for the other four UFs. This approach and justifications are similar to what Kumar & Xagoraraki (2010) and Kumari and Kumar (2020) did in their risk assessment. For the PoD that is a MTD value, both uncertainty factors according to Table 6 was applied, and UFs conducted by NRMMC (2008), see Table 7. While following the NRMMC (2008) guidance approach a total value of 1000 is set.

The ADI was calculated according to Equation 2, which is the same method as Schwab et al., (2005), NRMMC (2008) and WHO (2011a) present. The different PoD values, what kind of study it is retrieved from (animal or human), what end-point effect, the duration of the study, the uncertainty factors applied, and the ADI calculated is presented in Table 8. The calculated ADIs showed a range of 0.34 µg/kg/d (carbamazepine) to 54.2 µg/kg/d (carbamazepine).

Equation 2 Calculating ADI from PoD level

$$ADI = \frac{PoD}{UF1 \cdot UF2 \cdot UF3 \cdot UF4 \cdot UF5}$$

Table 6 Uncertainty factors applied to the PoD according to Schwab et.al., (2005) uncertainty factor guidance.

PoD	Uncertainty type	Value applied	Justification
Carbamazepine			
NOAEL (www.comtox.epa.gov)	UF1 (LOAEL to NOAEL)	1	NOAEL value is given
	UF2 (Duration of exposure)	10	19 days
	UF3 (Inter-species variation)	10	Animal data (mouse)
	UF4 (Intra individual susceptibility)	10	Accounting for variation among human beings
	UF5 (Data quality)	1	Already accounted for
MTD (The Swedish Association of the Pharmaceuticals Industry, 2020c)	UF1 (LOAEL to NOAEL)	3	As MTD represent LOEL
	UF2 (Duration of exposure)	10	No chronic data available
	UF3 (Inter-species variation)	1	Human study
	UF4 (Intra individual susceptibility)	10	Study only conducted on adults
	UF5 (Data quality)	1	Already accounted for
Diclofenac			
LOAEL 1 (Pfitzer, 2018)	UF1 (LOAEL to NOAEL)	10	LOAEL value is given
	UF2 (Duration of exposure)	3	5 weeks study
	UF3 (Inter-species variation)	10	Animal study (mouse)
	UF4 (Intra individual susceptibility)	10	Accounting for variation among human beings
	UF5 (Data quality)	1	Already accounted for
LOAEL 2 (Pfitzer, 2018)	UF1 (LOAEL to NOAEL)	10	LOAEL value is given
	UF2 (Duration of exposure)	1	26 weeks toxicity study
	UF3 (Inter-species variation)	10	Animal study (rat)
	UF4 (Intra individual susceptibility)	10	Accounting for variation among human beings
	UF5 (Data quality)	1	Already accounted for
NOEL (Pfitzer, 2018)	UF1 (LOAEL to NOAEL)	1	NOEL is given
	UF2 (Duration of exposure)	10	Duration not reported
	UF3 (Inter-species variation)	10	Animal study (rat)
	UF4 (Intra individual susceptibility)	10	Accounting for variation among human beings
	UF5 (Data quality)	1	Already accounted for

MTD (Webb et.al., 2003)	UF1 (LOAEL to NOAEL)	3	As MTD represent LOEL
	UF2 (Duration of exposure)	10	No chronic data available
	UF3 (Inter-species variation)	1	Human study
	UF4 (Intra individual susceptibility)	10	Study only conducted on adults
	UF5 (Data quality)	1	Already accounted for
Sulfamethoxazole			
NOAEL 1 (Pfitzer, 2018)	UF1 (LOAEL to NOAEL)	1	NOAEL value is given
	UF2 (Duration of exposure)	10	Duration not reported
	UF3 (Inter-species variation)	10	Animal data (rat)
	UF4 (Intra individual susceptibility)	10	Accounting for variation among human beings
	UF5 (Data quality)	1	Already accounted for
NOAEL 2 (Pfitzer, 2018)	UF1 (LOAEL to NOAEL)	1	NOAEL value is given
	UF2 (Duration of exposure)	10	Duration not reported and toxicity studies are generally conducted for short- duration (Kumar & Xagoraraki, 2010)
	UF3 (Inter-species variation)	10	Animal data (rat)
	UF4 (Intra individual susceptibility)	10	Accounting for variation among human beings
	UF5 (Data quality)	1	Already accounted for
LOAEL (Pfitzer, 2018)	UF1 (LOAEL to NOAEL)	10	LOAEL value is given
	UF2 (Duration of exposure)	1	60 weeks toxicity study
	UF3 (Inter-species variation)	10	Animal study (rat)
	UF4 (Intra individual susceptibility)	10	Accounting for variation among human beings
	UF5 (Data quality)	1	Already accounted for
MTD (Schwab et.al., (2005)	UF1 (LOAEL to NOAEL)	3	As MTD represent LOEL
	UF2 (Duration of exposure)	10	No chronic data available
	UF3 (Inter-species variation)	1	Human study
	UF4 (Intra individual susceptibility)	10	Study only conducted on adults
	UF5 (Data quality)	1	Already accounted for

Table 7 Uncertainty factors used for MTD in NRMMC (2008)

Uncertainty factors (UF 1-3)	Considerations for uncertainty factor selection
UF 1	• 10 for differences in response between humans including sensitive individuals (intraspecies variation)
UF2	• 10 for protection of sensitive subgroups including children and infants
UF3	• 10 for the lowest daily therapeutic dose not being a no-effect level

Table 8 Point of departure level for carbamazepine, diclofenac and sulfamethoxazole and uncertainty factors applied from Schwab et.al., (2005)

PoD	Level (µg/kg bw/day)	Animal studied	End point effect	Duration of study	Total UF calculated from Table 6	Total UF from NRRMC (2008)	ADI (µg/kg/d)
Carbamazepine							
NOAEL (www.comtox.epa.gov)	542,000	Mouse	Developmental	19 days	1,000		542
MTD (The Swedish Association of the Pharmaceuticals Industry, 2020c)	2,857*	Human	Therapeutic	NR	300	1,000	9.5/2.8 ***
Diclofenac							
LOAEL 1 (Pfitzer, 2018)	9,000	Mouse	Lungs, spleen	5 weeks	3,000		3
LOAEL 2 (Pfitzer, 2018)	50,000	Rat	Blood, gastrointestinal system	26 weeks	1,000		50
NOEL (Pfitzer, 2018)	2,000	Rat	Carcinogenicity**	NR	1,000		2
MTD (Webb, et.al., (2003)	357*	Human	Therapeutic	NR	300	1,000	1.2/0.36 ***
Sulfamethoxazole							
NOAEL 1 (Pfitzer, 2018)	512,000	Rat	Teratogenic (maternal toxicity)	NR	1,000		512
NOAEL 2 (Pfitzer, 2018)	350,000	Rat	Reproductive, fertility	NR	1,000		350
LOAEL (Pfitzer, 2018)	60,000	Rat	Thyroid tumors	60 weeks	1,000		60
MTD (Schwab, et.al., 2005)	11,429*	Human	Therapeutic	NR	300	1,000	38.1/11.4***

NR = Not reported
*MTD (mg/day) was multiplied with 1000 and divided by 70 kg (bodyweight).
**The carcinogenicity endpoint did not occur in the study and according to (EMEA, 2004) diclofenac is not likely to cause cancer.
***ADI based on UF from Schwab et.al.,(2005)/ADI based on UF from NRMMC (2008)

ADI used in the QCRA

As a final step in the development of ADI a distribution was set. An exponential distribution was chosen to be the most suitable and representative considering the uncertainties and variations within the ADIs. The exponential distribution should not be a negative value and therefore the minimum end of the distribution was truncated to zero i.e., the input for *trunc min* was set to zero. The input for β (mean) was set to the calculated ADI mean from Table 5 and Table 8. See Table 9 for the distribution, β and 5th percentiles to 95th percentiles of ADIs for carbamazepine, diclofenac and sulfamethoxazole. ADI recommended by NRMMC (2008) is also presented in Table 9 for comparison and was later used to calculated two DWEL's for comparison.

Table 9 Exponential distribution, β (mean) and 5th percentiles to 95th percentiles of ADI for carbamazepine, diclofenac and sulfamethoxazole in µg/kg bw/day

Pharmaceutical	Distribution	β (mean)	ADI* (5th – 95th percentiles)	ADI* recommended in NRMMC (2008)
Carbamazepine	Exponential	138.7	7.1-415.4	2.8
Diclofenac	Exponential	15.7	0.8-47.0	0.5
Sulfamethoxazole	Exponential	222.7	11.4-667.2	10

**ADI is in µg/kg body weight/day*

Calculating guideline value, denoted as drinking water equivalent level (DWEL)

The last step in the dose-response determination was to calculate a guideline value, denoted as drinking water equivalent level (DWEL) according to (WHO, 2011a), see Equation 3. ADIs [µg/kg/d] are showed in Table 9, and P is the proportion of ADI allocated to drinking water [%] and IR is the ingestion rate [l/kg body weight/day]. According to WHO (2011a) the default recommendation consumption of drinking water for an adult is 2 litres per day and body weight is 60 kg. For a child, the recommendation is 1 l/day and body weight is 10 kg (WHO, 2011a). However, this study took into account variation in ingestion rate and used the ingestion rates presented in the exposure handbook conducted by US EPA (2019) based on ingestion rates in the US.

Four populations group and their ingestion rates have been used in the QCRA-model, infants that are breast fed, infants that are formula fed, children with ages from 1 to 10 years and adults with ages from 20 to 64 years, see Table 10. The ingestion rates for infants that are formula fed is the population group that has the highest ingestion rate per kg body weight.

For the pharmaceuticals studied both diclofenac and sulfamethoxazole are both used as veterinary drugs which means that people can be exposed by the substances through other ingestions such as through food (in this case meat), and therefore the proportion of ADI allocated to drinking water for diclofenac was then assumed to be between 10-20%, see Table 11. For carbamazepine, a study showed that people are exposed to carbamazepine through ingestion of vegetables (from irrigation) (Schapira et al., 2020) and therefore, the proportion of ADI allocated to drinking water for carbamazepine was assumed to be 10-20%. Overall, the proportion of ADI allocated to drinking (P) is recommended to be set to 20% which is according to WHO a value reflecting a reasonable level of exposure but is also, based on experience, a protective value (WHO, 2011a). Previous, 10% was usually used, but WHO (2011a) mean that it can be too conservative. Also, to take into consideration that peoples diet varies among people, in this study a range between 10-20% of P with a uniform distribution was chosen. Except for infants, for them it was assumed that the proportion of ADI allocated to drinking water is higher, and the P was therefore assumed to have a variation between 40-50%, see Table 11.

For comparison for the DWELs of children and adults, two DWELs was calculated based on the recommendations from WHO (2011a) regarding ingestion rates in Table 10, 0.1 l/kg/day (1 l per day and 10 kg body weight) for children and 0.033 l/kg/day for adults (2 l/day and 60 kg body weight) and proportion of ADI allocated to drinking water (20%), it was also based on recommended ADIs from NRMMC (2008), 2.8 µg/kg/day, 0.5 µg/kg/day respectively 10 µg/kg/day for carbamazepine, diclofenac and sulfamethoxazole.

Equation 3 Calculation of DWEL

$$DWEL = \frac{ADI \cdot P}{IR \cdot 100}$$

DWEL= drinking water equivalent level (µg/l)
ADI = Acceptable daily intake (µg/kg/d)
P = Proportion of ADI allocated to drinking water (%)
IR= Ingestion rate (l/kg body weight/day)

Table 10 The ingestion rate from the US EPA exposure handbook (2019) [l/kg/day].

Population exposed	Distribution (mean, SD) [l/kg bw/day]	Source
Infants breast fed	Log-normal (0.0435, 0.0425)	US EPA (2019)
Infants formula fed	Normal (0.146, 0.24)*	US EPA (2019)
Children (1-10 yr)	Log-normal (0.0355, 0.0229)	US EPA (2019)
Adults (20-64 yr)	Log-normal (0.0199, 0.0108)	US EPA (2019)
Children	Point value (0.100)	(WHO, 2011a)
Adults	Point value (0.033)	(WHO, 2011a)

SD=standard deviation
*The minimum in the normal distribution is truncated to zero

Table 11 The proportion of ADI allocated to drinking water [%]

Population exposed	P [%] Distribution (min, max)
Infants breast fed	Uniform (40, 50)
Infants formula fed	Uniform (40, 50)
Children (1-10 yr)	Uniform (10, 20)
Adults (20-64 yr)	Uniform (10, 20)
Children (recommended by WHO, 2011a)	Point value (20)
Adults (recommended by WHO, 2011a)	Point value (20)

3.2.5 Risk characterization

The risk characterization was to compare the exposure concentration and the DWEL, in a hazard quotient (HQ), see Equation 4. A HQ above 1 means that the substance can pose a risk to the population that the DWEL is based on. A HQ below 1 means that there is no risk of health-related impacts of the population at this dose of exposure.

Equation 4 Calculation of hazard quotient

$$HQ = \frac{C_{final\ DW}\ (Exposure\ concentration)\ \ [\frac{\mu g}{l}]}{DWEL\ [\frac{\mu g}{l}]}$$

3.3 Interview study: perception of de facto water reuse

In this part the method of the Interview study among the public's perception using water from de facto water reuse will be presented.

As a first step a literature review of perception of water reuse and overall influences and factors affecting the perception was well investigated and researched. When finding interviewees, the focus was on finding people with different socio-economic and demographic background living along Berg River, with the aim to get a wide range of answers and a fair representation. This was done with help from the consultant company in collaboration (Chris Swartz Water Utalization Engineers) that provided contacts to an organisation called Mbeko Eco Club, that further provided contacts to potential interviewees. The interviewees were contacted through email and WhatsApp-messengers for arranging the interviews. The structure of the interview study was then formed and as a general method a semi-structured interview style was followed. The questions were formed to be mainly open-ended and was not available for the interviewees prior the interview, see Appendix 1 for the full questionnaire. The interview study was formed in a way to cover a broad spectrum, including the whole concept of water reuse, both de facto (unintendedly) water reuse and intendedly water reuse. The structure of the questions was formed in a way to be open with a potential room to use their imagination, for example:

- Do you have knowledge or an idea of where your tap water comes from?
- How do you use your tap water at home, what do you use it for?
- What is your feeling about the water situation and scarcity in South Africa today?
- Are you familiar with the term “water reuse”? What does it say to you?
- Do you have trust in water cleaning technologies?
- Do you have trust in your authorities such as municipalities or others working with water in your region?
- Can you think of anything that could help increase your trust in water reuse for drinking water?

Before the interviews the full questionnaire was tested on two test persons to discover the need of clarifications and justifications. Then, 11 interviews were conducted, and 10 out of 11 interviews were recorded and performed successfully. These 10 have therefore been the base and the content of the interview study. All interviews and results were conducted anonymous and was performed through WhatsApp calls, approximately time of 20-30 min each. Most of the interviews ran smoothly, except from some technical issues of unstable internet connection and WhatsApp data failure.

After the interviews was performed and completed, they were all transcribed, see Appendix 12-21. The empirical findings were analysed to get an understanding of potential links, common understandings and to evaluate key factors throughout the interviews. Questions asked when analysing the interviews were:

- Do they accept water reuse as a water source?
- Do they know of water reuse?
- Do they have doubts if it is safe to drink?
- Do they have trust in authorities?
- What could impact their trust in water reuse?

The answers of the mentioned questions were compared to each other in the aim to evaluate and structure what factors and barriers that was of most impact of the public perception. Also, different parameters such as occupation, education level, knowledge level, income, sex or age and their potential impact was analysed.

4 RESULT

The chapter consists of two parts: 1 – the results from the QCRA and part 2 – the results from the interview study of the perception of water reuse among the public using de facto water reuse.

4.1 Assessment of chemical health risks

The results from the health risk assessment (QCRA calculations) are presented in this chapter including the exposure concentration from the three scenarios of the three pharmaceuticals, the drinking water equivalent level and the hazard quotient.

4.1.1 Final drinking water concentration

In this part, the final drinking water concentration is presented, denoted as exposure concentration, which is the concentration the current population will be exposed to through drinking water. The exposure concentration is presented for the three pharmaceuticals (carbamazepine, diclofenac and sulfamethoxazole), for the three scenarios and for the three different raw water intakes. Scenario 1: conventional treatment + chlorination, scenario 2: no treatment of the pharmaceuticals, 3: conventional treatment + chlorination + GAC filter. The raw water intakes are for Withoogte DWTP, Piketberg DWTP and from Sesmylspruit River. See Table 4 for the scenarios used in the risk assessment.

The results for each scenario 1-3 using the raw water intakes from Withoogte and Piketberg DWTPs showed about the same exposure concentrations for the two DWTPs, the only small difference was the standard deviation. That the exposure concentrations were about the same, was expected since the raw water intakes had equal quality regarding raw water concentrations of carbamazepine and diclofenac. For all scenarios the exposure concentrations of carbamazepine resulted in the lowest concentration compared to diclofenac from both Withoogte DWTP and Piketberg DWTP, see Table 12 (Exposure concentrations from Withoogte DWTP) and Table 13 (Exposure concentrations from Piketberg DWTP). The standard deviation (SD) of the exposure concentration of carbamazepine at Withoogte DWTP were higher than at Piketberg DWTP, which means that the concentration of carbamazepine has a higher variance at Withoogte DWTP. This was also expected since the raw water concentrations of carbamazepine had a higher SD at Withoogte DWTP than Piketberg DWTP. Diclofenac had a higher exposure concentration than carbamazepine at both Withoogte DWTP and Piketberg DWTP and the SD was about the same for both DWTPs. Sulfamethoxazole was not detected in the raw water intakes for none of Withoogte or Piketberg DWTP and therefore no exposure concentrations was calculated for sulfamethoxazole.

The exposure concentration for scenario 1-3 using raw water intake from Sesmylspruit River was higher than the exposure concentration using raw water intake for Withoogte and Piketberg DWTP, for all three pharmaceuticals. The exposure concentration of carbamazepine was about 30 times higher using raw water from Sesmylspruit River, and the exposure concentrations of diclofenac was about 80 times higher using raw water from Sesmylspruit River. Using Sesmylspruit River as raw water in scenario 1 and scenario 2 the exposure concentrations of diclofenac was the highest, followed by sulfamethoxazole and carbamazepine. However, in scenario 3 (with additional treatment with GAC filter) sulfamethoxazole had the highest exposure concentrations followed by diclofenac and carbamazepine.

Looking at the results of the exposure concentrations from scenario 1-3 it is noticeable that scenario 2 has the highest concentrations for all pharmaceuticals, since there was no treatment. The exposure concentrations of carbamazepine for scenario 2 was about two times higher than the result of exposure concentration of carbamazepine for scenario 1. The exposure concentration of diclofenac and sulfamethoxazole from scenario 2 was about three times higher than the exposure concentration from scenario 1. This means that conventional treatment and chlorination that was used in scenario 1 had least impact on the reduction of carbamazepine, since it only reduced the exposure concentration of carbamazepine with 50% from scenario 2, meanwhile it reduced the exposure concentration of diclofenac and sulfamethoxazole with about 70% from scenario 2. In scenario 3, where GAC filters were used the exposure concentration of carbamazepine was reduced with 80% from scenario 1, meanwhile the exposure concentration of diclofenac was reduced with 70%, and the exposure concentration of sulfamethoxazole was reduced with 50%. This means that GAC filters had the most impact on the reduction of carbamazepine followed by diclofenac and sulfamethoxazole.

Table 12 Exposure concentration in final drinking water from Withoogte DWTP

Exposure concentration [µg/l]	Scenario 1	Scenario 2	Scenario 3
Carbamazepine (mean, SD)	0.005, 0,003	0.010, 0.002	0.001, 0.0008
Diclofenac (mean, SD)	0.006, 0.002	0.019, 0.001	0.002, 0.0005
Sulfamethoxazole (mean, SD)	ND	ND	ND

ND= not detected

Table 13 Exposure concentration in final drinking water from Piketberg DWTP

Exposure concentration [µg/l]	Scenario 1	Scenario 2	Scenario 3
Carbamazepine (mean, SD)	0.005,0.002	0.010,0.004	0.001,0.0006
Diclofenac (mean, SD)	0.006,0.002	0.019,0.001	0.002,0.0005
Sulfamethoxazole (mean, SD)	ND	ND	ND

ND= not detected

Table 14 Exposure concentration in final drinking water from Sesmylspruit River

Exposure concentration [µg/l]	Scenario 1	Scenario 2	Scenario 3
Carbamazepine (mean, SD)	0.140,0.048	0.280,0.024	0.038,0.015
Diclofenac (mean, SD)	0.460,0.200	1.500,0.510	0.150,0.063
Sulfamethoxazole (mean, SD)	0.370,0.200	1.010,0.290	0.210,0.120

In the health risk assessment (using Monte Carlo simulations) for the three scenarios, different input parameters affected the exposure concentrations of carbamazepine, diclofenac, and sulfamethoxazole:

- For scenario 1: the different input parameters were: raw water concentration, removal efficiency of conventional treatment and chlorination.
- For scenario 2: raw water concentration (as the only input parameter i.e., the assumption was no treatment)
- For scenario 3: raw water concentration, removal efficiency of conventional treatment, chlorination together with GAC filters.

These input parameters were ranked by the effect they had on the mean of the exposure concentration. The input parameters that had the most impact on the mean, were ranked the highest. In Figure 10 the input parameters affecting the exposure concentration of diclofenac in scenario 1 using raw water intake for Withoogte DWTP is showed. The figure shows that chlorination had the main impact on the mean of exposure concentration of diclofenac, followed by conventional treatment and least raw water concentration. As seen in Figure 10 all the input parameters are impacting the mean exposure concentration to both higher and lower values. In Figure 11 the input parameters affecting the exposure concentration of carbamazepine in scenario 3 using raw water intake for Withoogte DWTP is showed. The figure shows that for carbamazepine, the raw water concentration has the main impact followed by chlorination, GAC filters and least conventional treatment. That the raw water concentration of carbamazepine had higher impact was expected, due to its higher standard deviation (SD) than what diclofenac had (see Table 2 for the raw water concentration of carbamazepine and diclofenac). It was noticeable from the results, that out of the treatment efficiencies for all pharmaceuticals, chlorination had the main effect on the mean of exposure concentration for both scenario 1 and 3, followed by GAC filters and the least impact did conventional treatment have This result shows that the treatment with chlorination is affecting the exposure concentration significantly, and if the treatment with chlorination is performing as its best (the highest removal efficiency in Table 3 is used) the mean exposure concentration for the three pharmaceuticals could be reduced with about 50% or more, at the same time as if the chlorination is performing at is worst the exposure concentration will increase with about 50%. Meanwhile, treatment with GAC filters is more reliable since the variation in treatment efficiency is less.

In appendix 2-4 the ranking list is presented for scenario 3 for Withoogte DWTP, Piketberg DWTP respectively using raw water from Sesmylspruit River, where all input parameters are used (raw water concentration, removal efficiency with conventional treatment, chlorination and GAC-filters). In the appendices, it is clear that the ranking order of the treatment processes affecting the mean of the exposure concentration is: chlorination, GAC-filter and least conventional treatment.

What is different in the results using raw water intake of Sesmylspruit River, is that the SD for carbamazepine was lower, in relation to the mean and therefore the raw water concentration of carbamazepine had the least impact on the exposure concentration mean. Meanwhile, the raw water concentration of diclofenac in Sesmylspruit River had a significantly larger SD in relation to the mean than the raw water concentration in Withoogte and Piketberg DWTP and showed the main effect on the exposure concentration mean. In Sesmylspruit River sulfamethoxazole was detected, and in that case, chlorination had the most impact on the output, followed by the raw water concentration, GAC filters and conventional treatment.

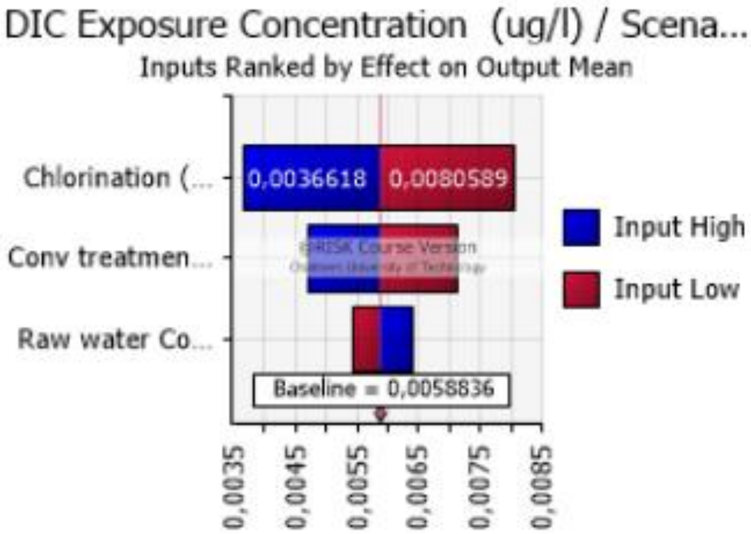

Figure 10 Inputs of exposure concentration that are ranked by the effect they have on the mean of the exposure concentration. This is for scenario 1, using raw water intake to Withoogte DWTP, for diclofenac

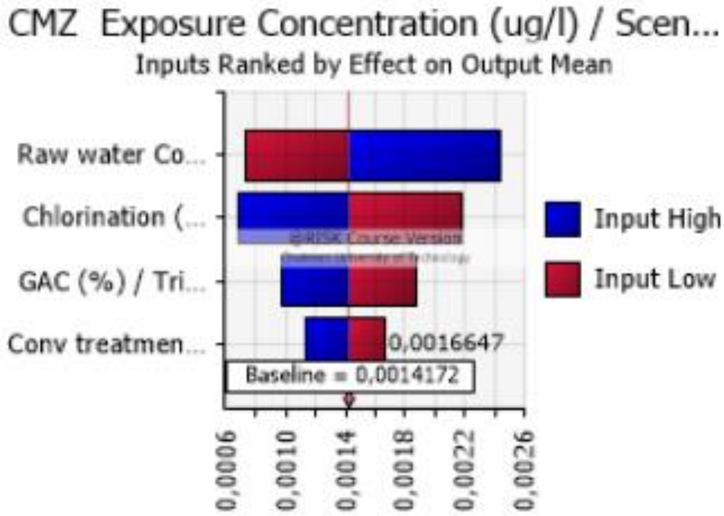

Figure 11 Inputs of exposure concentration that are ranked by the effect they have on the mean of the exposure concentration. This is for scenario 3, using raw water intake to Withoogte DWTP, for carbamazepine

4.1.2 Drinking water equivalent level

The drinking water equivalent levels (DWEL), mean and standard deviation for the different population groups studied: infants that are breast fed, infants that are formula fed, children in years 1 – 10 and adults between 20 years to 64 years are presented in Table 15 from the QCRA calculations using Monte Carlo simulations. For comparison, a DWEL for children and adults recommended by WHO (2011a) and Acceptable daily intakes (ADI) by NRMMC (2008) was used. WHO's recommended values are based on default values for ingestion rate (IR), body weight (BW) and proportion of ADI allocated to drinking water (P), and the DWEL's are all presented in Table 16. The results from the QCRA using the Monte Carlo simulations in Table 15 show that infants that are formula fed had the lowest DWEL, the second lowest DWEL was showed for children followed by DWEL for adults, and the highest DWEL had infants that are breastfed. Overall, diclofenac has showed the lowest DWEL compared to the other pharmaceuticals, both in Table 15 and in Table 16 meanwhile sulfamethoxazole has showed the highest DWEL for all population groups. Since diclofenac has a much lower and stricter DWEL value, the acceptable exposure concentration in final drinking water is lower than carbamazepine and sulfamethoxazole for it to be safe for human consumption, meaning it is the most toxic compound. The result of DWELs in Table 15 had a great variation, which is seen when studying the standard deviations. For example, the 5th percentile and 95th percentile of the DWEL developed for adults ($DWEL_{adult}$) varies between 52 µg/l to 4500 µg/l. The DWEL's with recommended default values for children ($DWEL_{children, recommended}$) and for adults ($DWEL_{adult, recommended}$) in Table 16, are significantly lower than the mean of the DWELs for children and adults that are showed in the result of the sensitivity analyses, $DWEL_{children}$ and $DWEL_{adult}$ (Table 15). The 5th percentile of the $DWEL_{children}$ and $DWEL_{adult}$ are more comparable with the recommended DWELs in Table 16, e.g., they are in the same order of magnitude, see Table 15 and Table 16.

Table 15 Calculated drinking water equivalent level (DWEL) with probability distributions of the inputs

DWEL [µg/l]		Infants, breast fed	Infants, formula fed	Children	Adults
Carbamazepine	mean, SD	2800, 4700	680, 8500	840, 1200	1300, 1700
	5th percentile	75	21	30	52
Diclofenac	mean, SD	320, 550	68, 270	94, 140	150, 200
	5th percentile	8.5	2.4	3.4	6.0
Sulfamethoxazole	mean, SD	4500, 8000	990, 6100	1300, 1800	2200, 2800

	5th percentile	120	33	44	85

SD=standard deviation

Table 16 Comparison values of DWEL, based on recommended values of WHO (2011a) and NRMMC (2008)

DWEL recommended [µg/l]	Children	Adults
Carbamazepine	6	17
Diclofenac	1	3
Sulfamethoxazole	20	60

**All values are recommended values, ADIs from NRMMC (2008) and ingestion rates (60 kg respectively 10kg, 2 litres respectively 1 litre for adults and children) and P (20%) recommended by WHO (2011a).*

In the health risk assessment (using Monte Carlo simulations) the input parameters were ranked by the effect they have on the mean of DWEL. For almost all DWEL the input effecting the mean of DWEL mostly is the parameter: ADI. In Figure 12 the ranking list for DWEL for adults and diclofenac is presented, where it is seen that ADI has a significant effect on the mean of DWEL. As seen in Figure 12, using the highest ADI as an input, the output of the DWEL mean will be 70 times higher than if the lowest ADI is used as input, which was the same for the other DWELs as well, see Appendix 5. ADI is affecting the DWEL mean towards lower values, as seen in Figure 12 and in Appendix 5. In one DWEL, for infants that are formula fed for sulfamethoxazole, the ingestion rate per body weight had the most impact on the mean, see Figure 13. However, as seen in the Figure 13 the ingestion rate of infants that are formula fed is about the same as the ADI. DWEL for both infants that are breastfed, and formula fed, the ADI and the ingestion rate per body weight had about the same effect, but ADI was slightly higher for the other ones which is seen in Appendix 5. For all DWELs the proportion of ADI allocated to drinking water (P) had significantly lower effect on the mean of DWEL. For DWELs for children and adults the ranking is similar, where the ADI is affecting mostly followed by ingestion rate and P, see Appendix 5.

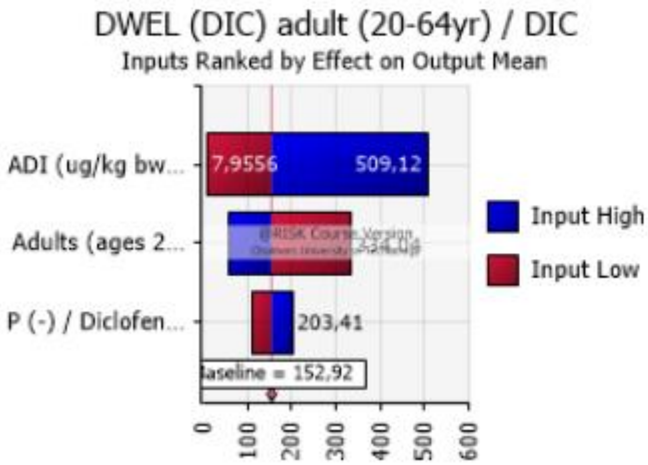

Figure 12 The inputs affecting the mean of DWEL for adults for diclofenac (DIC). Highest ranking did ADI in µg/kg body weight/day have, followed by ingestion rate for adults and least proportion of ADI allocated to drinking water (P)

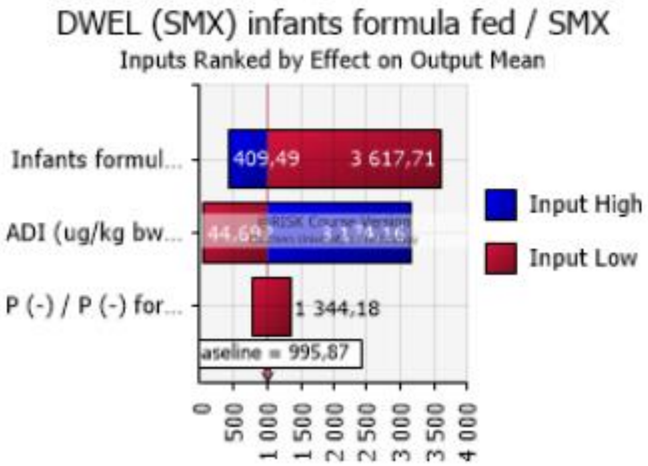

Figure 13 The inputs affecting the mean of DWEL for infants that are formula fed for sulfamethoxazole (SMX). Highest ranking did ingestion rate for infants that are formula fed, followed by ADI in µg/kg body weight/day have, and least proportion of ADI proportion to drinking water (P)

4.1.3 Risk characterization, Hazard quotient

The risk characterization is presented as a hazard quotient (HQ), which is expressed as the ratio between exposure concentration and the drinking water equivalent level (DWEL) of the studied pharmaceuticals. A HQ-value above 1 indicates that the exposure of the pharmaceutical can lead to health risks considering long-term exposure. See Table 17, Table 18 and Table 19 for the result of HQ for scenario 1-3 for Withoogte DWTP, Piketberg DWTP and from the Sesmylspruit River. These results are based on DWEL from Table 15. Table 18 shows the result of HQ for the worst case, where raw water concentration is from the Sesmylspruit River with no treatment and based on the DWEL with recommended default values of ingestion rate per body weight (IR), proportion of ADI allocated to drinking water (P) and ADI from WHO (2011a) and NRMMC (2008) from Table 16.

Hazard quotient for Withoogte and Piketberg DWTPs: *The* results of HQ for Withoogte and Piketberg are very similar since the raw water concentrations performed in the QCRA-model are in the same order of magnitude, and the treatment efficiencies are set to be the same. The small, but noticeable difference showed was that Piketberg had a higher variance since the standard deviation (SD) was higher, see Table 17 (HQ for Piketberg DWTP) and Table 18 (HQ for Withoogte DWTP), which was expected since SD in the raw water concentration to Piketberg DWTP was slightly higher. However, either carbamazepine or diclofenac show a human health risk (HQ<1), even for the worst scenario where there was no treatment (scenario 2). Diclofenac showed the highest HQ compared to carbamazepine for both DWTPs and scenarios. The most sensitive exposure population with the highest HQ was showed to be infants that are formula fed, followed by children, adults and infants that are breastfed. Below, the results for each scenario will be described in more detail for Withoogte DWTP and Piketberg DWTP.

***Hazard quotient, Scenario 1 for Withoogte and Piketberg DWTP*:** Exposure to carbamazepine from Withoogte DWTP and Piketberg DWTP had a HQ 95th percentile ranging between $7 \cdot 10^{-5}$ and 0.0002, where the highest risk, e.g., highest HQ, is showed for formula fed infants and children. The 95th percentile of HQ for diclofenac is about 10 times higher than for carbamazepine, and is ranging from 0.0007 to 0.002, where the highest risk showed is for formula fed infants and children. Since diclofenac had a lower DWEL but at the same time higher concentrations this was expected. The marginal for the HQ to become 1 is high (500 for the $HQ_{infants,\ formula\ fed}$ for diclofenac), and there is therefore no doubt that it will not be a risk with the raw water concentrations, the conventional treatment and chlorination performed in the QCRA-model for scenario 1.

Hazard quotient, Scenario 2 Withoogte and Piketberg DWTP: The HQ for carbamazepine is higher than for scenario 1 since there is no treatment. The 95th percentile of the HQ for carbamazepine is about two times higher than when there is treatment with conventional treatment and chlorination (scenario 1), and the 95th percentile of HQ for the two most sensitive exposure population is 0.0005 (infants that are formula fed) respectively 0.0004 (children). The 95th percentile of HQs for diclofenac is showed to be about 4 times higher than in scenario 1. The most sensitive exposure population (infants that are formula fed and children) had a HQ of 0.008 (95th percentile), which means that there is a margin of 125 before the HQ becomes 1. With this result, it means that the conventional treatment and chlorination that was performed in the QCRA-model in scenario 1 reduces the risk more significantly for diclofenac than for carbamazepine.

***Hazard quotient, Scenario 3 Withoogte and Piketberg DWTP*:** Additional treatment with GAC filters showed to reduce the HQ - 95th percentile, for carbamazepine ($6 \cdot 10^{-5}$ for infants that are formula fed, and to $5 \cdot 10^{-5}$ for children) for scenario 3, reducing the risk with a factor of 3, compared to scenario 1. The 95th percentile of HQ for diclofenac is also showed to reduce the risk with a factor 3, showing results much lower than HQ for scenario 1. For diclofenac, the 95th percentile of $HQ_{children}$ is 0.0006 and $HQ_{infants, formula fed}$ is 0.00008. The highest HQ for scenario 3 ($HQ_{infants, formula fed}$ for diclofenac) has a margin of 1 250 before HQ becomes 1.

Table 17 Hazard quotient (HQ) for the three scenarios for Withoogte DWTP in South Africa

HQ [-]		Infants, breast fed	Infants, formula fed	Children	Adults
Scenario 1					
Carbamazepine	mean, SD	$4 \cdot 10^{-5}$, 0.001	0.0001,0.003	0.0001,0.002	$6 \cdot 10^{-5}$,0.001
	95th percentile	$7 \cdot 10^{-5}$	0.0002	0.0002	0.0001
Diclofenac	mean, SD	0.0003,0.002	0.001,0.023	0.001,0.020	0.0005,0.007
	95th percentile	0.0007	0.002	0.002	0.001
Sulfamethoxazole		ND	ND	ND	ND
Scenario 2					
Carbamazepine	mean, SD	$9 \cdot 10^{-5}$,0.002	0.0003,0.009	0.0002,0.005	0.0001,0.002
	95th percentile	0.0001	0.0005	0.0004	0.0002
Diclofenac	mean, SD	0.001,0.008	0.004,0.084	0.004,0.071	0.002,0.027
	95th percentile	0.002	0.008	0.006	0.003
Sulfamethoxazole		ND	ND	ND	ND
Scenario 3					
Carbamazepine	mean, SD	$2 \cdot 10^{-5}$,0.0008	$6 \cdot 10^{-5}$, 0.003	$4 \cdot 10^{-5}$,0.002	$2 \cdot 10^{-5}$,0.001
	95th percentile	$2 \cdot 10^{-5}$	$6 \cdot 10^{-5}$	$5 \cdot 10^{-5}$	$3 \cdot 10^{-5}$
Diclofenac	mean, SD	$9 \cdot 10^{-5}$,0.008	0.0004,0.007	0.0003,0.007	0.0002,0.002
	95th percentile	0.0002	0.0008	0.0006	0.0003
Sulfamethoxazole		ND	ND	ND	ND

SD = standard deviation
ND=not detected

Table 18 Hazard quotient (HQ) for the three scenarios for Piketberg DWTP in South Africa

HQ [-]	Infants, breast fed	Infants, formula fed	Children	Adults

Scenario 1					
Carbamazepine	mean, SD	$4\cdot10^{-5}$,0.001	0.0001,0.005	0.0001,0.003	$5\cdot10^{-5}$,0.001
	95th percentile	$7\cdot10^{-5}$	0.0002	0.0002	0.0001
Diclofenac	mean, SD	0.0003,0.003	0.001,0.030	0.001,0.021	0.0005,0.009
	95th percentile	0.0007	0.002	0.002	0.001
Sulfamethoxazole		ND	ND	ND	ND
Scenario 2					
Carbamazepine	mean, SD	0.0001,0.004	0.0003,0.014	0.0002,0.007	0.0001,0.003
	95th percentile	0.0001	0.0005	0.0004	0.0002
Diclofenac	mean, SD	0.001,0.008	0.004,0.08	0.004,0.07	0.002,0.026
	95th percentile	0.002	0.008	0.006	0.003
Sulfamethoxazole		ND	ND	ND	ND
Scenario 3					
Carbamazepine	mean, SD	$1\cdot10^{-5}$,0.0002	$3\cdot10^{-5}$,0.0008	$2\cdot10^{-5}$,0.0004	$1\cdot10^{-5}$,0.0002
	95th percentile	$2\cdot10^{-5}$	$6\cdot10^{-5}$	$5\cdot10^{-5}$	$3\cdot10^{-5}$
Diclofenac	mean, SD	$9\cdot10^{-5}$,0.0008	0.0004,0.009	0.0004,0.008	0.0002,0.003
	95th percentile	0.0002	0.0008	0.0006	0.0003
Sulfamethoxazole		ND	ND	ND	ND

SD = standard deviation
ND=not detected

Hazard quotient for the river in Sesmylspruit River: Studying the HQ result from the QCRA-model when using raw water concentrations from Sesmylspruit River with the same scenarios as for Withoogte and Piketberg DWTP, it is noticeable that the HQs is significantly higher using the raw water intake from Sesmylspruit River. Carbamazepine had about 30 times higher HQ (95th percentile) than for Withoogte and Piketberg DWTP and diclofenac had about 80 times higher HQ (95th percentile). Since the raw water concentration in Sesmylspruit River was higher, this result was expected. For Sesmylspruit River sulfamethoxazole was detected, and it was seen that after diclofenac, sulfamethoxazole had the second highest HQ followed by carbamazepine for all scenarios. With conventional treatment and chlorination (scenario 1) there was no risk showed, either with additional GAC filter treatment (scenario 3). However, when there was no treatment (scenario 2) the HQ for diclofenac is ranging between 0.180 to 0.610 where the highest HQ is for formula fed infants. Sulfamethoxazole and carbamazepine were showed to have a higher marginal before it becomes a risk for scenario 2, and the highest HQ is 0.013 for carbamazepine, and 0.03 for sulfamethoxazole. The HQs for sulfamethoxazole are showed to be 3 times higher in scenario 2 when there is no treatment, than in scenario 1 where there are conventional treatment + chlorination used. When GAC filters are used (scenario 3) the HQ for sulfamethoxazole is reduced, and the HQ in scenario 3 is two times lower than in scenario 1.

Comparison to HQ based on DWEL's with recommended default values: Compared with the HQ that is based on recommended values (see Table 20), the HQ based on recommended values ($HQ_{recommended}$) shows higher values compared to the all the HQs presented above, showed in Table 17, Table 18 and Table 19. Only, scenario 2 are presented, showing the worst-case-scenario. See Appendix 9 for the $HQ_{recommended}$ for Withoogte

DWTP, Appendix 10 for Piketberg DWTP and Appendix 11 for Sesmylspruit River. Since the recommended default values for ingestion rate per body weight was higher for both children and adults, at the same time as the ADI was one of the most conservative ADI, it was expected that these $HQ_{recommended}$ would result in higher values. Diclofenac showed the highest $HQ_{recommended}$, which was the same result as in Table 17, Table 18 and Table 19. Results of $HQ_{recommended}$ for Withoogte and Piketberg DWTP had higher values than the HQs in Table 17 and Table 18, but not significantly higher, and $HQ_{recommended}$ was still below 1 with a high margin. However, for the results from Sesmylspruit River the “worst case” scenario 2, with no treatment, the result of $HQ_{children, recommended}$ for diclofenac was above one (HQ>1) both for the mean ($HQ_{children, recommended}$ = 1.5) and the 95th percentile ($HQ_{children, recommended}$ =2.4), indicating a risk for children exposed of diclofenac from drinking water. With conventional treatment and removal with chlorination (scenario 1) of the river water in Sesmylspruit River the $HQ_{children, recommended}$ (95th percentile) was showed to be reduced to 0.8, and with additional treatment of GAC (scenario 3) the $HQ_{children, recommended}$ was reduced to 0.3.

Table 19 Hazard quotient (HQ) for the three scenarios for Sesmylspruit River, South Africa

HQ [-]		Infants, breast fed	Infants, formula fed	Children	Adults
Scenario 1					
Carbamazepine	mean, SD	0.001,0.036	0.004,0.100	0.003,0.063	0.002,0.030
	95th percentile	0.002	0.006	0.005	0.003
Diclofenac	mean, SD	0.022, 0.160	0.090,1.50	0.072,1.40	0.036,0.540
	95th percentile	0.055	0.190	0.140	0.080
Sulfamethoxazole	mean, SD	0.002,0.080	0.006,0.160	0.004,0.070	0.003,0.090
	95th percentile	0.003	0.010	0.007	0.004
Scenario 2					
Carbamazepine	mean, SD	0.003,0.110	0.010,0.400	0.006,0.200	0.003,0.0.085
	95th percentile	0.004	0.013	0.010	0.005
Diclofenac	mean, SD	0.070, 0.540	0.300, 5.000	0.240,4.200	0.120, 1.700
	95th percentile	0.180	0.610	0.440	0.250
Sulfamethoxazole	mean, SD	0.007,0.350	0.020,0.710	0.012,0.260	0.009,0.400
	95th percentile	0.009	0.030	0.021	0.012
Scenario 3					
Carbamazepine	mean, SD	0.0004, 0.02	0.001,0.070	0.0009,0.034	0.0005,0.014
	95th percentile	0.0005	0.002	0.0013	0.0008
Diclofenac	mean, SD	0.007,0.057	0.030,0.510	0.025,0.430	0.012,0.170
	95th percentile	0.017	0.060	0.044	0.025
Sulfamethoxazole	mean, SD	0.002,0.130	0.005,0.250	0.003,0.080	0.002,0.140
	95th percentile	0.002	0.006	0.004	0.002

SD = standard deviation

Table 20 As comparison, Hazard quotient (HQ) for Sesmylspruit River, South Africa with DWEL from recommendations, for scenario 2.

HQ recommendations [-] for scenario 2		Children	Adults
Carbamazepine	mean, SD	0.050,0.004	0.017,0.001
	95th percentile	0.060	0.019
Diclofenac	mean, SD	1.500,0.510	0.490,0.170
	95th percentile	2.400	0.800
Sulfamethoxazole	mean, SD	0.051,0.015	0.017,0.005
	95th percentile	0.080	0.026

SD = standard deviation

Ranking parameters that affecting the HQ: In the health risk assessment (using Monte Carlo simulations), the inputs are ranked by the effect they have on the mean of HQ. For almost all HQ the input affecting the mean of HQ mostly was the acceptable daily intake (ADI), which was significant compared to the other input parameters: raw water concentration, treatment efficiencies of conventional treatment, chlorination, GAC filters, ingestion rate per body weight (IR), and proportion of ADI allocated to drinking water (P). Even though the ADI affected the mean of HQ to become significantly higher HQs, it did not, in any of the scenarios or pharmaceuticals, for any of the populations group or for none of the raw water intake for Withoogte or Piketberg DWTPs, go above 1. Which means that even if ADI contributes to a high variance of HQ it is no risk using any of the ADI, not even the most conservative ADI. See Figure 14 for the inputs affecting the mean of HQ for carbamazepine and children for scenario 3 in Piketberg DWTP, that shows that a low ADI can affect the mean of HQ to go up to 0.00019, which means that even if the lowest ADI is used for carbamazepine in scenario 3 for children in Piketberg DWTP it never shows a risk. This was the same for all pharamaceuticals, scenarios and population group for Withoogte DWTP and Piketberg DWTP, that even if the lowest ADI was used it never affected the mean to the extent that it showed a risk (HQ>1). However, for Sesmylspruit River the mean for HQ for diclofenac for scenario 2 was above 1 for children and infants that are formula fed using the lowest ADI as input. In Figure 15 the inputs affecting the mean of HQ for diclofenac and children for scenario 2, that shows that a low ADI can affect the mean of HQ to go up to 1.98, which was similar values as when HQ was based on recommended default values, in Table 20. The other input parameters have about the same effect on the HQ mean, but the order varies between the scenarios and population group.

In Appendix 6-8 the ranking list of the input that are affecting the mean of the HQ for scenario 1-3 for infants that are formula fed is presented for Withoogte DWTP, Piketberg DWTP respectively using raw water from Sesmylspruit River. Only the population group: infants that are formula fed is presented in the appendix, since it is the “worst case” and it is therefore possible to see if the ADI can affect the mean to the extent that it becomes a risk (HQ>1).

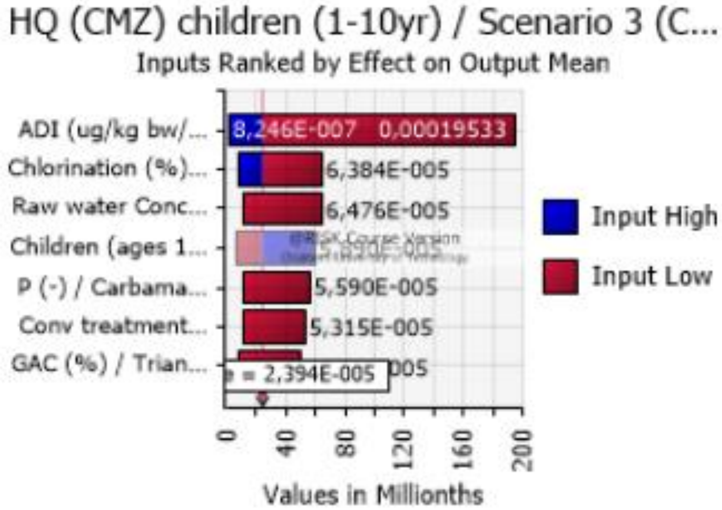

Figure 14 The inputs affecting the mean of Hazard Quotient (HQ) for children for diclofenac (DIC) in scenario 3 using raw water intake for Piketberg DWTP. Highest ranking did ADI have

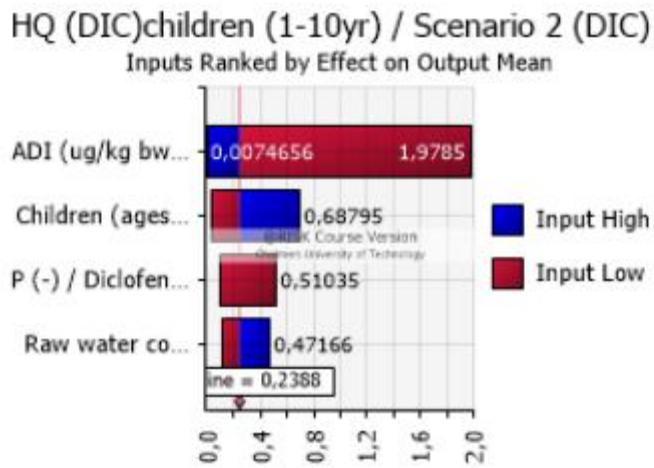

Figure 15 The inputs affecting the mean of Hazard Quotient (HQ) for children for diclofenac (DIC) in scenario 2 using raw water intake for Sesmylspruit River. Highest ranking did ADI have, and showed HQ mean >1 when the lowest ADI was used

4.2 Empirical summary of interview study

In this part the empirical results of the investigation of the public's perception of de facto water reuse are presented.

During the interviews, the overall feeling was that people seem to be positive and supportive to the concept of water reuse but would really like more knowledge and education within the area to support it in a greater extent. The results from 9 out of 10 interviews was that they would like more knowledge within the area. Among the interviewees, it was seen a wide range of knowledge level about water reuse and the overall water cycle. Independent of knowledge level, the same result was significant: either if you are an expert, had some knowledge or not a clue of what the concept are or mean, they all expressed the same importance of knowledge sharing and spreading of information to the public. Expressed by several of the interviewees was that the public involvement and education within water reuse need to increase and it is of highly importance to reach out to many more people than today. The majority also expressed that more knowledge and education of water reuse together with information of that the water is safe to drink, they think will lead to positive perception among the people. 8 out of 10 of the interviewees described that they would like more involvement from politicians, municipalities, and water suppliers. One interview that had a high knowledge in the subject stated: "E*veryone needs a bit of education around and maybe we need campaigning and showing that we can ensure safe water"* and some other with low knowledge asked for education and knowledge and suggested study visits, flyers or movies reaching out to the public. Overall, the majority expressed situation from their ordinary life witnesses and showing that they are open to water reuse actions.

The majority of the interviewees expressed a concern of potential health risks due to unsafe water quality. Health related risks connected to contaminated water showed to be of high importance for many of the interviewees, which emerged in different ways. Some expressed that the water could show inconsistency in taste, colour and smell, a factor influencing the trust, if it is safe or not. The study showed that most of the interviewees sometimes had doubts if the water in their tap is safe to drink, and two interviewees mentioned that they would always buy bottled water if they could afford it. Some interviewees stated that it was not only bacteria's and contamination of treated wastewater that is of concern, but also chlorination was a concern since the potential of harmful by-products appearing after the treatment processes. One interviewee also mentioned concerns regarding chemicals and pharmaceuticals in the drinking water, and health related issues connected to that. These health-related concerns seemed to be independent on education level, occupation, and age.

The combination of having health-related doubts if the water is safe to drink together with a feeling of lack of knowledge is potentially the most significant result in the interview study. Some interviewees expressed that ”The *water that comes out of the tap, I don't know if that water is reused water or fresh water or how fresh or how safe that water really is*” and another interviewee stated *“I don’t know if the wastewater is 100% clean. I don’t know if the chlorine will kill all the bacteria in the water. They don’t educate us about that”*, and another said *“I'm not an expert on that field, I don't know the things that they are using, what they can do, what harm they could do to our human body. You see, if those things can be 100% sure I would not have a problem”*. These sayings in the interviews left a mixed feeling of fear and helplessness among the people. When talking about authorities and politicians involving the public in any actions in South Africa, a feeling of mistrust and no involvement together with lack of stakeholder analysis was sometimes showed, and this was an overall feeling of the interviews. Some of the interviews expressed that they had no choice, the water they are offered is the water they will consume. Upon this, emotions connected to contaminated water was mentioned and was pointed out during the interviews. One interviewee described having a grandma and grandpa that had no idea of the concept of water reuse but drank the tap water without any doubts at all, blissfully unaware, but when they later heard about the concept of water reuse and that they are using that water source they directly expressed disgust.

While asking about what impact the level of trust to authorities and the people operating and maintaining the water system the result showed to vary in this study. The majority showed trust to cleaning techniques, but some interviewees expressed a concern and said that this was based on the people operating the system or human error. 4 out of 10 of the interviewees expressed a lack of trust for authorities and some expressed the correlation to other issues such as corruption in municipalities and governments maintaining the water systems in South Africa. The perceptions and trust to the system and authorities was among people working for the municipality and government high, but also others were positive. One student said, *“I do have 100 % trust in all municipalities so far”*. Others, independent on occupation expressed more of the opposites, *“I don’t have trust in the people, I don't have trust in the politicians”* and another explained *“I don’t have a lot of faith in the municipality”* and the same person expressed that they would trust the water quality so much more if the water supply system was private.

To overcome the barriers of water reuse connected to trust the interviewees were asked what could help them to increase their trust for authorities and in the end increase the support of water reuse. For many, the key seems to be the involvement of the public. Some people highlighted that all people need to be involved and need to feel that they are involved. One described *“They must be open with the people, transparent with the people”*. Another said that all people need water, and they are forced to use the water supply that is available where they live. Some interviewees really pointed out that there is no other water to choose and therefore they need to accept the water they get, but the thing is that they would support and trust the water quality more if they felt that they got information that it is totally clean and safe to drink. On the other hand, the two interviewees that stated that they had full trust in the system said that for them, the best proof of all that the water is clean is the fact that they have been drinking it their whole life without getting sick, *"That is proof enough for me"* one said.

Overall, the acceptance compared to the rejection of the concept of water reuse seemed to be impendent. The deeper understanding of the interview study has been that most people seem to be opened to water reuse implementations, and some interviewees expressed motivation in being environmentally friendly and this could result in higher acceptance. Still, some of the interviewees described health related concerned that they sometimes feel doubts if the water is safe. The same people pointed out that this concerned could easily be milder if more actions would take place such as campaigning or projects among the people. When asking about practical actions that could increase the trust study visits, movies of how cleaning technologies works, public health tests, flyers with information and commercial trying to spread information come to their minds. Some interviewees pointed out if water actions like these would take place and information would be spread and found with easy access, this could have ripples on the water. Especially one interviewee stated that he felt responsibility to share the information he has with his friends and family and all people he met and they in turn told all they know and so on.

Table 21 present and sum up the main statements of the interviews in the aim to get an overview of the different results and perception (acceptance or rejection) in water reuse. The table describes the interpretations of the main arguments that emerged in the interview study, based on the questions: Do the interviewee know of the concept water reuse, do the interviewee sometimes have doubts if the water is safe to drink, do the interviewee have trust in authorities such as municipalities, do the interviewee accept the water reuse as a water source and how could their trust be increased. For the full transcription of interviews conducted, see Appendix 12-21.

Table 21 Empirical interview study

Interviewee	Occupation	Know of WR?	Doubts on safe to drink?	Trust in authorities?	Accept WR? (comment)	How to increase trust?
Interviewee 1	Government/ Municipality	Yes	Have doubts	Yes, very much	Yes/No (rather no, but OK if nothing else available)	Improve cleaning technics, (ozonation)
Interviewee 2	Unemployed	No	Have doubts	Not that much	No	Public involvement, Knowledge sharing
Interviewee 3	Government/ Municipality	Yes	No doubts	Yes, very much	Yes	Public involvement, Knowledge sharing
Interviewee 4	Unemployed	No	Have doubts	Not that much	Yes/No (rather no, but OK if nothing else available)	Public involvement, Knowledge sharing
Interviewee 5	Cleaner	No	Have doubts	Not that much	Yes/No (are concerned, want proof of that it is safe)	Public involvement, Knowledge sharing
Interviewee 6	Student	Yes	No doubts	Yes, very much	Yes	Public involvement, Knowledge sharing
Interviewee 7	Student	Yes	Have doubts	Yes, very much	Yes	Public involvement, Knowledge sharing
Interviewee 8	Government/ Municipality	Yes	Have doubts	Not that much	Yes	Public involvement, Knowledge sharing
Interviewee 9	Teacher	Have heard of	No doubts	Yes, very much	Yes	Public involvement, Knowledge sharing
Interviewee 10	Unemployed	Have heard of	No doubts	Yes	Yes	Nothing

WR=Water reuse

5 DISCUSSION

5.1 Raw water input in the QCRA-model

The pharmaceutical concentrations in the raw water intakes in Berg River are based on few samples (10 samples per raw water intake). If concentrations are measured for a substance, the number of measuring points affect how well the distribution correspond to the reality. Due to the few samples in this study it was difficult to see what distribution the concentrations where following, but since pharmaceutical concentrations have been seen following a Log-normal distribution in the environment, in the past, it was also assumed to be the case in this study (Kumar & Xagoraraki, 2010; Kumari & Kumar, 2020). Due to the low amount of data from Berg River and that it was normal flow during the time of sampling which means that the pharmaceutical concentration was diluted, pharmaceutical concentrations from Sesmylspruit River, South Africa was used to exemplify a worst-case scenario, since it is possible that the concentrations could be higher than detected in the few samples made in this study, due to season, trends in pharmaceutical usage and disposal, drought or rain intensity or population growth (WHO, 2011b). For example, a period of drought may increase the content of treated wastewater in Berg River, and the pharmaceutical concentrations will probably then be increased significantly and be in the same order of magnitude as the concentrations measured in the Sesmylspruit River.

In general, Berg River seem to be a less contaminated river compared to other rivers in South Africa and the WWTPs along Berg River are better than other WWTPs in the country (C. Swartz, personal communication, April 09, 2021). Comparing the concentrations in the raw water intake for Withoogte and Piketberg DWTPs the concentrations are in the same order of magnitude as in Swedish surface waters which indicate that the results are relatively low since Swedish surface water are known to be pristine regarding pharmaceuticals (Karki et al., 2020; Tröger et al., 2018; Ullberg et al., 2021a). The concentrations measured in Withoogte and Piketberg are as well in the same order of magnitude as the concentration in surface water in the Germany and the USA (Snyder, 2008; Webb et al., 2003). However, the raw water concentration in the Sesmylspruit River used in the Health risks assessment as a worst-case scenario, showed higher concentrations all pharmaceuticals than observed in Sweden (Karki et al., 2020; Tröger et al., 2018; Ullberg et al., 2021a). The highest detected concentration of carbamazepine in Sesmylspruit River was showed to be 30 times higher than the mean concentration detected in Swedish surface waters (Karki et al., 2020; Ullberg et al., 2021a). For diclofenac the concentration detected in Sesmylspruit River was about 40 times higher than in Swedish surface waters (Tröger et.al., 2018). However, Sesmylspruit River does not have the highest detected concentrations in surface waters in South Africa and according to Archer et.al. (2017) and Schwab et.al. (2005) the concentrations of pharmaceuticals have been detected in the same order of magnitude, in other surface waters in South Africa and in the US. Knowing this, it was reasonable to use the Sesmylspruit River as a worst-case scenario in this study.

Comparing the three pharmaceuticals studied, diclofenac had the highest concentration in Withoogte and Piketberg raw water intake, meanwhile carbamazepine showed the most variation. Sulfamethoxazole was not detected, and probably occurred in too low concentrations for detection at that given time. For raw water in Sesmylspruit River, diclofenac had the highest concentrations followed by sulfamethoxazole and then carbamazepine. A possible explanation of the relatively high concentration of diclofenac and sulfamethoxazole can be explained by both diclofenac and sulfamethoxazole are distinguished by the fact that they are used by basically everyone, while carbamazepine has a narrower consumption group (The Swedish Association of the Pharmaceuticals Industry, 2020c).

Lastly, Schwab et.al. (2005) means that the minimum therapeutic dose (MTD) is correlated to the environmental concentrations, e.g., higher doses taken by the public the higher doses will be detected in the environment. This is opposite to the results seen in this study, since diclofenac, which has the lowest MTD (25 mg/day) was the pharmaceutical showing the highest detected concentrations in all raw water intake in this study, compared to sulfamethoxazole (MTD of 800 mg/day) and carbamazepine (MTD of 200 mg/day). To put the MTD in a context, the raw water concentrations in Sesmylspruit River are 10,000 - 1,000,000 lower than the MTD which prove that doses measured from the environment, are significantly lower and will thus never reach the level of MTD, which is in line with Schwab et.al. (2005) statements.

5.2 Exposure concentration from the different scenarios

In this part the exposure concentrations in the final drinking water are discussed for the three scenarios.

Scenario 1

When analyzing scenario 1 (conventional treatment + chlorination) it showed a relatively high removal of the studied pharmaceuticals (mean reduction of the pharmaceuticals of 50-70%). The exposure concentration of carbamazepine from scenario 1 from Withoogte and Piketberg DWTP showed more than ten times higher concentrations than detected in drinking water in Sweden (Karki et.al., 2020), but more than 2 times lower than the concentrations detected in drinking water in other places in South Africa (Archer et.al., 2017a). Diclofenac, on the other hand, measured in Withoogte and Piketberg was 50% lower than concentrations detected in Swedish drinking water (Tröger et al., 2018). Data on diclofenac in final drinking water was not found for other parts in South Africa. It was not expected that diclofenac would have lower concentrations than other parts of the world since the literature showed that South Africa generally has higher concentrations of pharmaceuticals (Archer et.al., 2017a). Therefore, the exposure concentrations using raw water from Sesmylspruit River validates the reliability of the study since they result in higher exposure concentrations than using raw water for Withoogte and Piketberg DWTP.

Even though some studies (Snyder et.al., 2003; Vieno et.al., 2007; Tröger et.al., 2018) have stated that the removal efficiency can be negligible for conventional treatment if the log K_{ow} (the level of hydrophobicity) of the pharmaceutical is lower than 5, which is the case for carbamazepine (log K_{ow} =2.45) diclofenac (log K_{ow} =4.51) and sulfamethoxazole (log K_{ow} =0.89), other studies reported removal up to 30% for carbamazepine, 37% for diclofenac and 20% for sulfamethoxazole (McKie et al., 2016; Snyder et al., 2003; Ullberg et al., 2021b). These removal efficiencies were used in the simulation of the QCRA-model. Since the removal of sulfamethoxazole was found for only coagulation and sedimentation processes combined, and not including sand filtration, the treatment efficiency used in the QCRA-model might be too low compared to the actual case. However, since removal of sulfamethoxazole according to the literature are expected to be reduced less efficient than carbamazepine and diclofenac due to a lower log K_{ow} it was argued to be a reasonable assumption. One of the most reliable sources and study found was a full-scale study of Ullberg et.al. (2021b) with removal efficiencies of carbamazepine, chosen to be used in the QCRA-model. The removal efficiency for carbamazepine in coagulation, flocculation, sedimentation, and rapid sand filtration was shown to have negative removal which was probably due to desorption of previously adsorbed carbamazepine (Ullberg et al., 2021b). For diclofenac and sulfamethoxazole, no minimum removal was found in the literature review and therefore the value zero was assumed and set as the minimum removal in the QCRA-model, as the lowest value in triangular distribution. However, according to Ullberg et.al. (2021a) desorption might occur even for other chemicals, and this might be the case for diclofenac and sulfamethoxazole but was not considered in this study since no data on this was found. Comparing all the treatment steps chlorination had the most significant variation in treatment efficiency, especially for carbamazepine (from 2.6% up to 85% removal efficiency). This means that removal with chlorination is the most uncertain treatment step, even if it has the possibility to remove up to 85% of the compounds, it might only remove 2.6% if the conditions are bad, such as to high/low pH.

Scenario 2

When analysing scenario 2 (no treatment) it was assumed that the final drinking water (exposure concentration) was equal to the raw water concentration. The exposure concentration of carbamazepine in this scenario are in line with concentrations found in drinking water in other places in South Africa (Archer et.al., 2017a), diclofenac was not found in other South Africa's drinking water, but where about two times higher than diclofenac detected in Swedish drinking water (Tröger et al., 2018). It is important to note that this assumes a technical failure or other occasions when the DWTPs does not work properly, therefore this scenario might be too conservative and does not represent a whole lifetime of exposure concentrations, since the technical failure will probably only last for a short period of time. However, the result from this scenario gives an indication of what the exposure concentration can be if the treatment does not work according to the literature. It could also be a scenario used when no data is available of treatment efficiency, or if it is not possible to fully rely on that the treatment efficiency are as effective than predicted (Schwab et.al., 2005).

Scenario 3

In scenario 3 (conventional treatment + chlorination + GAC filter) it was seen that the exposure concentration was reduced, and the levels of carbamazepine was only 5 times higher than concentrations detected in Swedish drinking water (Karki, et.al., 2020), and more than ten times lower than levels detected in drinking water in other places in South Africa's (Archer et.al., 2017a). Levels of diclofenac from Withoogte and Piketberg DWTPs was about five times lower than concentrations detected in Swedish waters (Tröger et.al., 2018). As stated in the theoretical background, the most important parameter affecting the treatment efficiency is the log K_{ow} (Snyder et al., 2003). GAC filters removes hydrophobic compounds (with a log K_{ow} >2) more efficiently. In this study removal efficiency for sulfamethoxazole was chosen, based on literature, to be relatively low, which is reasonable because of that sulfamethoxazole is not a hydrophobic compound, meanwhile carbamazepine and diclofenac had higher removal since they have log K_{ow} >2. However, there was not enough data on removal efficiency of diclofenac with GAC filters found, only one reported removal of 69%. This might impact the reliability since the efficiency depends much on prevailing circumstances and conditions and will therefore probably vary. Though, the variation of the treatment efficiency with GAC filters was relatively low for both carbamazepine and sulfamethoxazole, compared to for example chlorination. Hence, it was argued reasonable to only use one value of treatment efficiency of diclofenac. The result for this future scenario with additional treatment with GAC filters has the potential to be very good as an additional step to conventional treatment and chlorination. Though, it is of highly importance to ensure the right conditions for GAC filters because this may impact the treatment efficiency. If there is too high content of organic matter, or if the GAC filters is too old the removal efficiency will be reduced (Snyder et.al., 2003).

5.3 Dose-response development

The drinking water equivalent level (DWEL) [µg/l] is the highest acceptable daily dose, where there will be *no* response or effect in any human being. Within all the population group studied (breastfed and formula fed infants, children and adults) the variation of DWEL was significant and the 95th percentile was about 100 times higher than the 5th percentile. Comparing the DWELs to reference values in the literature (denoted as either DWEL, PNEC or guideline value) a significant variation was seen as well, where carbamazepine varied from 10 µg/l, to 3333 µg/l (Snyder, 2008; Kumar & Xagoraraki, 2010; NRMMC, 2008). For diclofenac it varied between 1.8 µg/l - 48 µg/l which was a lower variation than seen in this study (Snyder, 2008; NRMMC, 2008). For sulfamethoxazole, the reference values in the literature varied between 35 µg/l to 8,400 µg/l (Snyder, 2008; Schwab et.al., 2005; NRMMC, 2008). Even though there is a great variation in the DWEL calculated in this study, there is a reasonable certainty that there will not be risk if a human is exposed to the same level as the DWEL, since uncertainty factors have been applied and are relatively similar order of magnitude to what is found in the literature, or even higher (Schwab et.al., 2005; NRMMC, 2008). Though, it is more uncertain to say that if the exposed concentration is above the calculated DWEL there *will* be a risk.

The variation in the DWEL was mainly due to the variation and uncertainties in ADI, since the input parameter affecting the mean of the DWEL the most was ADI. The other input parameters where ingestion rate (IR) and proportion of ADI allocated to drinking water (P). Since the calculated ADIs in this study was based on different animal studies, variations on the duration of exposure, as well as variations in different toxicological or therapeutic endpoints, that impacts the ADI. The uncertainty factors used in this study were set between 300-3000 which is a significant factor impacting the variance of ADI. ADI developed is of high importance, since it shows that, depending on what ADI that is chosen for the calculation of DWEL, it turns out affecting the dose response function development significantly. Depending on assumptions made in the development of ADI the result of the dose response function development will turn out differently.

Analysing the results, the calculated DWEL for the different population groups (formula fed and breastfed infants, children and adults) have different DWELs. The calculated $DWEL_{infants,\ formula\ fed}$ was the lowest in comparison to the other population groups followed by $DWEL_{children}$. The low $DWEL_{infants,\ formula\ fed}$ can be explained of that infants that are formula fed ingest significantly more tap water per body weight compared to the other population groups, and the ingestion rate per body weight is about 7 times higher than for adults. However, infants that are breastfed ingest about 2 times more water than adults per body weight but still has a higher DWEL than adults. When calculating DWEL, ingestion rate per body weight (IR) and the proportion of ADI allocated to drinking water (P), works as two opposing parameters, are weighed against each other and therefore often even out the final result. A high value of P turns out in a less conservative DWEL, but a high ingestion rate express that you ingest a high amount of water per body weight, and therefore the DWEL will be lower, e.g. more conservative. In this study, the ingestion rate for infants that are formula fed was showed to be very high, (7 times higher compared to adults) but this are also weighted and balanced by the parameter P that was also very high, which turns out in a DWEL with a smaller difference: $DWEL_{adults}$ is only 3 higher than $DWEL_{infants,\ formula\ fed}$.

One important factor to notice, is that the DWEL is based on daily water intakes per body weight from an over 30 years old study, reported on daily intakes in America (US EPA, 2019). Why this is important is because daily water intakes can vary a lot between countries, depending on season and particularly where consumers are involved in physical work in hot climate (WHO, 2011a). Therefore, the intake rate per body weight might not be fully representative for South Africa. Compared to the default values recommended by WHO (2011a) of 60 kg body weight for an adult are 2 l/day, the mean from the study by US EPA (2019) based on drinking water consumption statics, are 1.2 l/day for a 60 kg body weight person. That is one possible explanation of why the DWEL based on recommended values is significantly lower than this study's result, using the old American study (US EPA, 2019) in health risk assessment. Another reason why the recommended values compared to the ones in the sensitivity analysis, is that the ADI established by NRMMC (2008) was used in the calculation, and NRMMC (2008) used a conservative approach, meanwhile the ADI used in the health risk assessment simulation included both the ADIs from NRMMC (2008) and ADIs using a less conservative approach.

5.4 Hazard Quotient and potential health risks

The results from the case study show that, with the concentrations that were detected in Berg River in in March and April 2021, there is no indication of human health risk in Withoogte or Piketberg DWTP (HQ<1). The method that was performed using Monte Carlo simulations gave the possibilities to simulate a range of possible outcomes and scenarios, with high and low ADI, high and low ingestion rates, both poor and good removal efficiency, leading to a certainty that the results of the hazard quotient (HQ) is showing the truth - that there is no risk of exposure to these three pharmaceuticals from the DWTPs today for any population group. This result is in line with the literature, that also show that there is no human health risk due to exposure of carbamazepine, diclofenac or sulfamethoxazole in other studies (Kumar & Xagoraraki, 2010; Kumari & Kumar, 2020; NRMMC, 2008; Schwab et al., 2005; Snyder, 2008; Webb et al., 2003). What differs in this study is that diclofenac had the highest HQ giving the indication that diclofenac is *closest* to a human health risk, which was the opposite of what the on study by Snyder (2008), where diclofenac was showed to have a lower HQ than carbamazepine and sulfamethoxazole (Snyder, 2008). This can partly be explained by the fact that the concentration from this case study shows higher concentrations of diclofenac than carbamazepine, meanwhile in the literature diclofenac has lowest exposure concentrations in final drinking water (Snyder, 2008; Webb et.al. 2003). Another possible explanation is that Snyder (2008) used a lower ADI for carbamazepine than diclofenac, meanwhile in this study, diclofenac was considered the most toxic compound and the most potent compound since it clearly has the lowest therapeutic dose compared to carbamazepine and sulfamethoxazole.

The raw water concentrations of the pharmaceuticals were measured during a normal flow and might increase in the future if there would come a severe drought and the raw water will have higher content of treated wastewater. Using the concentrations from reference river (Sesmylspruit River) could be seen a future scenario, where the concentrations have increased with up to 80 times, and even then, there are no risk (HQ<1) with the treatment processes that is used in Withoogte and Piketberg DWTPs.

However, when using a case with higher raw water concentrations (using raw water from Sesmylspruit River) the HQ showed to be significantly higher. For diclofenac in scenario 2, when there was no treatment, the HQ was almost 1, e.g., almost indicating a human health risk. With these concentrations, conventional treatment and chlorination is important in order to reduce the risk e.g., reduce the value of HQ. However, the removal by conventional treatment and chlorination might not be enough since the margin for HQ to become 1 is low for both infants that are formula fed and children. Therefore, in this case GAC filter, or other additional treatment may be argued necessary to ensure safe drinking water e.g., reduce the HQ so it has a higher margin before it becomes 1. The results when using the recommended default values ADI, ingestion rate (IR) and proportion of ADI allocated to drinking water (P) (NRMMC, 2008; WHO, 2011a) for the scenario with no treatment, is giving a HQ>1 for children exposed to diclofenac, which is indicating a human health risk. When using conventional treatment, chlorination and GAC filter (scenario 3) the HQ is reduced to 0.3, which means that there is no risk. This result also raises the importance of implementing an additional treatment step such as GAC filters if the raw water concentrations to the DWTPs is increased to the level like in Sesmylspruit River.

However, from these results it shows that diclofenac is closest to a risk, and during some circumstances (no treatment and higher raw water concentration) it might even be a human health risk. This means that it may be important to monitor diclofenac in the raw water concentration and in the final drinking water concentration to ensure that it does not exceed the DWEL. Also, since diclofenac is not recommended for children below 18 years, it is of extra importance to monitor diclofenac if the raw water concentrations are increasing to this level. Anyhow, if there would be no treatment, the DWTPs would have more potential health risks to be concerned about due to other substances than pharmaceuticals.

It is important to consider that the DWEL developed in this study is for long term exposure, meaning that if the exposure concentrations would exceed the DWEL for a short period of time, human health risk may not even then be of concern e.g., if the HQ would be above 1 for a short period of time. Therefore, the results from scenario 2 (with no treatment of the pharmaceuticals) should be taken as an indication if the exposure of the pharmaceuticals should be of concern or not since scenario 2 may only occur occasionally if there is a failure or breakdown in the DWTP. Further, since the DWELs developed are for a lifetime, it might not be fully representative to say that HQ>1 is a risk for infants, since they are only infants for a shorter period of time, but it gives an indication that it might be a risk.

As a last note, the DWELs developed are based on acceptable daily intakes e.g., the DWEL developed is the concentration of a pharmaceutical that are acceptable and does *not* cause a human health effect. This means that according to the result in this study a HQ below 1 for sure does not cause a human health risk. However, if the HQ goes above 1, it is no longer safe to say that there will *not* be a risk, but it is not certain if there *will* be an elevated risk either.

From the results in the sensitivity analysis, it was seen that ADI was the input parameter that are affecting the output mean the most. This result was expected since ADI had a great variation, but also that previous sensitivity analysis of sulfamethoxazole and carbamazepine stated that ADI is one of the main inputs contributing to variance (Kumar & Xagoraraki, 2010; Kumari & Kumar, 2020). However, this means that depending on what ADI chosen the results of the risk assessment will vary significantly, especially when using the raw water concentrations of diclofenac from the reference river (Sesmylspruit River). Since the raw water concentration of diclofenac was relatively high in the reference river, depending on what ADI that was used in the simulation the results showed a risk or not, HQ >1 when using a low ADI, and HQ < 1 when using a high ADI in the simulation, see Figure 15 (in the result chapter). Therefore, it may be necessary to standardize ADI to get similar risk assessment results in the future.

5.5 Interview study

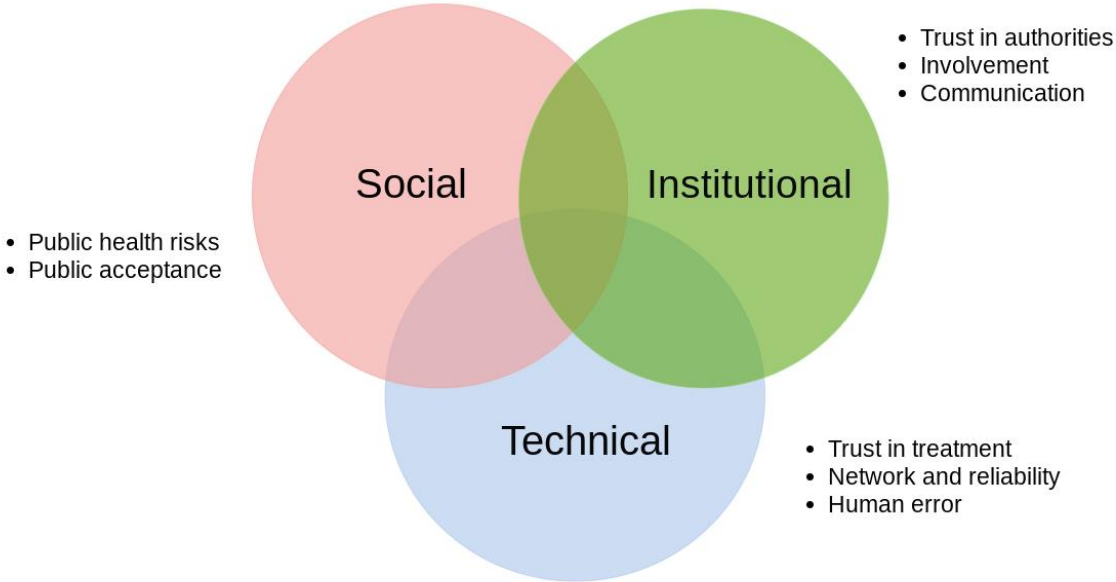

Figure 16 Factors and head categories influencing the perception of water reuse

Figure 16 describes the different head categories of factors showed to influence the perception of the concept water reuse, according to the literature study together with the empirical results of the interview study. Social, institutional, and technical influences are described to play an important role in the perception and acceptance or rejection connected to the concept of water reuse. Social aspects such as health risks impact the perception and technical aspects such as trust in treatment, reliability in the system together with human errors operating and maintaining have also showed to be critical in forming the perception. The three different factors that play an important role individually and in combination, but the most significant, stand-alone factor are the institutional aspect such as, trust in authorities, public involvement, knowledge sharing and communication within all stakeholders.

Health risk perception

The concern about health risk and health related awareness caused by exposure of potential contaminants drinking water has been highlighted as a huge barrier for water reuse implementations in the literature review. According to several studies of Alhumoud & Madzikanda (2010), Chen et al. (2015), Fielding et al. (2019), Friedler et al. (2006) and Garcia-Cuerva et al. (2016). This concern is connected to the acceptance or rejection and people overall experience of the concept of water reuse. These theories are also strengthened of the result in the empirical study, where the majority expressed health related concerned and that they sometimes had doubts if the water is safe to drink. A deeper understanding of people's concern was showed in many of the interviews, and if people had the economic possibilities, it seemed that they would rather buy bottled water instead of using tap water for drinking water purposes to make sure the water it is clean.

Also, the literature highlight that there is a need of that scientific information is available, such as that proof of that the water is quality tested is available for ordinary people not working within water supply. Dolnicar & Hurlimann (2009) and Water research commission (2018) points out that there is a lack of information and that people miss evidence and research available to overcome their health-related concern. The same mindset and pattern were showed in some of the interviews conducted in this study, and the interviewees said for example *"..I don't know what harm they could do to our human body…"* to express their health related concerns. The findings from literature putted together with the findings from the interview study points in the same direction: the publics overall perceptions on drinking water quality together with potential health risks perception is correlated to the level of acceptance of water reuse as an alternative water source.

According to the literature (Garcia-Cuerva et al., 2016) the so-called yuck-factor or feeling of instinctive disgust associated with getting in contact with contaminant water, especially from sewage is a feeling impacting the level of acceptance. The same expression and feeling were highlighted among some of the interviewees. Two of the interviewees expressed the feeling of this intrinsic disgust but could in a later stage of the interview see the whole picture and expressed that they could alter their view, and therefore accept water reuse as a necessary concept, when no other water sources being available. Other interviewees expressed if there is information available, such as proof of safe water to drink, this would increase their acceptance of water reuse. Weighting this together, experience negative emotions such as disgust in relation to reused water will be related to less acceptance, and on the other hand, feeling of positive emotions such as scientific evidence available or motivation of being environment friendly would reduce the concern of risk and generate greater acceptance. Dolnicar & Hurlimann (2009) points out that the motivation or acceptance for water reuse have a higher support in a proposition like this.

Public involvement and knowledge sharing of water reuse
The most significant link between the literature and the empirical study was that knowledge sharing and involvement of the public is the most impacting factor of all the parameters studied. If there is a lack of public involvement this have shown to be a major barrier for implementing water reuse programs (Fielding et al., 2019). Fielding et al. (2019) also points out some case studies proving results of successful implantations of water reuse programs, thanks to high public involvement - the higher public engagement, the higher public acceptance for water reuse. Also, according to Rice et al. (2016) having information of water reuse make you 10 times more likely to accept reused water for drinking water supply. The correlation between acceptance of water reuse and public engagement was highlighted in most of the interviews. Out of the 10 interviewees, 8 mentioned public involvement and knowledge sharing among the public as the most important factors to increase their trust for the concept of water reuse. The results from the literature study and the empirical study are strikingly agreeing. Many of the studies (Chen et al., 2015; Fielding & Roiko, 2014) examining the relationship between self-reported knowledge or awareness of reused water and acceptance conclude that more knowledge or awareness is associated with higher acceptance of the concept, and this relationship is the most significant result of the empirical study, which strengthen the reliability of the result.

An interesting approach that has developed, while looking into the relations in the literature review and empirical study are: what kind of information are available, how do the information reach out to the public, and also, is it formed to educate the public? Questions like: where is the focus in the knowledge that is meant to be shared? Several of the interviewees mentioned that they would like more knowledge within the area of water reuse and the overall water cycle. The majority stated themselves not having knowledge enough in the subject, and they would really like to have more knowledge to feel safe and involved, that in a long run would increase their trust. This, together with the literature review, confirms that public knowledge and information sharing regarding water reuse, the water cycle and cleaning techniques plays an important role. The analysis from this result is that there is of important to consider, confirm and make sure, there is public outreach and involvement as a part of the implementation in water reuse projects. Also, the public outreach must be targeted to all people such as all different stakeholder groups including general education together with proactive marketing of the water cycle. It is also of important that the focus is on transferring information and knowledge from experts to non-experts and how to improve the communication within the transferring.

In line with the literature together with the empirical findings, it has been showed in public outreach that there is critically important to emphasizing the benefits of reused water together with pushing on evidence that the water is safe to drink. There is a need of sharing information not only about the concept of water reuse, but also the evidence that it is 100% safe to drink. Out of the findings from the interview study it has been showed to be of highly importance to include both these parts, because a cropped part of knowledge (only water reuse concept, not that it is safe) could imply an opposite effect on the publics level of acceptance. This study was trying to answer the provocative questions asked by Dolnicar & Hurlimann (2009): *Is it better to avoid public consultation in introducing water from alternative sources?* The findings showed risks connected to this question, if only information is spread of how water reuse works, the yuck-factor kicks in and this may decrease the level of acceptance. Conclusions drawn from this interview study, there is a risk of leaving the public with only one part of the knowledge. Another point of view and potential risk in outreach to the public is to maybe create a concern that no one expressed or had before. Adding something interesting to the discussion a survey from a water reclamation plant in Windhoek, Namibia the majority of the drinking water consumers were very satisfied with their drinking water but only a minority knew that it originates from reused water (Fielding et al., 2019).

Trust in technologies and authorities

According to the literature of Fielding et al. (2019) and Haldar et al. (2021) the trust in authorities such as municipalities, governments, other water suppliers but also people working operating the water supply system, have been showed to play an important role in the amount of acceptance. These statements were strengthened of the results from the empirical study. In 4 out of 10 of the interviews the interviewees said that they had "not very much" of trust for authorities and some others pointed out that risk of human errors are significant factors impacting their trust negatively. Upon this, emotions connected to distrust is a potential barrier and something that need to be considered in implementations of water reuse programs. The empirical findings sometimes showed emotions of fear, helplessness and exclusion within area of water reuse, which showed to be impacting the overall perception of the concept badly. Some of the interviewees mentioned corruption and other related problems that impacting the level of trust. These emotions of helplessness expressed can be caused of a potential combination of having health-related doubts together with lack of involvement of authorities such as politicians, governments etc. The key findings of all interviews were that authorities/municipalities must be transparent and open with the people. The same theories were mentioned of Water research commission (2018) that a major part is that people seem to lack of trust in people operating the system. Hence, the findings from the empirical study together with the literature review the key seem to be that the involvement and transparentness with the people need to increase, and that could in a long-run potentially lead to increase of trust, that may turn in higher acceptance. One potential explanation of this is that people seem to be by nature aware of the unknown, and for many persons the psychological most logical is to treat ideas with contempt until they are proven trustworthy (Fielding et al., 2019).

The majority interviewed showed trust in cleaning technology and science, following the same result that studies from Fielding et al. (2019) showed. They describe that reliability in the network and potential system break down are relatively high compared to the concern of human error such as lack of management or operating working with the systems. The analyse of this is that there is of high importance to ensure the technical solutions together with improving the trust in authorities and people operating the water treatment schemes. The trust in reliability in technologies are relatively high but what have been seen is that only one single public health incident can destroy in the blink of an eye public trust gained over decades (Fielding et al., 2019). The conclusion of this is that the trust is strongly independent of that the technical systems are 100% sure because that trust is something very fragile and can easily fall apart if not managed right.

Socio-economic and demographic influences

Dolnicar & Hurlimann (2009) and Garcia-Cuerva et al. (2016) points out that education level is correlated with acceptance of water reuse. Also, Haldar et al. (2021) show that education together with socio-economic standard such as family income and house structure type, play an important role in level of acceptance. The empirical findings in this study does not say if education or socio-economic standard is correlated with acceptance of water reuse due to the limited size of the study (only 10 interviewees) and that the variation in education level, occupation, household standard, age etc., differed between the interviewees making it difficult to come up with a conclusion. However, the empirical findings from this study can give a hint if there is any correlation between education or socio-economic standard with acceptance of water reuse. What have been seen in the interview study is that the people that show the most rejection against water reuse are the persons with lower education level, and 2 out of 3 that was negative towards water reuse was unemployed. No other significant socio-economic and demographic links was detected in this study. However, an observation from the empirical findings was that the acceptance of water reuse does not seem to be depended on sex or age.

Upon this, another interesting aspect that have showed to be relevant is how people affect others in their surroundings. Fielding et al. (2019) mentioned studies that showed: perceptions of other people's level of support are often based on or reflected in their own level of support, those who are supportive think that other also are supportive, and those who do reject it think that other people also reject it. This theory was easy to find in the stories and mindset of the people interviewed in this study. Also, Dolnicar & Hurlimann (2009) describe that friends and family are the most common to influence the level of support and the overall behaviour, what we also have seen proof of in the interview study asking about who have learned them what they know about water reuse. Two of interviewees even expressed that they in every situation possible they try to spread the information and knowledge they have to the people they meet. They expressed that it felt that they had a task to educate their friends and family, in the aim to spread the important information they have about water reuse. According to Haldar et al. (2021) many people express feelings of understanding of the increasing water scarcity situation worldwide. This feeling of responsibility within the task to spread information and knowledge people have, either for health-related reasons or for taking environmental responsibility or both, could really support the involvement and possibility to reach out to the public. If involvement and public engagement of the public such as campaigning, would be done as a part of the implementations of water reuse programs water reuse this analyse predict that it would be with higher success. The conclusion is that it could perhaps return in a win-win situation and that knowledge that is out there will then be spread even more by the public themself. This could later return in that the public show higher support and therefor also responsibly that will turn into willingness of be a part of water saving actions. Hence, the public will be on the right track and will be motivated to support water reuse programs in a higher scale.

6 CONCLUSIONS AND FUTURE STUDIES

In this chapter the final findings and conclusions will be presented, together with potential links of the QCRA and the perception of the concept of water reuse. Also, suggestions of future studies will be presented.

6.1 Conclusions

- The result from the Quantitative Chemical Risk Assessment (QCRA) show that there is no human health risk for any of the population groups studied through exposure of carbamazepine, diclofenac or sulfamethoxazole in the drinking water supply from Withoogte or Piketberg DWTP, even if there would be events with no treatment.

- Diclofenac is the pharmaceutical that show results closest to a human health risk. If a strict conservative approach would been applied, with higher raw water concentrations from a more polluted river in South Africa and no treatment in the DWTPs, the risk assessment indicates that diclofenac may pose a health risk for children. Hence, diclofenac is the pharmaceutical from this study showing the highest importance to monitor in the future.

- Additional treatment with GAC filters in the DWTPs was seen to reduce the human health risk. If the incoming raw water concentrations of carbamazepine, diclofenac or sulfamethoxazole to the DWTPs will increase in the future, it is suggested to implement an additional treatment step, such as GAC filters to reduce the potential health risks. According to this study it is of most important to reduce the potential health risk of diclofenac.

- Most people seem to accept water reuse as a water source, but the majority expressed a concern of health-related risks and doubts if the water is safe to drink. The most significant findings from the interview study on perceptions show that more knowledge sharing, information spread and outreach to the public within the area of water reuse is crucial to accept water reuse as an alternative water source. This literature review together with interview study have showed that public involvement is lacking, that correlates to a lower acceptance of the concept of water reuse. The public, independent on education level, strive to be informed and be ensured there are no health risks of drinking the tap water they are offered.

- This study concludes that concerns regarding health risks are a great barrier to implement water reuse actions. Therefore, risk assessments like performed in this study which proof chemically safe water quality together with higher public involvement actions are key factors suggested for a successful water reuse implementation.

- The methodology of the QCRA developed in this study can be used for other chemicals and pharmaceuticals of concern in drinking water.

6.2 Future studies

- As a future study it would be valuable to investigate a wider range of chemicals, such as other pharmaceuticals, hormones, pesticides or PFAS and following the same method for QCRA as in this study. A benefit of doing a risk assessment of more pharmaceuticals is the possibility to rank and prioritize the pharmaceuticals based on the level of risk. The priority list could later then be used in decision making for what treatment and strategies for further development of drinking water plants and management, and to priorities what pharmaceutical that is important to monitor in the existing DWTPs.

- Future studies of health effects and which toxicological effect of long-term exposure of the pharmaceuticals studied may occur, are suggested to be further investigated. The findings from the literature review in this study point out that long-term exposure of low doses of pharmaceuticals is a relatively unexplored topic and therefore many uncertainty factors have been applied. Upon this, it would be interesting to study the effect that the pharmaceuticals might have together. Are there any potential cocktail effects and can toxicological pathways be added? How is the bioaccumulation in the body and how is the pharmaceuticals transferred to the embryos and further generations? These questions could be interesting to investigate in further studies.

- Since it was showed that public involvement and communication between the water suppliers and the public is important to gain trust and acceptance of water reuse programs, it would be interesting to further investigate how the involvement could be done in a successful way. A suggestion would be to further investigate the successfulness of different actions such as health tests, movies about the drinking water treatment plant, study visits or other campaigning in the aim to get the public to feel safe to drink the water such as communicating results of risk assessments.

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Appendix 1

Hey, we are Emelie and Ellen, Swedish students from Chalmers University of Technology working with a consulting company in Capetown..

We will investigate: *"The public's knowledge and overall view of the water cycle and drinking water behavior along the Berg River"* All results will be Anonymous.

- Is it okay that we record this?

Introduction/Background:

1. Can you describe a little bit of yourself? What is your occupation, where do you live?

2. How old are you?

3. In which region (municipality) do you live and how long have you been living in this region?

4. What does your household look like? apartment, villa etc. and how many people?

And now we will ask you about water and your drinking water behaviour.

5. Do you have knowledge or an idea of where your tap water comes from?

6. Do you have any idea of how the water cycle works where you live? wastewater, drinking water etc? After using the water for flushing what do you think happens with it?

7. How do you use your tap water at home, what do you use it for?

8. Do you drink it straight from the tap?
    1. If not, do you treat it yourself?
    2. How do you do this?
    3. Why do you treat the water?

9. Do you sometimes use other water sources for drinking water (beside the tap water in your household)?
    1. When do you do this?
    2. Why do you do this?

10. Do you anytime feel doubts that the tap water is safe to drink?
    1. If you have doubt, can you say what is your doubt based on?

11. What is your feeling about the water situation and scarcity in South Africa today?

12. Have you heard about "water reuse"? Are you familiar with the term "water reuse"? What does it say to you? Are you familiar with water reuse for public or municipal use?

    What do you think it is? What does it say to you when you hear it?

Let them describe what it is, if they don't know, let them know the definition. Explanation: Using river water mixed with wastewater that later is cleaned for drinking water.

13. Have you heard anyone talk about water reuse?
    1. The knowledge you have, Where did you get information about this? (television/radio, family and friends, your work, school)

14. How would you feel to drink water that originally comes from wastewater?

15. Would you be encouraged to drink reused water in the aim to overcome water scarcity?
    1. Why or what is that feeling based on?

16. Do you feel that you have enough knowledge about water reuse to decide if it is safe to drink?

17. Do you have trust in water cleaning technologies in general?
    1. Do you have trust in water cleaning technologies where you live?

18. Do you have trust in your authorities such as municipalities or others working with water in your region?

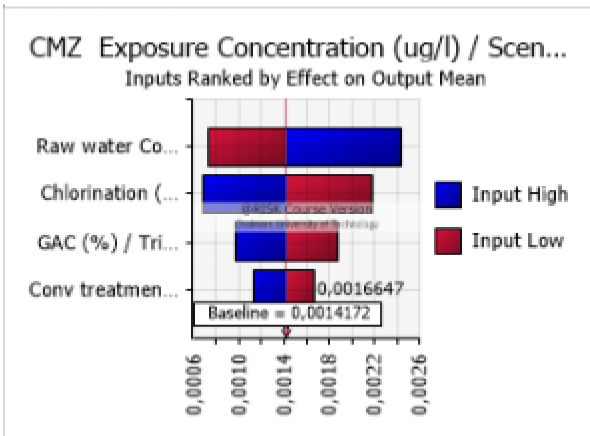
19. Can you think of anything that could help increase your trust in water reuse for drinking water? (if no answer, give examples.. further cleaned/treated water, more knowledge/information from authorities such as study visits, cheaper water, further health impact tests)

20. About your friends and family, do you think they have a similar perception than you have on these topics? Please explain what you think.

..Thank you so much for your participation!..

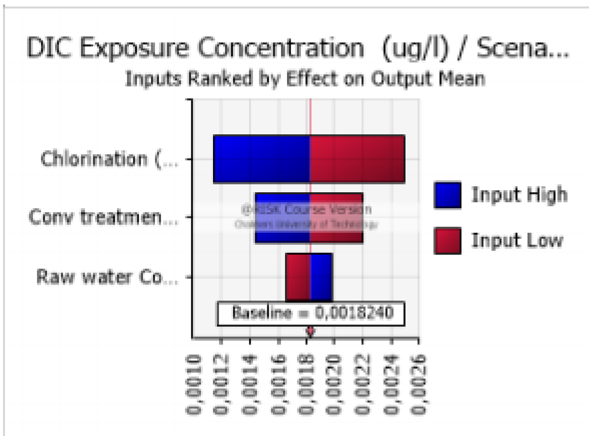
Appendix 2

In this appendix, presents the effect the inputs have on the mean of exposure concentrations of carbamazepine (CMZ), diclofenac (DIC) and sulfamethoxazole (SMX) for scenario 3 using raw water intake for **Withoogte DWTP**. The figures are retrieved from @risk.



Change in Output			
Rank	Name	Lower	Upper
1	Raw water Concentr...	0,0007331	0,0024415
2	Chlorination (%) / T...	0,0006772	0,0021857
3	GAC (%) / Triangula...	0,0009748	0,0018719
4	Conv treatment (%)...	0,0011347	0,0016647

Figure C. Shows the inputs affecting the exposure concentrations for scenario 3 for carbamazepine (CMZ) using raw water for Withoogte DWTP.

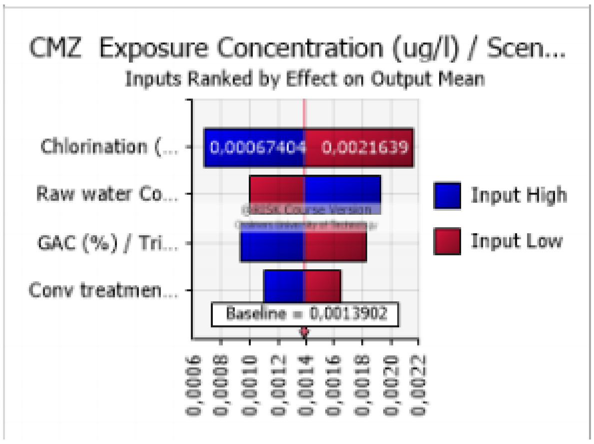


Change in Output			
Rank	Name	Lower	Upper
1	Chlorination (%) / T...	0,0011383	0,0024998
2	Conv treatment (%)...	0,0014353	0,0021969
3	Raw water Concentr...	0,0016615	0,0019796

Figure D. Shows the inputs affecting the exposure concentrations for scenario 3 for diclofenac (DIC) using raw water for Withoogte DWTP.

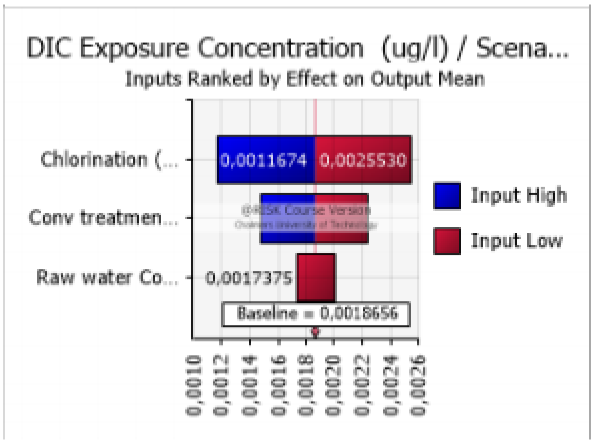
Appendix 3

In this appendix, presents the effect the inputs have on the mean of exposure concentrations of carbamazepine (CMZ), diclofenac (DIC) and sulfamethoxazole (SMX) for scenario 3 using raw water intake for **Piketberg DWTP**. The figures are retrieved from @risk.



Change in Output			
Rank	Name	Lower	Upper
1	Chlorination (%) / T...	0,0006740	0,0021639
2	Raw water Concentr...	0,0010006	0,0019274
3	GAC (%) / Triangula...	0,0009402	0,0018259
4	Conv treatment (%)...	0,0011016	0,0016457

Figure A. Shows the inputs affecting the exposure concentrations for scenario 2 for carbamazepine (CMZ) using raw water for Withoogte DWTP.

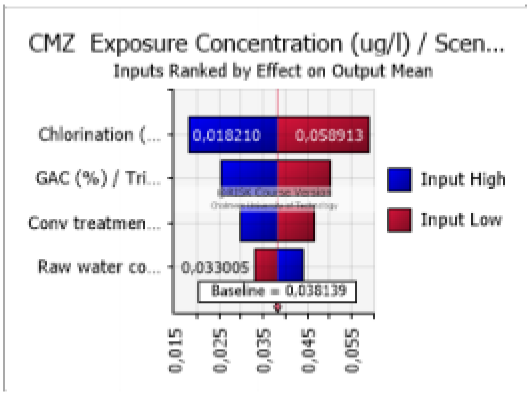


Change in Output			
Rank	Name	Lower	Upper
1	Chlorination (%) / T...	0,0011674	0,0025530
2	Conv treatment (%)...	0,0014777	0,0022372
3	Raw water Concentr...	0,0017375	0,0020055

Figure B. Shows the inputs affecting the exposure concentrations for scenario 3 for diclofenac (DIC) using raw water for Withoogte DWTP.

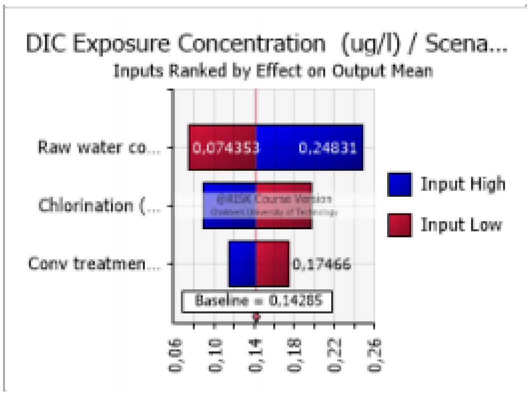
Appendix 4

In this appendix, presents the effect the inputs have on the mean of exposure concentrations of carbamazepine (CMZ), diclofenac (DIC) and sulfamethoxazole (SMX) for scenario 3 using raw water intake from Sesmylspruit River. The figures are retrieved from @risk.



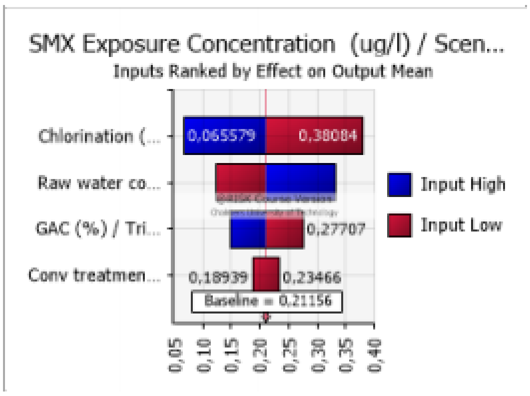
Change in Output			
Rank	Name	Lower	Upper
1	Chlorination (%) / T...	0,018210	0,058913
2	GAC (%) / Triangula...	0,025569	0,050149
3	Conv treatment (%)...	0,029968	0,046406
4	Raw water concentr...	0,033005	0,044086

Figure A. Shows the inputs affecting the exposure concentrations for scenario 2 for carbamazepine (CMZ) using raw water for Withoogte DWTP.



Change in Output			
Rank	Name	Lower	Upper
1	Raw water concentr...	0,07435	0,24831
2	Chlorination (%) / T...	0,08927	0,19647
3	Conv treatment (%)...	0,11431	0,17466

Figure B. Shows the inputs affecting the exposure concentrations for scenario 3 for diclofenac (DIC) using raw water for Withoogte DWTP.



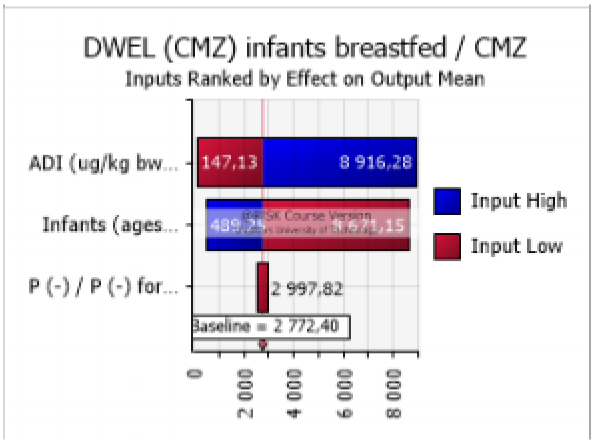
Change in Output			
Rank	Name	Lower	Upper
1	Chlorination (%) / T...	0,06558	0,38084
2	Raw water concentr...	0,12448	0,33259
3	GAC (%) / Triangula...	0,14739	0,27707
4	Conv treatment (%)...	0,18939	0,23466

Figure C. Shows the inputs affecting the exposure concentrations for scenario 3 for sulfamethoxazole (SMX) using raw water for Withoogte DWTP.

Appendix 5

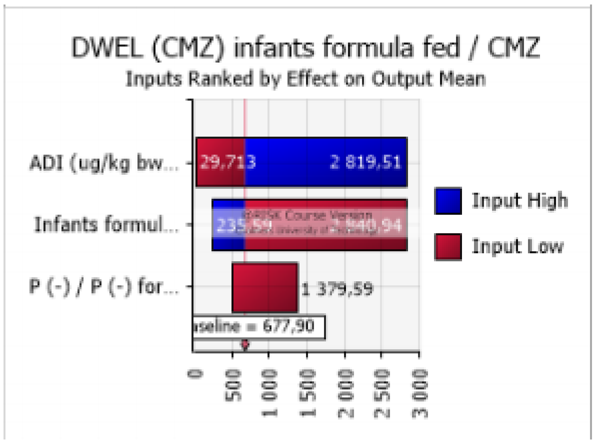
In this appendix, presents the effect the inputs have on the mean of the DWEL of carbamazepine (CMZ), diclofenac (DIC) and sulfamethoxazole (SMX) for the four population groups: infants that are breastfed, infants that are formula fed, children and adults. The inputs for DWEL is ADI, ingestion rate per body weight (expressed in the populations groups concerned). The figures are retrieved from @risk.

DWEL for carbamazepine (CMZ) and all four population groups



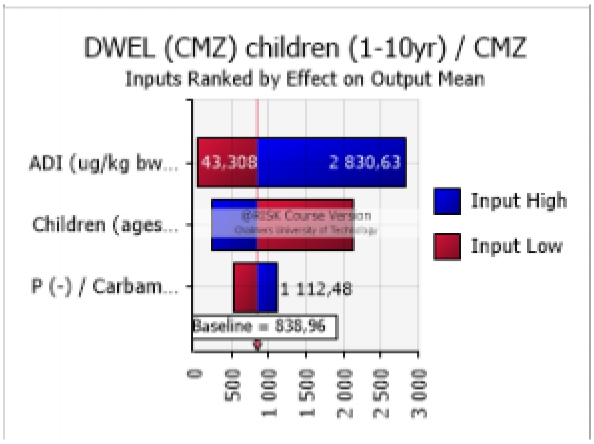
Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	147,13	8 916,28
2	Infants (ages <1) /...	489,25	8 671,15
3	P (-) / P (-) for infants	2 509,83	2 997,82

Figure A. Shows the inputs affecting the mean of DWEL for carbamazepine (CMZ) for infants that are breastfed



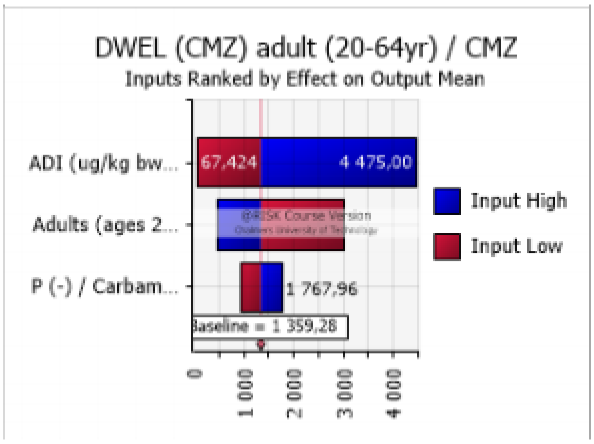
Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	29,71	2 819,51
2	Infants formula fed...	235,59	2 840,94
3	P (-) / P (-) for infants	513,36	1 379,59

Figure B. Shows the inputs affecting the mean of DWEL for carbamazepine (CMZ) for infants that are formula fed



Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	43,31	2 830,63
2	Children (ages 1 to...	249,78	2 119,69
3	P (-) / Carbamazepine	540,82	1 112,48

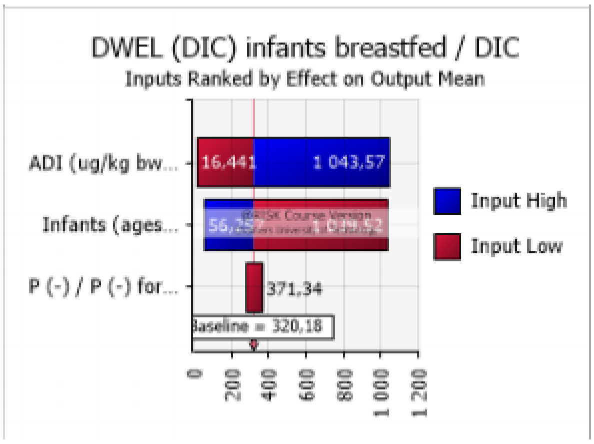
Figure C. Shows the inputs affecting the mean of DWEL for carbamazepine (CMZ) for children



Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	67,42	4 475,00
2	Adults (ages 20 to 6...	474,32	3 005,16
3	P (-) / Carbamazepine	931,90	1 767,96

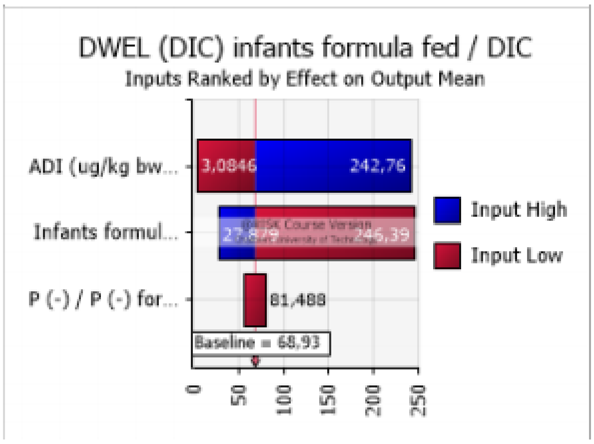
Figure D. Shows the inputs affecting the mean of DWEL for carbamazepine (CMZ) for adults

DWEL for Diclofenac (DIC) and all four population groups



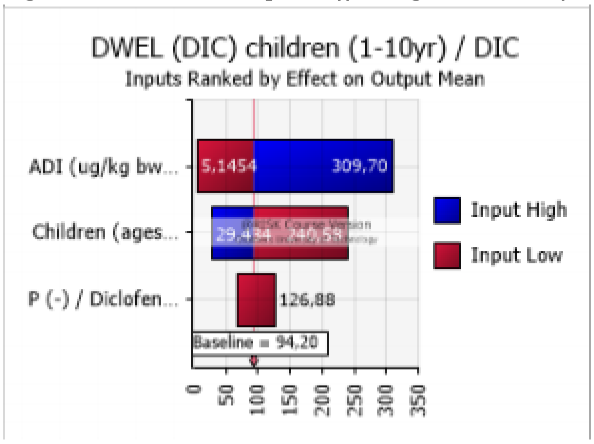
Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	16,44	1 043,57
2	Infants (ages <1) /...	56,26	1 039,52
3	P (-) / P (-) for infants	281,07	371,34

Figure E. Shows the inputs affecting the mean of DWEL for diclofenac (DIC) for infants that are breastfed



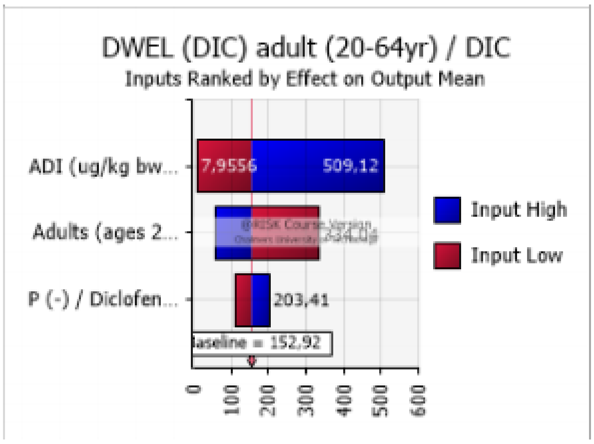
Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	3,08	242,76
2	Infants formula fed...	27,88	246,39
3	P (-) / P (-) for infants	55,57	81,49

Figure F. Shows the inputs affecting the mean of DWEL for diclofenac (DIC) for infants that are formula fed



Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	5,15	309,70
2	Children (ages 1 to...	29,43	240,58
3	P (-) / Diclofenac	68,49	126,88

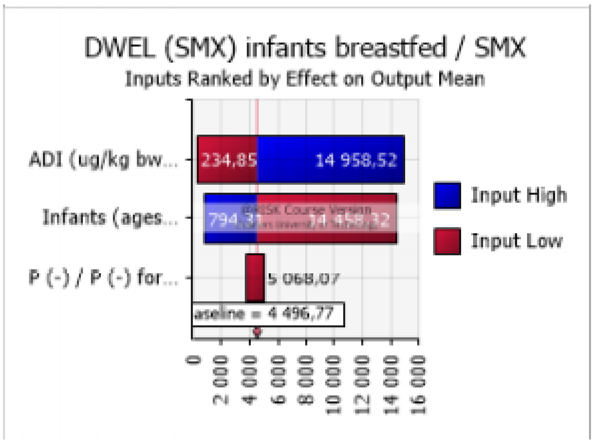
Figure G. Shows the inputs affecting the mean of DWEL for diclofenac (DIC) for children



Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	7,96	509,12
2	Adults (ages 20 to 6...	58,34	334,04
3	P (-) / Diclofenac	109,16	203,41

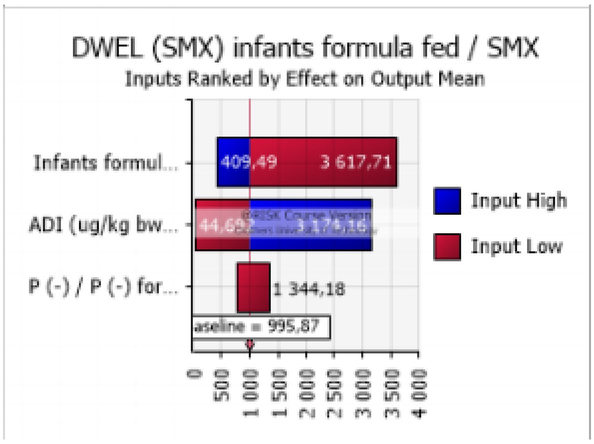
Figure H. Shows the inputs affecting the mean of DWEL for diclofenac (DIC) for adults

DWEL for Sulfamethoxazole (SMX) and all four population groups



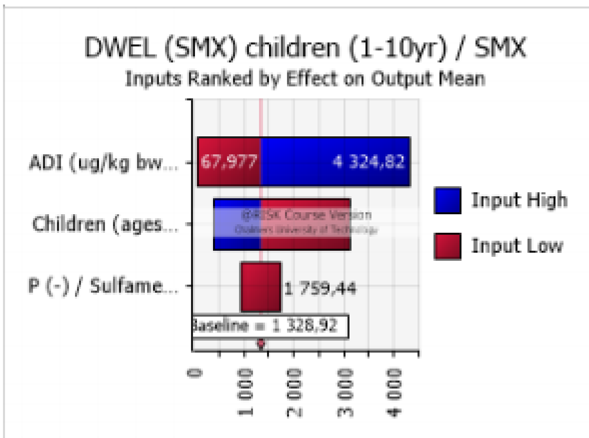
Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	234,85	14 958,52
2	Infants (ages <1) /...	794,31	14 458,32
3	P (-) / P (-) for infants	3 751,75	5 068,07

Figure I. Shows the inputs affecting the mean of DWEL for sulfamethoxazole (SMX) for infants that are breastfed



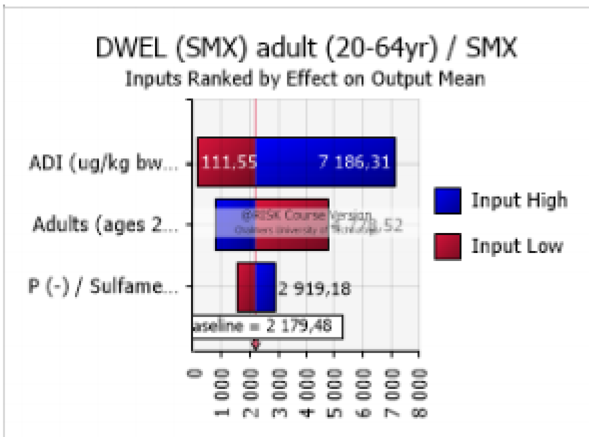
Change in Output			
Rank	Name	Lower	Upper
1	Infants formula fed...	409,49	3 617,71
2	ADI (ug/kg bw/d) /...	44,69	3 174,16
3	P (-) / P (-) for infants	786,07	1 344,18

Figure J. Shows the inputs affecting the mean of DWEL for sulfamethoxazole (SMX) for infants that are formula fed



Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	67,98	4 324,82
2	Children (ages 1 to...	410,28	3 135,63
3	P (-) / Sulfamethoxa...	928,97	1 759,44

Figure K. Shows the inputs affecting the mean of DWEL for sulfamethoxazole (SMX) for children



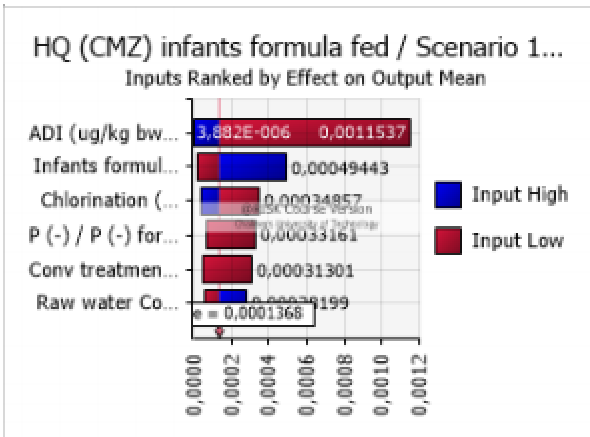
Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	111,55	7 186,31
2	Adults (ages 20 to 6...	793,10	4 778,52
3	P (-) / Sulfamethoxa...	1 528,58	2 919,18

Figure L. Shows the inputs affecting the mean of DWEL for sulfamethoxazole (SMX) for adults

Appendix 6

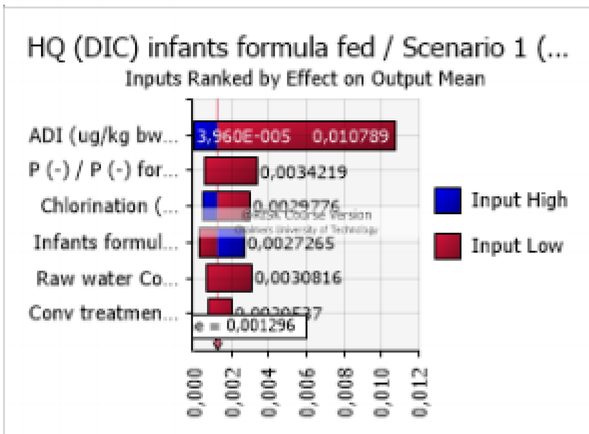
In this appendix, presents the effect the inputs have on the mean of the HQ of carbamazepine (CMZ), diclofenac (DIC) and sulfamethoxazole (SMX) only for the infants that are formula fed since it was the ”worst case” population group in the scenario 1-3 for Withoogte DWTP. The figures are retrieved from @risk.

HQ for scenario 1 for infants that are formula fed for carbamazepine (CMZ) and diclofenac (DIC)



Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	3,882E-006	0,0011537
2	Infants formula fed...	2,338E-005	0,0004944
3	Chlorination (%) / T...	4,233E-005	0,0003486
4	P (-) / P (-) for infants	7,023E-005	0,0003316
5	Conv treatment (%)...	5,317E-005	0,0003130
6	Raw water Concentr...	5,556E-005	0,0002820

Figure A. Shows the inputs affecting the mean of HQ for carbamazepine (CMZ) for infants that breastfed scenario 1 using raw water from Withoogte DWTP

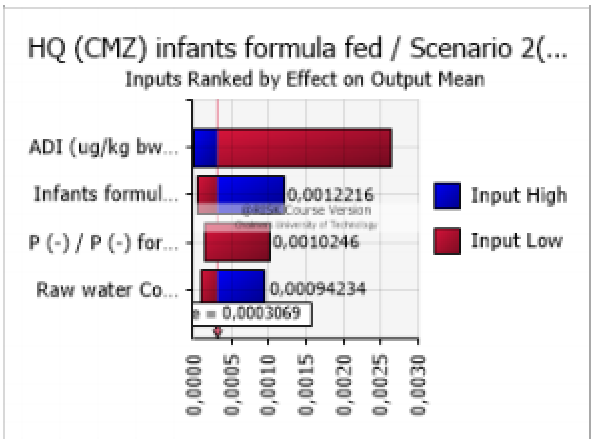


Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	3,960E-005	0,010789
2	P (-) / P (-) for infants	0,000606	0,003422
3	Chlorination (%) / T...	0,000454	0,002978
4	Infants formula fed...	0,000325	0,002726
5	Raw water Concentr...	0,000719	0,003082
6	Conv treatment (%)...	0,000740	0,002054

Figure B. Shows the inputs affecting the mean of HQ diclofenac (DIC) for infants that formula fed scenario 1 using raw water from Withoogte DWTP

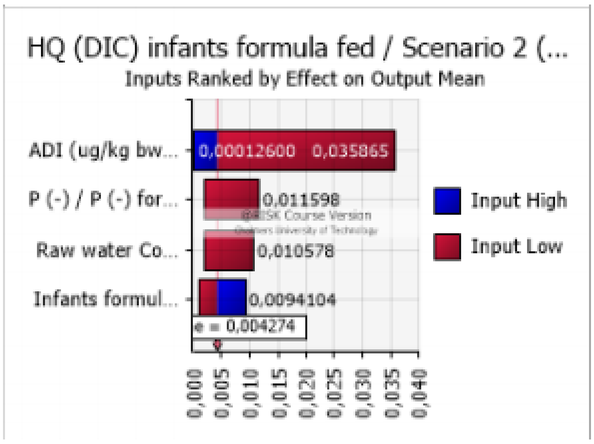
HQ for scenario 2 for infants that are formula fed for carbamazepine (CMZ) and diclofenac (DIC)

Figure F. Shows the inputs affecting the mean of HQ diclofenac (DIC) for infants that formula fed scenario 1 using raw water from Withoogte DWTP



Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	7,879E-006	0,0026357
2	Infants formula fed...	5,693E-005	0,0012216
3	P (-) / P (-) for infants	0,0001332	0,0010246
4	Raw water Concentr...	9,865E-005	0,0009423

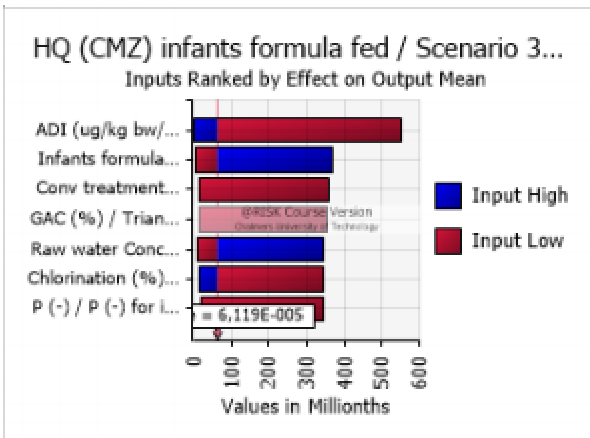
Figure C. Shows the inputs affecting the mean of HQ for carbamazepine (CMZ) for infants that formula fed scenario 3 using raw water from Withoogte DWTP



Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	0,000126	0,035865
2	P (-) / P (-) for infants	0,002032	0,011598
3	Raw water Concentr...	0,001932	0,010578
4	Infants formula fed...	0,001075	0,009410

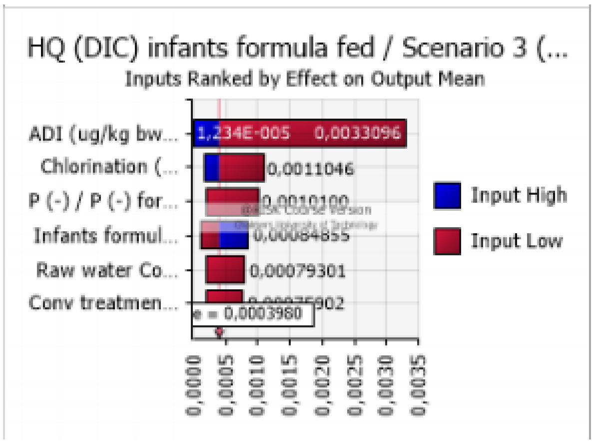
Figure D. Shows the inputs affecting the mean of HQ diclofenac (DIC) for infants that breastfed scenario 2 using raw water from Withoogte DWTP

HQ for scenario 3 for infants that are formula fed for carbamazepine (CMZ) and diclofenac (DIC)



Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	1,067E-006	0,00055291
2	Infants formula fed...	7,059E-006	0,00036815
3	Conv treatment (%)...	1,593E-005	0,00036031
4	GAC (%) / Triangula...	1,355E-005	0,00035415
5	Raw water Concentr...	9,394E-006	0,00034226
6	Chlorination (%) / T...	1,589E-005	0,00034312
7	P (-) / P (-) for infants	1,881E-005	0,00034249

Figure E. Shows the inputs affecting the mean of HQ for carbamazepine (CMZ) for infants that breastfed scenario 3 using raw water from Withoogte DWTP



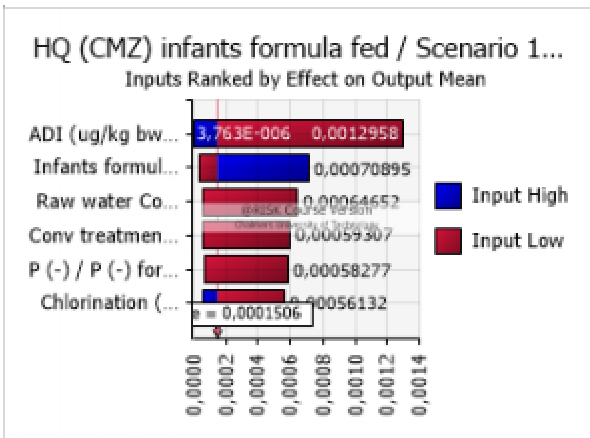
Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	1,234E-005	0,0033096
2	Chlorination (%) / T...	0,0001638	0,0011046
3	P (-) / P (-) for infants	0,0002011	0,0010100
4	Infants formula fed...	0,0001062	0,0008485
5	Raw water Concentr...	0,0001941	0,0007930
6	Conv treatment (%)...	0,0002036	0,0007590

Figure F. Shows the inputs affecting the mean of HQ diclofenac (DIC) for infants that are formula fed scenario 3 using raw water from Withoogte DWTP

Appendix 7

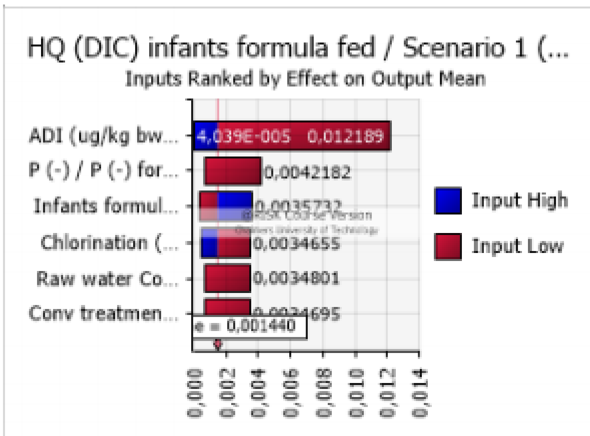
In this appendix, presents the effect the inputs have on the mean of the HQ of carbamazepine (CMZ), diclofenac (DIC) and sulfamethoxazole (SMX) only for the infants that are formula fed since it was the ”worst case” population group, in the scenario 1-3 for Piketberg DWTP. The figures are retrieved from @risk.

HQ for scenario 1 for infants that are formula fed for carbamazepine (CMZ) and diclofenac (DIC)



Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	3,763E-006	0,0012958
2	Infants formula fed...	2,921E-005	0,0007090
3	Raw water Concentr...	5,273E-005	0,0006465
4	Conv treatment (%)...	5,837E-005	0,0005931
5	P (-) / P (-) for infants	6,299E-005	0,0005828
6	Chlorination (%) / T...	6,198E-005	0,0005613

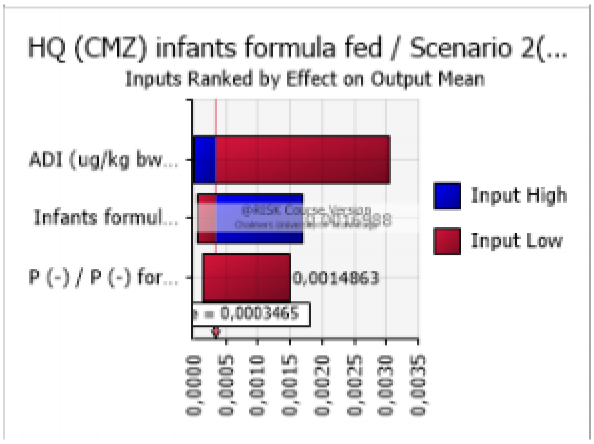
Figure A. Shows the inputs affecting the mean of HQ for carbamazepine (CMZ) for infants that breastfed scenario 1 using raw water from Piketberg DWTP



Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	4,039E-005	0,012189
2	P (-) / P (-) for infants	0,000694	0,004218
3	Infants formula fed...	0,000327	0,003573
4	Chlorination (%) / T...	0,000419	0,003465
5	Raw water Concentr...	0,000650	0,003480
6	Conv treatment (%)...	0,000655	0,003470

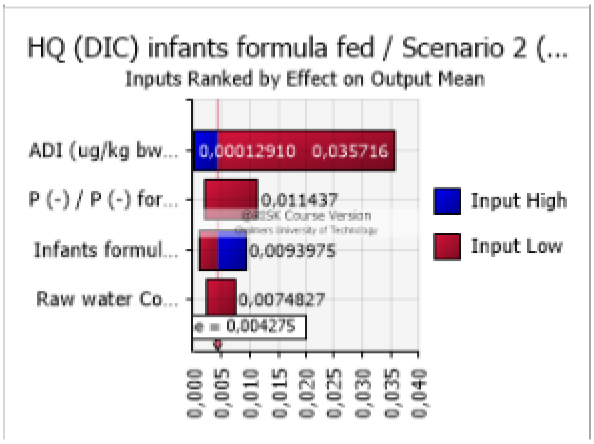
Figure B. Shows the inputs affecting the mean of HQ diclofenac (DIC) for infants that formula fed scenario 1 using raw water from Piketberg DWTP

HQ for scenario 2 for infants that are formula fed for carbamazepine (CMZ) and diclofenac (DIC)



Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	7,736E-006	0,0030406
2	Infants formula fed...	5,305E-005	0,0016988
3	P (-) / P (-) for infants	0,0001364	0,0014863

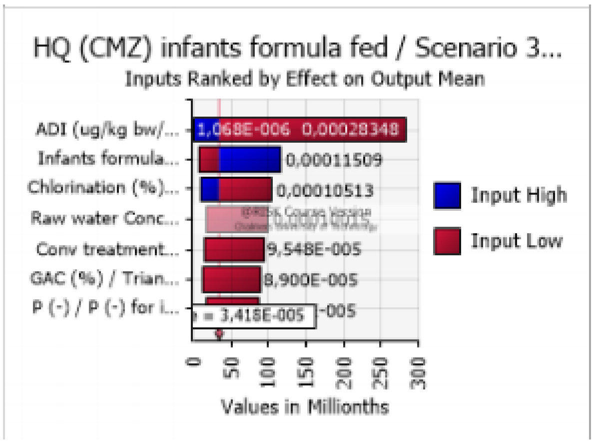
Figure C. Shows the inputs affecting the mean of HQ for carbamazepine (CMZ) for infants that formula fed scenario 2 using raw water from Piketberg DWTP



Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	0,000129	0,035716
2	P (-) / P (-) for infants	0,002078	0,011437
3	Infants formula fed...	0,001088	0,009397
4	Raw water Concentr...	0,002362	0,007483

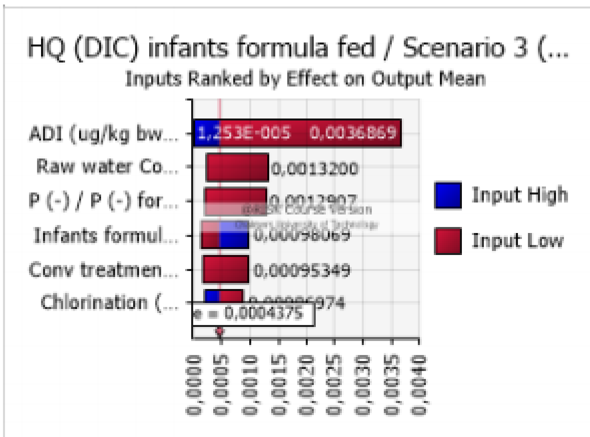
Figure D. Shows the inputs affecting the mean of HQ diclofenac (DIC) for infants that breastfed scenario 2 using raw water from Piketberg DWTP

HQ for scenario 3 for infants that are formula fed for carbamazepine (CMZ) and diclofenac (DIC)



Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	1,068E-006	0,00028348
2	Infants formula fed...	6,939E-006	0,00011509
3	Chlorination (%) / T...	1,070E-005	0,00010513
4	Raw water Concentr...	1,810E-005	0,00010015
5	Conv treatment (%)...	1,531E-005	9,548E-005
6	GAC (%) / Triangula...	1,248E-005	8,900E-005
7	P (-) / P (-) for infants	1,764E-005	8,807E-005

Figure E. Shows the inputs affecting the mean of HQ for carbamazepine (CMZ) for infants that breastfed scenario 3 using raw water from Piketberg DWTP



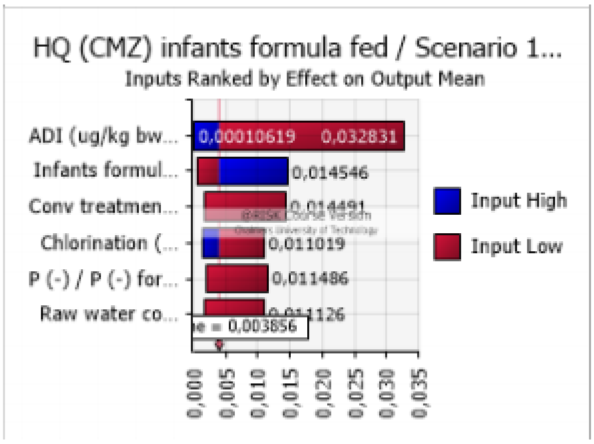
Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	1,253E-005	0,0036869
2	Raw water Concentr...	0,0002124	0,0013200
3	P (-) / P (-) for infants	0,0002017	0,0012907
4	Infants formula fed...	0,0001131	0,0009807
5	Conv treatment (%)...	0,0001499	0,0009535
6	Chlorination (%) / T...	0,0002040	0,0008697

Figure F. Shows the inputs affecting the mean of HQ diclofenac (DIC) for infants that are formula fed scenario 3 using raw water from Piketberg DWTP

Appendix 8

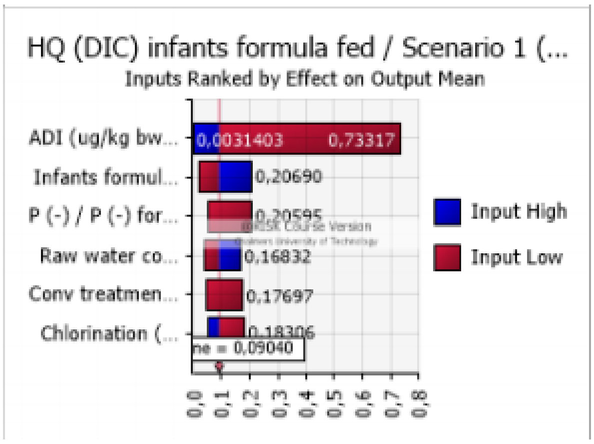
In this appendix, presents the effect the inputs have on the mean of the HQ of carbamazepine (CMZ), diclofenac (DIC) and sulfamethoxazole (SMX) only for the infants that are formula fed since it was the "worst case" population group in the scenario 1-3 using raw water from Sesmylspruit River. The figures are retrieved from @risk.

HQ for scenario 1 for infants that are formula fed for carbamazepine (CMZ), diclofenac (DIC) and sulfamethoxazole (SMX)



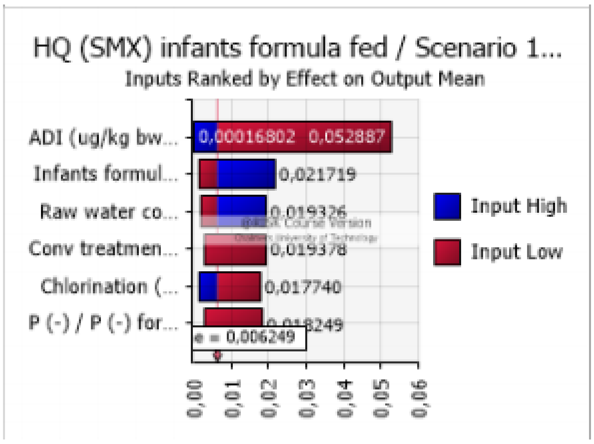
Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	0,000106	0,032831
2	Infants formula fed...	0,000668	0,014546
3	Conv treatment (%)...	0,001578	0,014491
4	Chlorination (%) / T...	0,001309	0,011019
5	P (-) / P (-) for infants	0,001934	0,011486
6	Raw water concentr...	0,001703	0,011126

Figure A. Shows the inputs affecting the mean of HQ for carbamazepine (CMZ) for infants that breastfed scenario 1 using raw water from Sesmylspruit River



Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	0,00314	0,73317
2	Infants formula fed...	0,02159	0,20690
3	P (-) / P (-) for infants	0,05179	0,20595
4	Raw water concentr...	0,03626	0,16832
5	Conv treatment (%)...	0,04503	0,17697
6	Chlorination (%) / T...	0,05394	0,18306

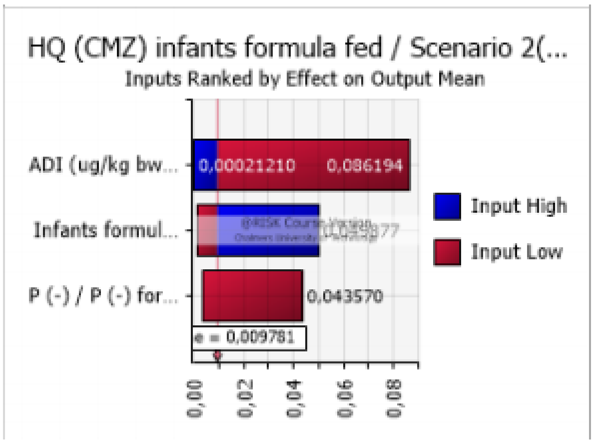
Figure B. Shows the inputs affecting the mean of HQ diclofenac (DIC) for infants that are formula fed scenario 1 using raw water from Sesmylspruit River



Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	0,000168	0,052887
2	Infants formula fed...	0,001350	0,021719
3	Raw water concentr...	0,001737	0,019326
4	Conv treatment (%)...	0,002880	0,019378
5	Chlorination (%) / T...	0,001563	0,017740
6	P (-) / P (-) for infants	0,003023	0,018249

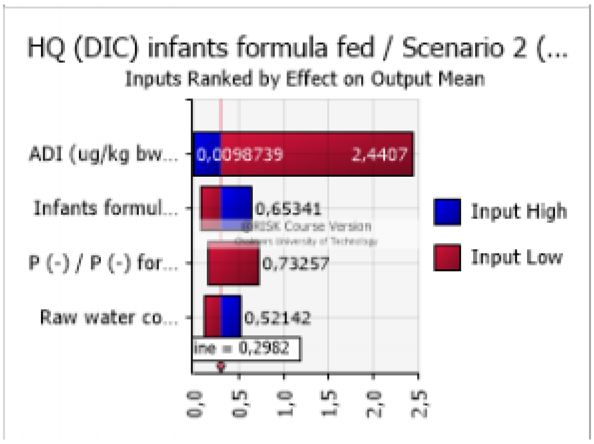
Figure C. Shows the inputs affecting the mean of HQ for sulfamethoxazole (SMX) for infants that are breastfed for scenario 1 using raw water from Sesmylspruit River

HQ for scenario 2 for infants that are formula fed for carbamazepine (CMZ), diclofenac (DIC) and sulfamethoxazole (SMX)



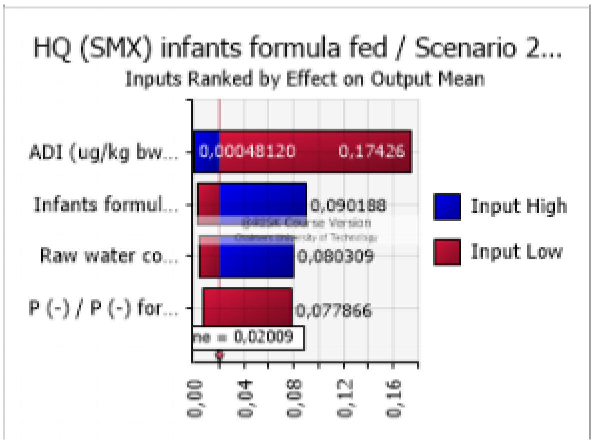
Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	0,000212	0,086194
2	Infants formula fed...	0,001420	0,049877
3	P (-) / P (-) for infants	0,003854	0,043570

Figure D. Shows the inputs affecting the mean of HQ for carbamazepine (CMZ) for infants that breastfed scenario 2 using raw water from Sesmylspruit River



Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	0,00987	2,4407
2	Infants formula fed...	0,0726	0,6534
3	P (-) / P (-) for infants	0,1634	0,7326
4	Raw water concentr...	0,1194	0,5214

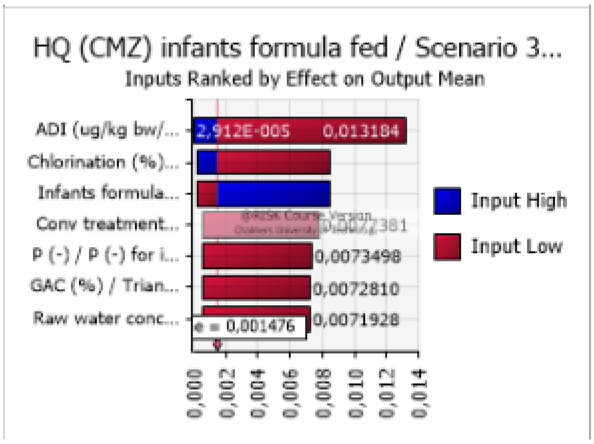
Figure E. Shows the inputs affecting the mean of HQ diclofenac (DIC) for infants that are formula fed scenario 2 using raw water from Sesmylspruit River



Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	0,000481	0,17426
2	Infants formula fed...	0,00353	0,09019
3	Raw water concentr...	0,00484	0,08031
4	P (-) / P (-) for infants	0,00759	0,07787

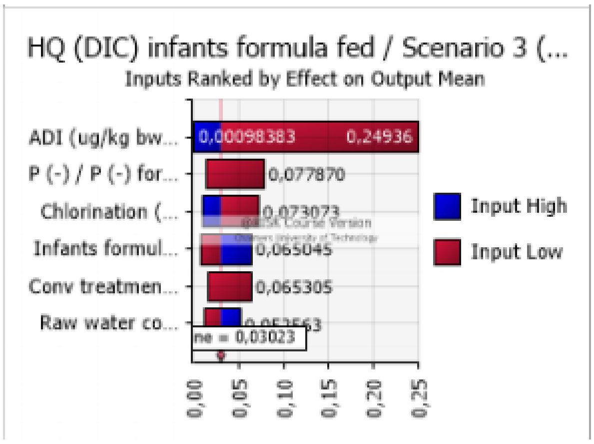
Figure F. Shows the inputs affecting the mean of HQ sulfamethoxazole (SMX) for infants that are formula fed scenario 2 using raw water from Sesmylspruit River

HQ for scenario 3 for infants that are formula fed for carbamazepine (CMZ), diclofenac (DIC) and sulfamethoxazole (SMX)



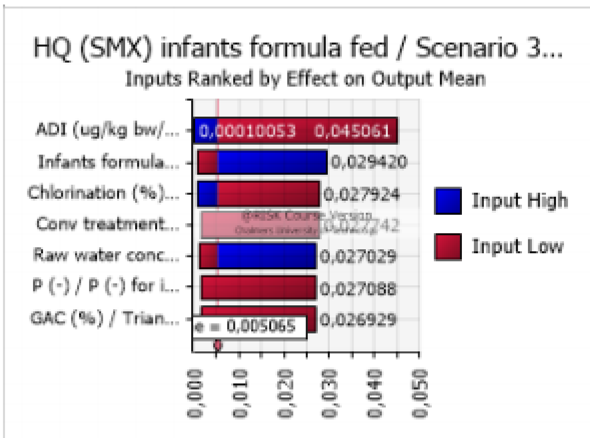
Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	2,912E-005	0,0131840
2	Chlorination (%) / T...	0,0002055	0,0084808
3	Infants formula fed...	0,0002218	0,0084561
4	Conv treatment (%)...	0,0005398	0,0077381
5	P (-) / P (-) for infants	0,0005508	0,0073498
6	GAC (%) / Triangula...	0,0005220	0,0072810
7	Raw water concentr...	0,0005150	0,0071928

Figure G. Shows the inputs affecting the mean of HQ for carbamazepine (CMZ) for infants that breastfed scenario 3 using raw water from Sesmylspruit River



Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	0,000984	0,24936
2	P (-) / P (-) for infants	0,01508	0,07787
3	Chlorination (%) / T...	0,01055	0,07307
4	Infants formula fed...	0,00751	0,06504
5	Conv treatment (%)...	0,01569	0,06531
6	Raw water concentr...	0,01204	0,05256

Figure H. Shows the inputs affecting the mean of HQ diclofenac (DIC) for infants that are formula fed scenario 3 using raw water from Sesmylspruit River



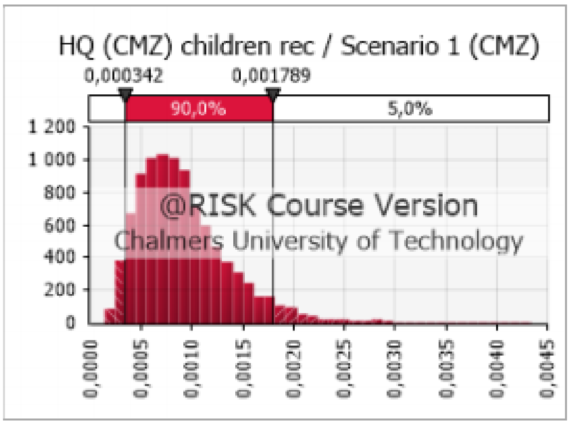
Change in Output			
Rank	Name	Lower	Upper
1	ADI (ug/kg bw/d) /...	0,000101	0,045061
2	Infants formula fed...	0,000707	0,029420
3	Chlorination (%) / T...	0,000644	0,027924
4	Conv treatment (%)...	0,001725	0,027742
5	Raw water concentr...	0,001050	0,027029
6	P (-) / P (-) for infants	0,001450	0,027088
7	GAC (%) / Triangula...	0,001537	0,026929

Figure I. Shows the inputs affecting the mean of HQ sulfamethoxazole (SMX) for infants that are formula fed scenario 3 using raw water from Sesmylspruit River

Appendix 9

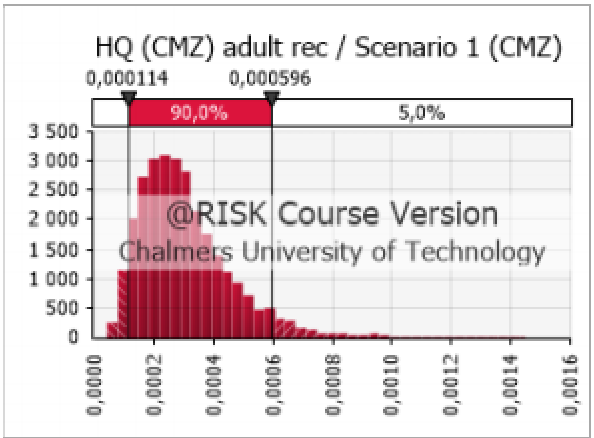
This appendix presents the results of the hazard quotient of Withoogte raw water intake, based on the recommended values of WHO (2011a) for carbamazepine (CMZ), diclofenac (DIC) for the population groups: children and adults, for scenario 1, 2 and 3. Not for sulfamethoxazole since it was not detected.

HQ for scenario 1 for children and adults (recommended ingestion rates and ADI) for carbamazepine (CMZ), diclofenac (DIC)



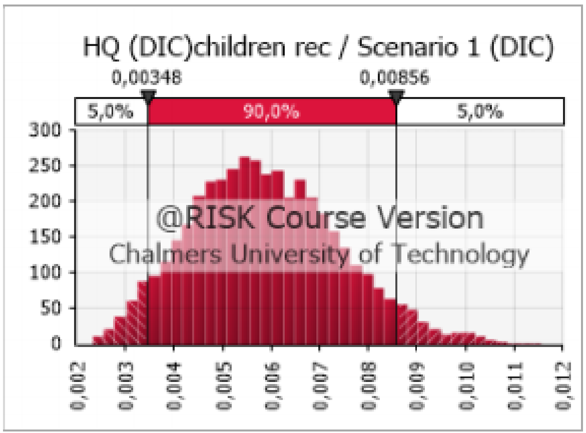
Summary Statistics	
Statistic	Value
Minimum	0,0001292
Maximum	0,0043519
Mean	0,0009148
Std. Deviation	0,0004591
Variance	2,107E-007
Skewness	1,3450
Kurtosis	6,1310
Median	0,0008300
Mode	0,0006405
Left X	0,0003422
Left P	5%
Right X	0,0017894
Right P	95%

Figure A. HQ for carbamazepine (CMZ) for scenario 1 from Withoogte raw water raw water intake based on recommended values, for the population group children.



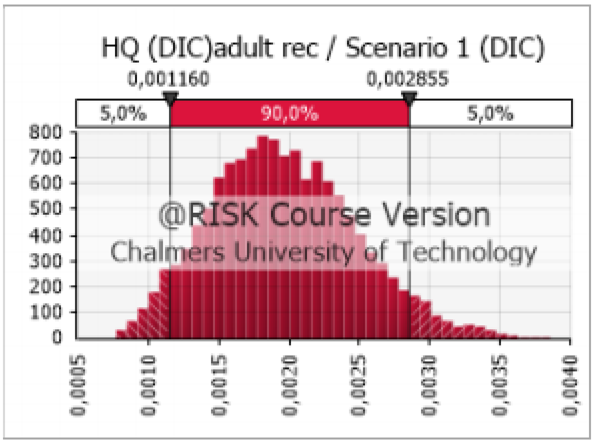
Summary Statistics	
Statistic	Value
Minimum	4,307E-005
Maximum	0,00145064
Mean	0,00030493
Std. Deviation	0,00015302
Variance	2,342E-008
Skewness	1,3450
Kurtosis	6,1310
Median	0,00027667
Mode	0,00021352
Left X	0,00011408
Left P	5%
Right X	0,00059648
Right P	95%

Figure B. HQ for carbamazepine (CMZ) for scenario 1 from Withoogte raw water raw water intake based on recommended values, for the population group adults.



Summary Statistics	
Statistic	Value
Minimum	0,0023275
Maximum	0,0115695
Mean	0,0058836
Std. Deviation	0,0015283
Variance	2,336E-006
Skewness	0,3180
Kurtosis	2,8235
Median	0,0057845
Mode	0,0057337
Left X	0,0034804
Left P	5%
Right X	0,0085644
Right P	95%

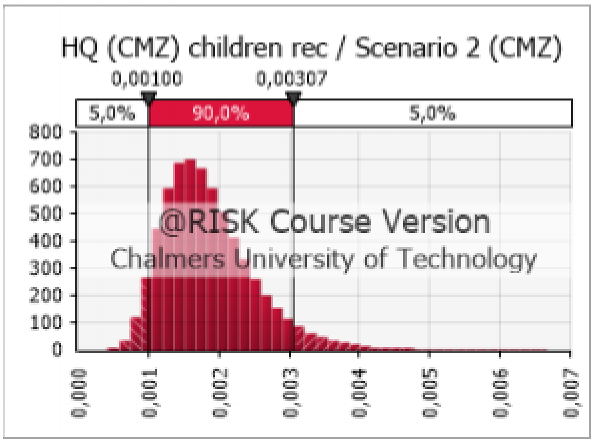
Figure C. HQ for diclofenac (DIC) for scenario 1 from Withoogte raw water raw water intake based on recommended values, for the population group children.



Summary Statistics	
Statistic	Value
Minimum	0,0007758
Maximum	0,0038565
Mean	0,0019612
Std. Deviation	0,0005094
Variance	2,595E-007
Skewness	0,3180
Kurtosis	2,8235
Median	0,0019282
Mode	0,0019112
Left X	0,0011601
Left P	5%
Right X	0,0028548
Right P	95%

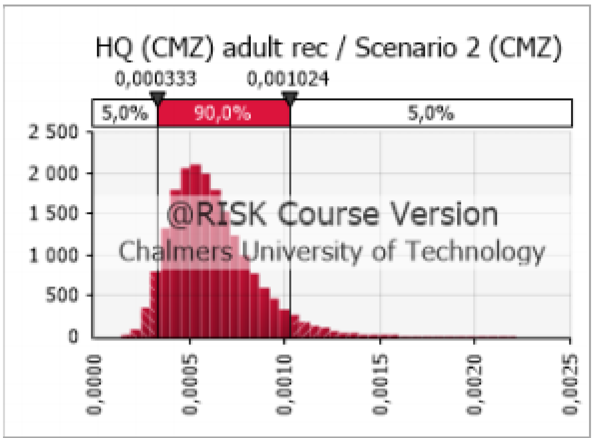
Figure D. HQ for diclofenac (DIC) for scenario 1 from Withoogte raw water raw water intake based on recommended values, for the population group adults.

HQ for scenario 2 for children and adults (recommended ingestion rates and ADI) for carbamazepine (CMZ), diclofenac (DIC)



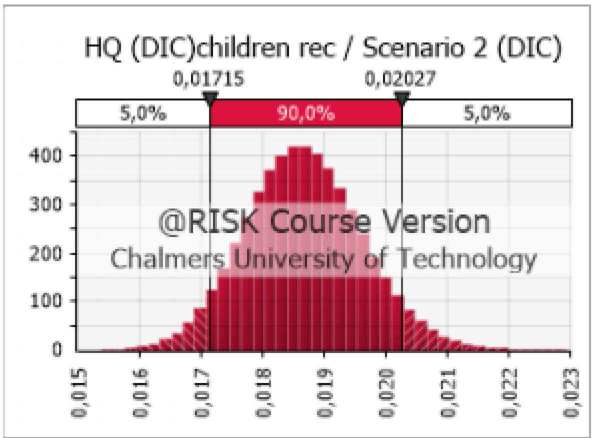
Summary Statistics	
Statistic	Value
Minimum	0,0004237
Maximum	0,0066580
Mean	0,0018571
Std. Deviation	0,0006524
Variance	4,256E-007
Skewness	1,0908
Kurtosis	5,1370
Median	0,0017520
Mode	0,0015292
Left X	0,0009994
Left P	5%
Right X	0,0030708
Right P	95%

Figure E. HQ for carbamazepine (CMZ) for scenario 2 from Withoogte raw water raw water intake based on recommended values, for the population group children.



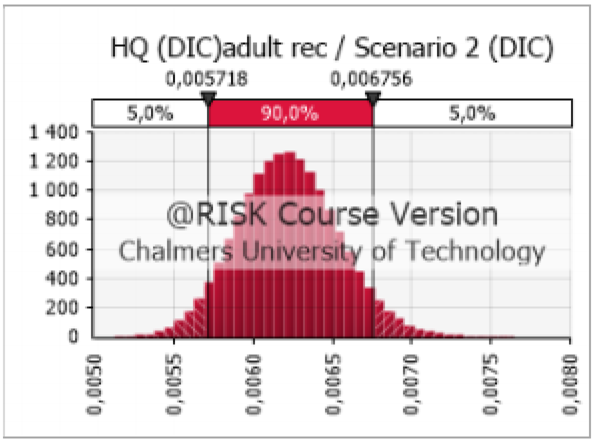
Summary Statistics	
Statistic	Value
Minimum	0,0001412
Maximum	0,0022193
Mean	0,0006190
Std. Deviation	0,0002175
Variance	4,729E-008
Skewness	1,0908
Kurtosis	5,1370
Median	0,0005840
Mode	0,0005097
Left X	0,0003331
Left P	5%
Right X	0,0010236
Right P	95%

Figure F. HQ for carbamazepine (CMZ) for scenario 2 from Withoogte raw water raw water intake based on recommended values, for the population group adults.



Summary Statistics	
Statistic	Value
Minimum	0,0153880
Maximum	0,0229292
Mean	0,0186700
Std. Deviation	0,0009477
Variance	8,980E-007
Skewness	0,1537
Kurtosis	3,0440
Median	0,0186459
Mode	0,0185394
Left X	0,0171535
Left P	5%
Right X	0,0202675
Right P	95%

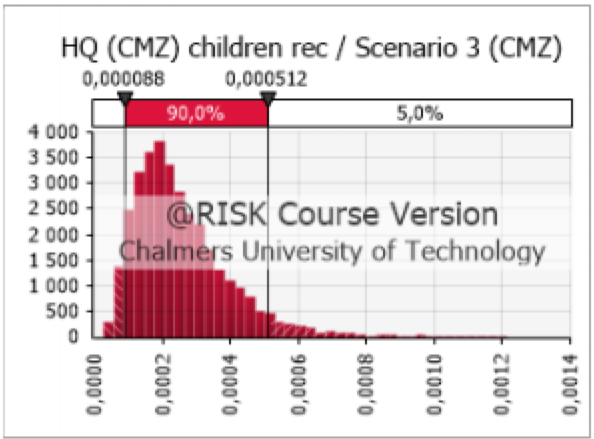
Figure G. HQ for diclofenac (DIC) for scenario 2 from Withoogte raw water raw water intake based on recommended values, for the population group children.



Summary Statistics	
Statistic	Value
Minimum	0,0051293
Maximum	0,0076431
Mean	0,0062233
Std. Deviation	0,0003159
Variance	9,978E-008
Skewness	0,1537
Kurtosis	3,0440
Median	0,0062153
Mode	0,0061798
Left X	0,0057178
Left P	5%
Right X	0,0067558
Right P	95%

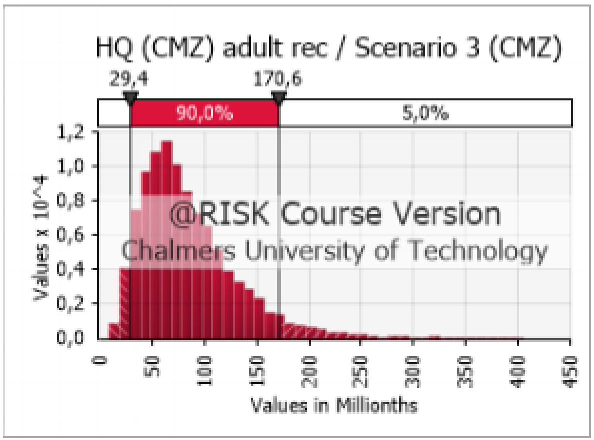
Figure H. HQ for diclofenac (DIC) for scenario 2 from Withoogte raw water raw water intake based on recommended values, for the population group adults.

HQ for scenario 2 for children and adults (recommended ingestion rates and ADI) for carbamazepine (CMZ), diclofenac (DIC)



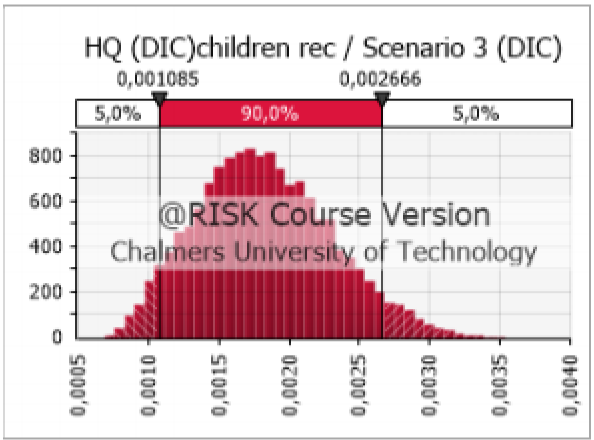
Summary Statistics	
Statistic	Value
Minimum	2,822E-005
Maximum	0,00121275
Mean	0,00025307
Std. Deviation	0,00013619
Variance	1,855E-008
Skewness	1,3777
Kurtosis	6,1111
Median	0,00022403
Mode	0,00018400
Left X	8,830E-005
Left P	5%
Right X	0,00051181
Right P	95%

Figure I. HQ for carbamazepine (CMZ) for scenario 3 from Withoogte raw water raw water intake based on recommended values, for the population group children.



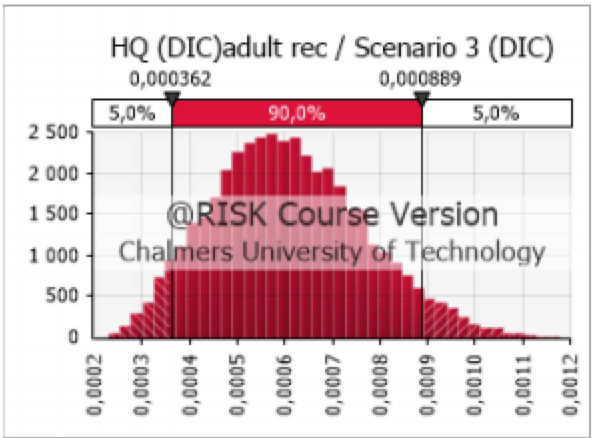
Summary Statistics	
Statistic	Value
Minimum	9,405E-006
Maximum	0,00040425
Mean	8,436E-005
Std. Deviation	4,540E-005
Variance	2,061E-009
Skewness	1,3777
Kurtosis	6,1111
Median	7,468E-005
Mode	6,133E-005
Left X	2,943E-005
Left P	5%
Right X	0,00017060
Right P	95%

Figure J. HQ for carbamazepine (CMZ) for scenario 3 from Withoogte raw water raw water intake based on recommended values, for the population group adults.



Summary Statistics	
Statistic	Value
Minimum	0,0006900
Maximum	0,0035308
Mean	0,0018240
Std. Deviation	0,0004744
Variance	2,251E-007
Skewness	0,3096
Kurtosis	2,7406
Median	0,0017946
Mode	0,0016684
Left X	0,0010849
Left P	5%
Right X	0,0026657
Right P	95%

Figure K. HQ for diclofenac (DIC) for scenario 3 from Withoogte raw water raw water intake based on recommended values, for the population group children.



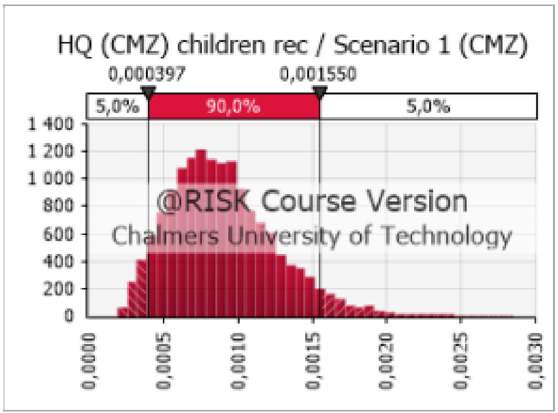
Summary Statistics	
Statistic	Value
Minimum	0,00023000
Maximum	0,00117693
Mean	0,00060802
Std. Deviation	0,00015814
Variance	2,501E-008
Skewness	0,3096
Kurtosis	2,7406
Median	0,00059818
Mode	0,00055614
Left X	0,00036162
Left P	5%
Right X	0,00088858
Right P	95%

Figure L. HQ for diclofenac (DIC) for scenario 3 from Withoogte raw water raw water intake based on recommended values, for the population group adults. The figure presents summary statistics (first picture and table) percentiles (second figure and table) and the inputs affecting the mean of exposure concentration (last figure and table).

Appendix 10

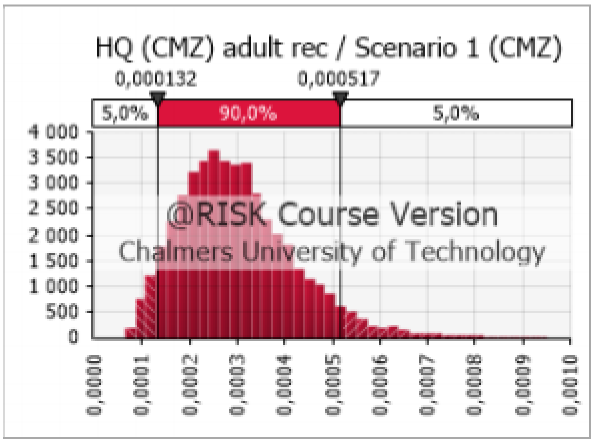
This appendix presents the results of the hazard quotient of Piketberg raw water intake, based on the recommended values of WHO (2011a) for carbamazepine (CMZ), diclofenac (DIC) for the population groups: children and adults, for scenario 1, 2 and 3. Not for sulfamethoxazole since it was not detected.

HQ for scenario 2 for children and adults (recommended ingestion rates and ADI) for carbamazepine (CMZ), diclofenac (DIC)



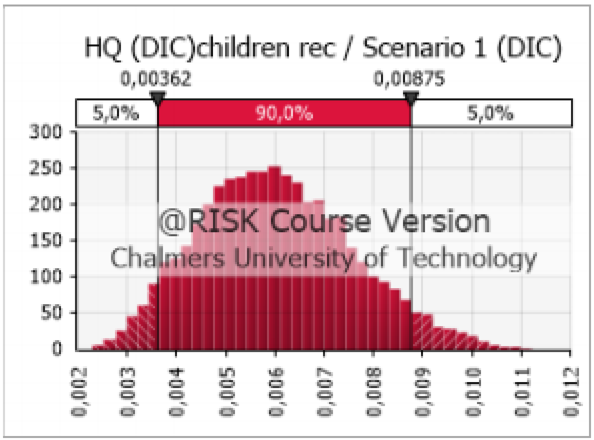
Summary Statistics	
Statistic	Value
Minimum	0,0001914
Maximum	0,0028487
Mean	0,0008981
Std. Deviation	0,0003557
Variance	1,265E-007
Skewness	0,7860
Kurtosis	3,8984
Median	0,0008552
Mode	0,0007652
Left X	0,0003971
Left P	5%
Right X	0,0015501
Right P	95%

Figure A. HQ for carbamazepine (CMZ) for scenario 1 from Piketberg raw water raw water intake based on recommended values, for the population group children.



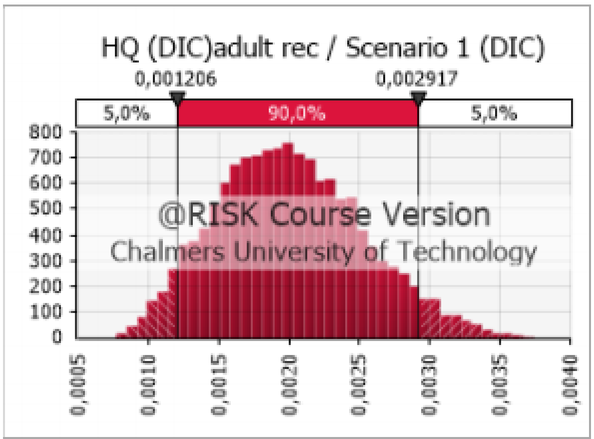
Summary Statistics	
Statistic	Value
Minimum	6,382E-005
Maximum	0,00094958
Mean	0,00029936
Std. Deviation	0,00011857
Variance	1,406E-008
Skewness	0,7860
Kurtosis	3,8984
Median	0,00028505
Mode	0,00025506
Left X	0,00013236
Left P	5%
Right X	0,00051672
Right P	95%

Figure B. HQ for carbamazepine (CMZ) for scenario 1 from Piketberg raw water raw water intake based on recommended values, for the population group adults.



Summary Statistics	
Statistic	Value
Minimum	0,0023089
Maximum	0,0112282
Mean	0,0060179
Std. Deviation	0,0015461
Variance	2,390E-006
Skewness	0,2896
Kurtosis	2,6910
Median	0,0059363
Mode	0,0059536
Left X	0,0036187
Left P	5%
Right X	0,0087518
Right P	95%

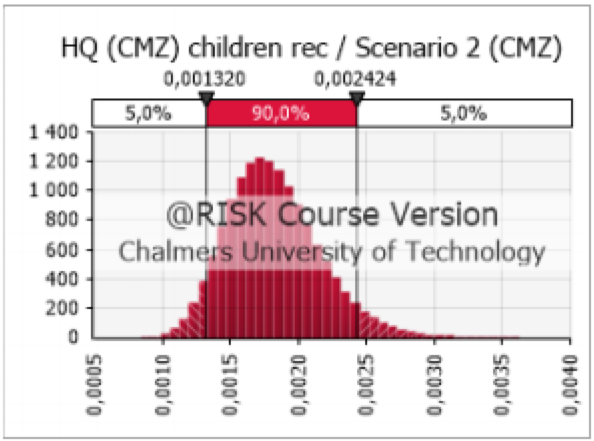
Figure C. HQ for diclofenac (DIC) for scenario 1 from Piketberg raw water raw water intake based on recommended values, for the population group children.



Summary Statistics	
Statistic	Value
Minimum	0,0007696
Maximum	0,0037427
Mean	0,0020060
Std. Deviation	0,0005154
Variance	2,656E-007
Skewness	0,2896
Kurtosis	2,6910
Median	0,0019788
Mode	0,0019845
Left X	0,0012062
Left P	5%
Right X	0,0029173
Right P	95%

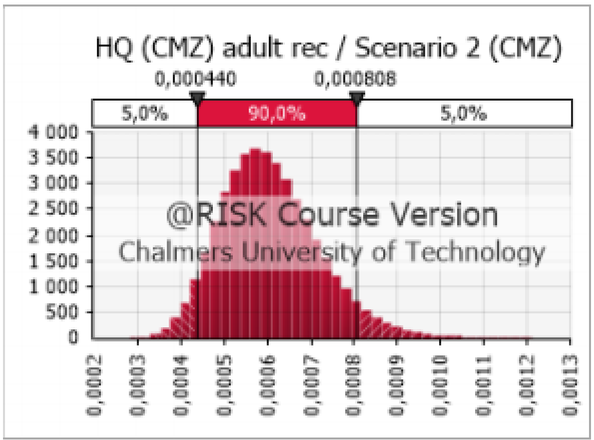
Figure D. HQ for diclofenac (DIC) for scenario 1 from Piketberg raw water raw water intake based on recommended values, for the population adults.

HQ for scenario 2 for children and adults (recommended ingestion rates and ADI) for carbamazepine (CMZ), diclofenac (DIC)



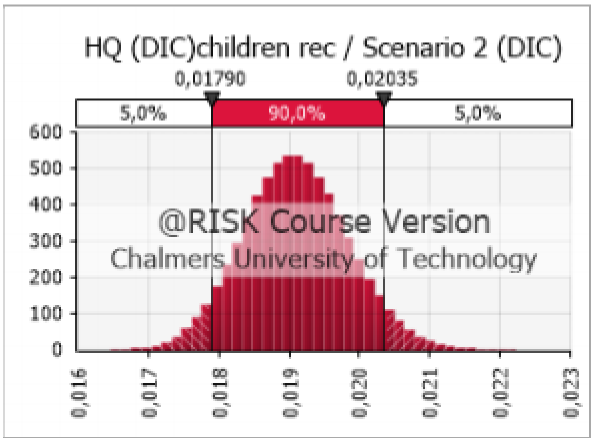
Summary Statistics	
Statistic	Value
Minimum	0,0008498
Maximum	0,0036334
Mean	0,0018196
Std. Deviation	0,0003390
Variance	1,149E-007
Skewness	0,5646
Kurtosis	3,5659
Median	0,0017888
Mode	0,0017275
Left X	0,0013201
Left P	5%
Right X	0,0024236
Right P	95%

Figure E. HQ for carbamazepine (CMZ) for scenario 2 from Piketberg raw water raw water intake based on recommended values, for the population group children.



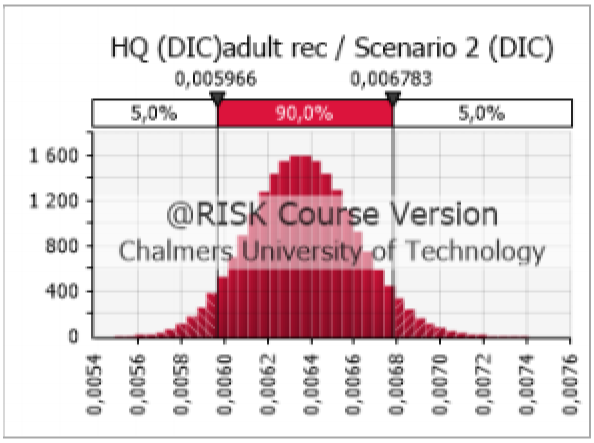
Summary Statistics	
Statistic	Value
Minimum	0,00028325
Maximum	0,00121113
Mean	0,00060655
Std. Deviation	0,00011300
Variance	1,277E-008
Skewness	0,5646
Kurtosis	3,5659
Median	0,00059628
Mode	0,00057582
Left X	0,00044003
Left P	5%
Right X	0,00080788
Right P	95%

Figure F. HQ for carbamazepine (CMZ) for scenario 2 from Piketberg raw water raw water intake based on recommended values, for the population group adults.



Summary Statistics	
Statistic	Value
Minimum	0,0164674
Maximum	0,0222249
Mean	0,0191000
Std. Deviation	0,0007454
Variance	5,556E-007
Skewness	0,1179
Kurtosis	3,0232
Median	0,0190854
Mode	0,0190202
Left X	0,0178992
Left P	5%
Right X	0,0203500
Right P	95%

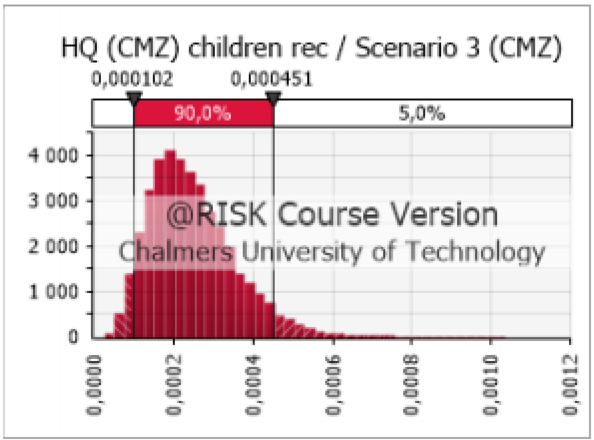
Figure G. HQ for diclofenac (DIC) for scenario 2 from Piketberg raw water raw water intake based on recommended values, for the population group children.



Summary Statistics	
Statistic	Value
Minimum	0,0054891
Maximum	0,0074083
Mean	0,0063667
Std. Deviation	0,0002485
Variance	6,173E-008
Skewness	0,1179
Kurtosis	3,0232
Median	0,0063618
Mode	0,0063401
Left X	0,0059664
Left P	5%
Right X	0,0067833
Right P	95%

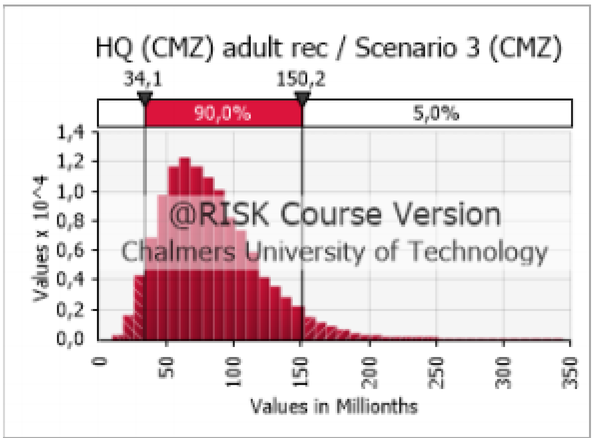
Figure H. HQ for diclofenac (DIC) for scenario 2 from Piketberg raw water raw water intake based on recommended values, for the population group adults.

HQ for scenario 3 for children and adults (recommended ingestion rates and ADI) for carbamazepine (CMZ), diclofenac (DIC)



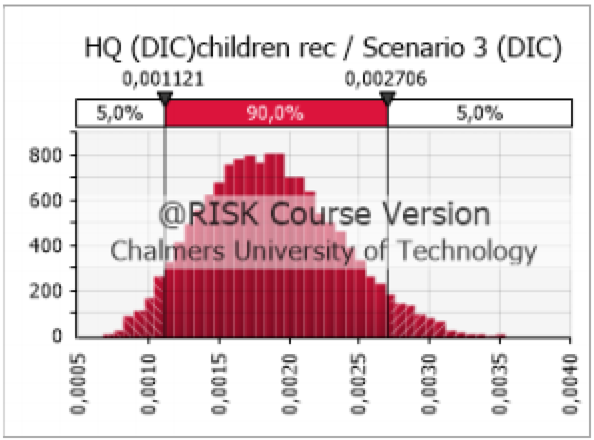
Summary Statistics	
Statistic	Value
Minimum	2,678E-005
Maximum	0,00103422
Mean	0,00024825
Std. Deviation	0,00010954
Variance	1,200E-008
Skewness	1,0093
Kurtosis	4,8055
Median	0,00023120
Mode	0,00018200
Left X	0,00010216
Left P	5%
Right X	0,00045060
Right P	95%

Figure I. HQ for carbamazepine (CMZ) for scenario 3 from Piketberg raw water raw water intake based on recommended values, for the population group children.



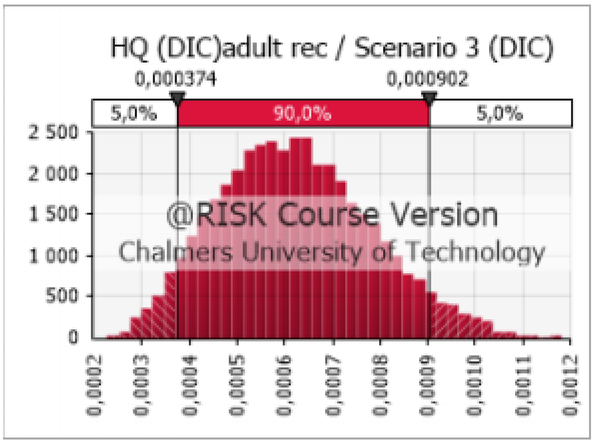
Summary Statistics	
Statistic	Value
Minimum	8,928E-006
Maximum	0,00034474
Mean	8,275E-005
Std. Deviation	3,651E-005
Variance	1,333E-009
Skewness	1,0093
Kurtosis	4,8055
Median	7,707E-005
Mode	6,067E-005
Left X	3,405E-005
Left P	5%
Right X	0,00015020
Right P	95%

Figure J. HQ for carbamazepine (CMZ) for scenario 3 from Piketberg raw water raw water intake based on recommended values, for the population group adults.



Summary Statistics	
Statistic	Value
Minimum	0,0006843
Maximum	0,0035409
Mean	0,0018656
Std. Deviation	0,0004797
Variance	2,301E-007
Skewness	0,2967
Kurtosis	2,7224
Median	0,0018396
Mode	0,0018105
Left X	0,0011210
Left P	5%
Right X	0,0027064
Right P	95%

Figure K. HQ for diclofenac (DIC) for scenario 3 from Piketberg raw water raw water intake based on recommended values, for the population group children.



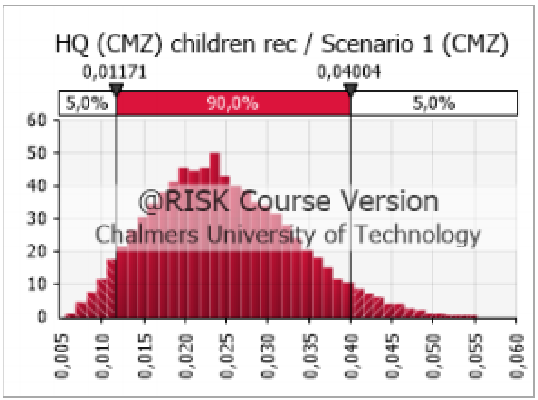
Summary Statistics	
Statistic	Value
Minimum	0,00022809
Maximum	0,00118030
Mean	0,00062187
Std. Deviation	0,00015989
Variance	2,557E-008
Skewness	0,2967
Kurtosis	2,7224
Median	0,00061319
Mode	0,00060351
Left X	0,00037366
Left P	5%
Right X	0,00090213
Right P	95%

Figure L. HQ for diclofenac (DIC) for scenario 3 from Piketberg raw water raw water intake based on recommended values, for the population group adults.

Appendix 11

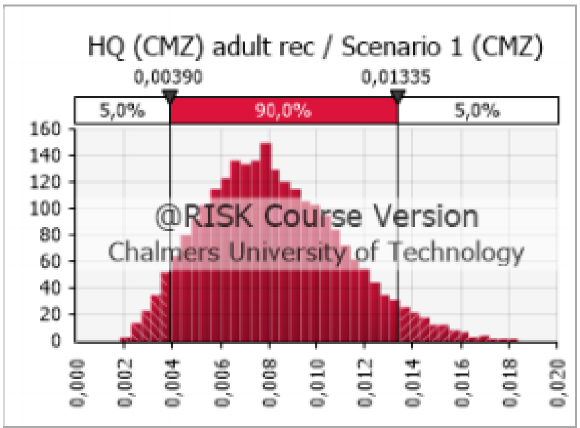
This appendix, presents the results of the hazard quotient of the Sesmylspruit River for carbamazepine (CMZ), diclofenac (DIC) and sulfamethoxazole (SMX) for the population groups: children and adults, for scenario 1, 2 and 3.

HQ for scenario 1 for children and adults (recommended ingestion rates and ADI) for carbamazepine (CMZ), diclofenac (DIC) and sulfamethoxazole (SMX)



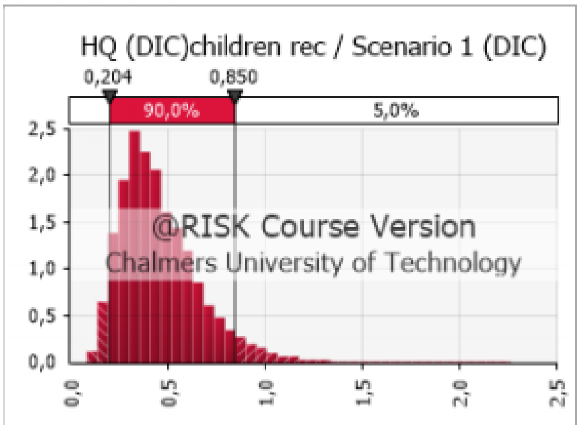
Summary Statistics	
Statistic	Value
Minimum	0,005609
Maximum	0,055232
Mean	0,024589
Std. Deviation	0,008578
Variance	7,358E-005
Skewness	0,4306
Kurtosis	2,8746
Median	0,023815
Mode	0,020289
Left X	0,011711
Left P	5%
Right X	0,040042
Right P	95%

Figure A. HQ for carbamazepine (CMZ) for scenario 1 using raw water raw water intake in Sesmylspruit River for the population group children.



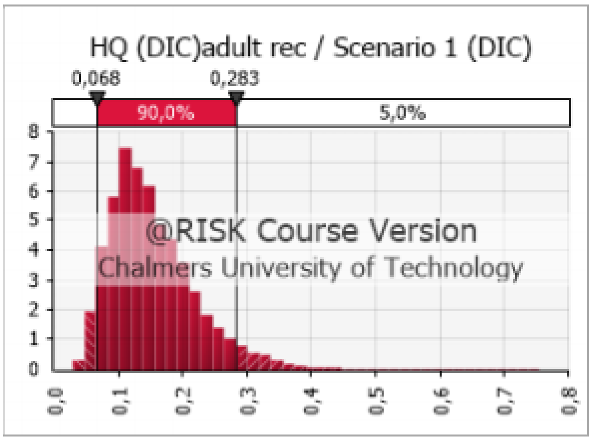
Summary Statistics	
Statistic	Value
Minimum	0,001870
Maximum	0,018411
Mean	0,008196
Std. Deviation	0,002859
Variance	8,175E-006
Skewness	0,4306
Kurtosis	2,8746
Median	0,007938
Mode	0,006763
Left X	0,003904
Left P	5%
Right X	0,013347
Right P	95%

Figure B. HQ for carbamazepine (CMZ) for scenario 1 using raw water raw water intake in Sesmylspruit River for the population group adults.



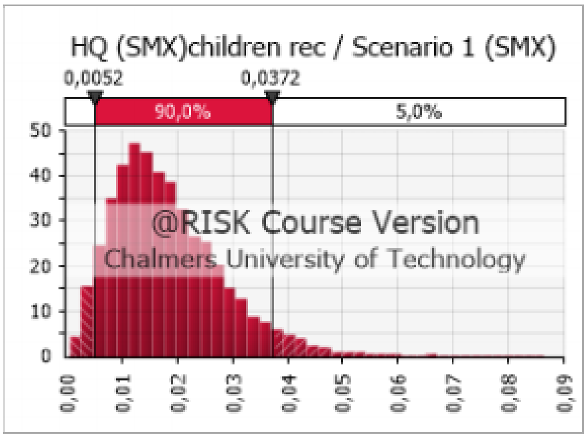
Summary Statistics	
Statistic	Value
Minimum	0,08576
Maximum	2,26761
Mean	0,46111
Std. Deviation	0,20410
Variance	0,04165
Skewness	1,2749
Kurtosis	6,1868
Median	0,42179
Mode	0,35396
Left X	0,20376
Left P	5%
Right X	0,84985
Right P	95%

Figure C. HQ for diclofenac (DIC) for scenario 1 using raw water raw water intake in Sesmylspruit River for the population group children.



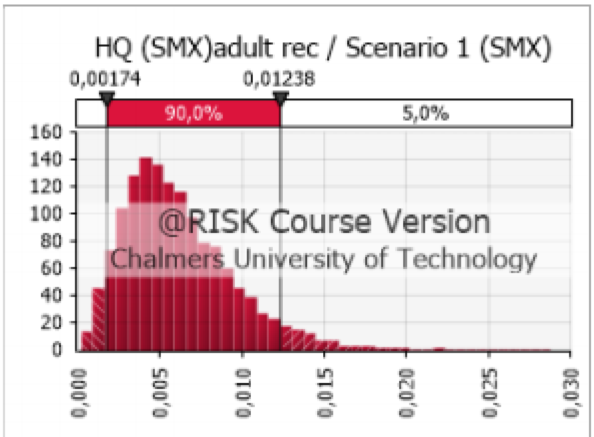
Summary Statistics	
Statistic	Value
Minimum	0,02859
Maximum	0,75587
Mean	0,15370
Std. Deviation	0,06803
Variance	0,004628
Skewness	1,2749
Kurtosis	6,1868
Median	0,14060
Mode	0,11799
Left X	0,06792
Left P	5%
Right X	0,28328
Right P	95%

Figure D. HQ for diclofenac (DIC) for scenario 1 using raw water raw water intake in Sesmylspruit River for the population group adults.



Summary Statistics	
Statistic	Value
Minimum	0,000524
Maximum	0,086398
Mean	0,018213
Std. Deviation	0,009888
Variance	9,778E-005
Skewness	1,0101
Kurtosis	4,5166
Median	0,016468
Mode	0,015013
Left X	0,005227
Left P	5%
Right X	0,037153
Right P	95%

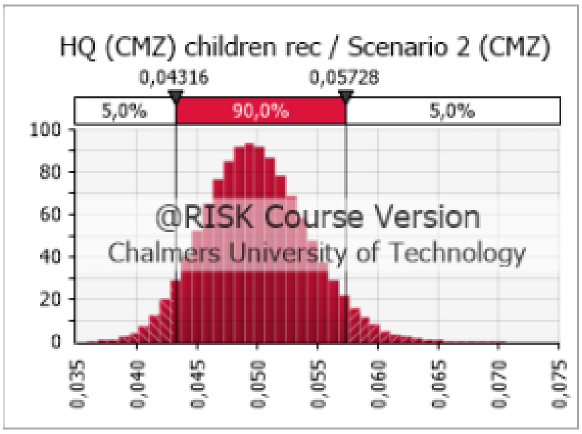
Figure E. HQ for sulfamethoxazole (SMX) for scenario 1 using raw water raw water intake in Sesmylspruit River for the population group children.



Summary Statistics	
Statistic	Value
Minimum	0,000175
Maximum	0,028799
Mean	0,006071
Std. Deviation	0,003296
Variance	1,086E-005
Skewness	1,0101
Kurtosis	4,5166
Median	0,005489
Mode	0,005004
Left X	0,001742
Left P	5%
Right X	0,012384
Right P	95%

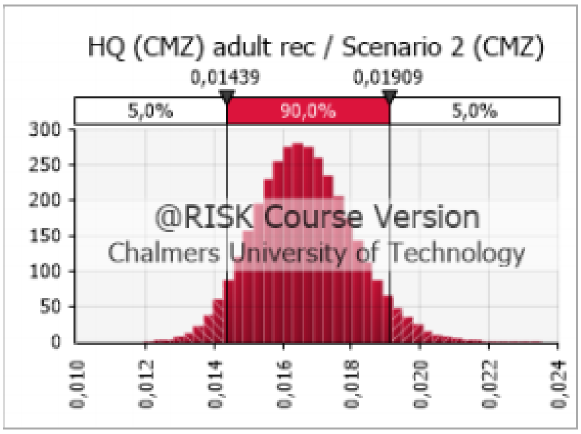
Figure F. HQ for sulfamethoxazole (SMX) for scenario 1 using raw water raw water intake in Sesmylspruit River for the population adults.

HQ for scenario 2 for children and adults (recommended ingestion rates and ADI) for carbamazepine (CMZ), diclofenac (DIC) and sulfamethoxazole (SMX)



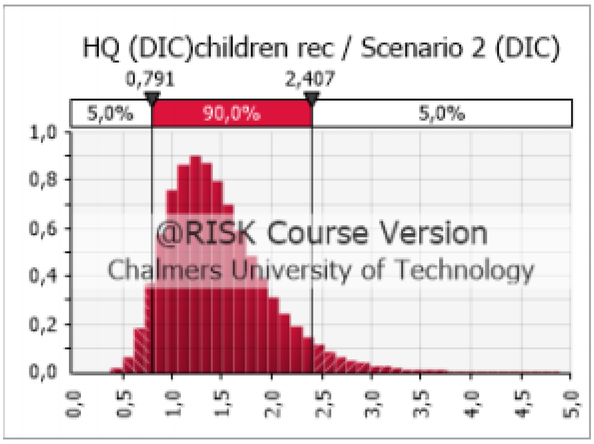
Summary Statistics	
Statistic	Value
Minimum	0,035875
Maximum	0,070628
Mean	0,049911
Std. Deviation	0,004304
Variance	1,852E-005
Skewness	0,2607
Kurtosis	3,1238
Median	0,049725
Mode	0,049031
Left X	0,043162
Left P	5%
Right X	0,057285
Right P	95%

Figure G. HQ for carbamazepine (CMZ) for scenario 2 using raw water raw water intake in Sesmylspruit River for the population children.



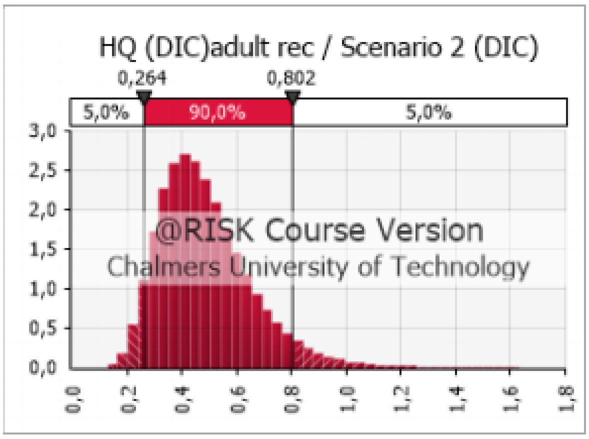
Summary Statistics	
Statistic	Value
Minimum	0,0119585
Maximum	0,0235426
Mean	0,0166370
Std. Deviation	0,0014346
Variance	2,058E-006
Skewness	0,2607
Kurtosis	3,1238
Median	0,0165752
Mode	0,0163436
Left X	0,0143873
Left P	5%
Right X	0,0190949
Right P	95%

Figure H. HQ for carbamazepine (CMZ) for scenario 2 using raw water raw water intake in Sesmylspruit River for the population adults.



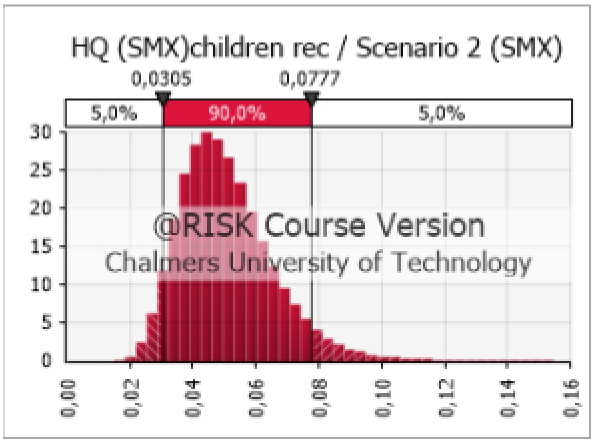
Summary Statistics	
Statistic	Value
Minimum	0,3881
Maximum	4,8890
Mean	1,4615
Std. Deviation	0,5085
Variance	0,2586
Skewness	1,0773
Kurtosis	5,0586
Median	1,3802
Mode	1,1950
Left X	0,7914
Left P	5%
Right X	2,4071
Right P	95%

Figure I. HQ for diclofenac (DIC) for scenario 2 using raw water raw water intake in Sesmylspruit River for the population children.



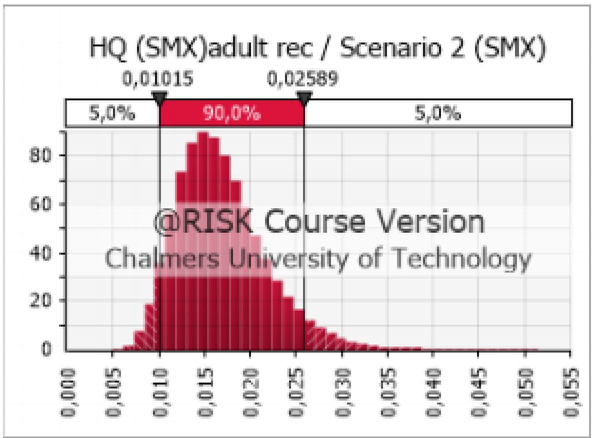
Summary Statistics	
Statistic	Value
Minimum	0,12935
Maximum	1,62967
Mean	0,48716
Std. Deviation	0,16950
Variance	0,02873
Skewness	1,0773
Kurtosis	5,0586
Median	0,46007
Mode	0,39834
Left X	0,26380
Left P	5%
Right X	0,80237
Right P	95%

Figure J. HQ for diclofenac (DIC) for scenario 2 using raw water raw water intake in Sesmylspruit River for the population adults.



Summary Statistics	
Statistic	Value
Minimum	0,014782
Maximum	0,154592
Mean	0,050661
Std. Deviation	0,014718
Variance	0,0002166
Skewness	0,9016
Kurtosis	4,5070
Median	0,048648
Mode	0,045101
Left X	0,030462
Left P	5%
Right X	0,077677
Right P	95%

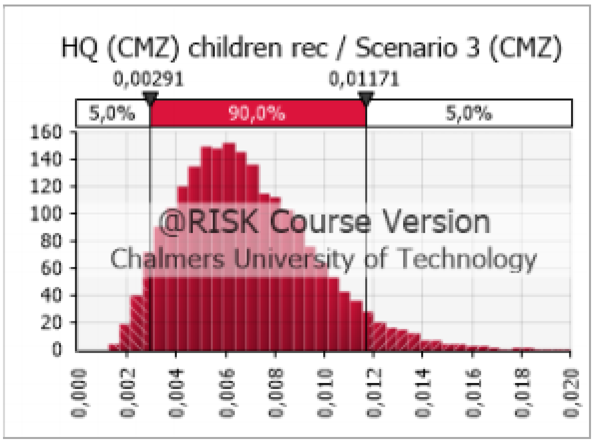
Figure K. HQ for sulfamethoxazole (SMX) for scenario 2 using raw water raw water intake in Sesmylspruit River for the population children.



Summary Statistics	
Statistic	Value
Minimum	0,004927
Maximum	0,051531
Mean	0,016887
Std. Deviation	0,004906
Variance	2,407E-005
Skewness	0,9016
Kurtosis	4,5070
Median	0,016216
Mode	0,015034
Left X	0,010154
Left P	5%
Right X	0,025892
Right P	95%

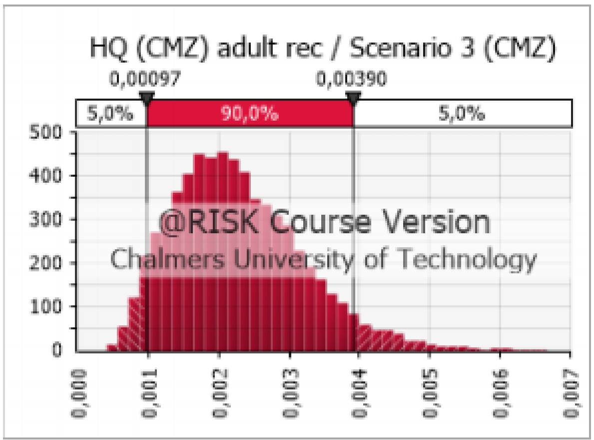
Figure L. HQ for sulfamethoxazole (SMX) for scenario 2 using raw water raw water intake in Sesmylspruit River for the population adults.

HQ for scenario 3 for children and adults (recommended ingestion rates and ADI) for carbamazepine (CMZ), diclofenac (DIC) and sulfamethoxazole (SMX)



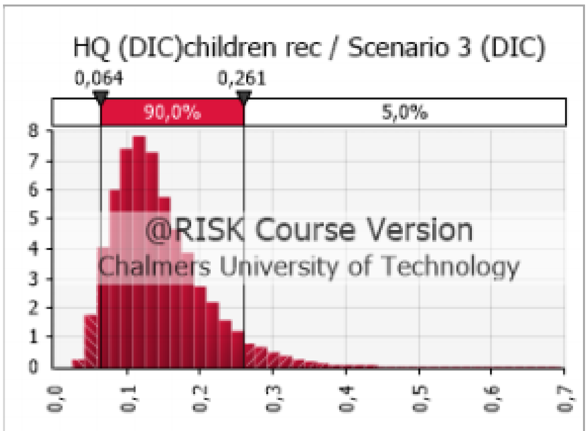
Summary Statistics	
Statistic	Value
Minimum	0,001225
Maximum	0,019969
Mean	0,006810
Std. Deviation	0,002730
Variance	7,454E-006
Skewness	0,6713
Kurtosis	3,4306
Median	0,006481
Mode	0,005982
Left X	0,002914
Left P	5%
Right X	0,011707
Right P	95%

Figure M. HQ for carbamazepine (CMZ) for scenario 3 using raw water raw water intake in Sesmylspruit River for the population children.



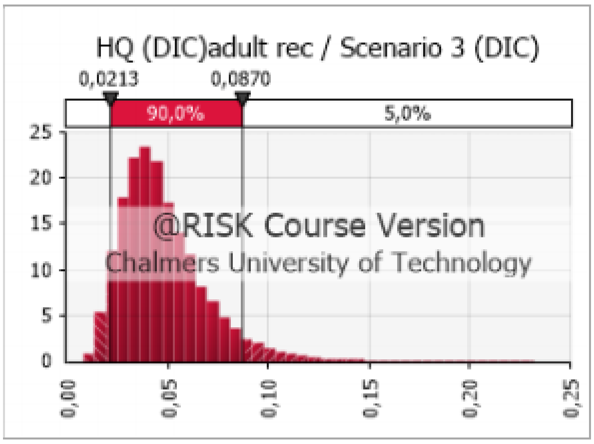
Summary Statistics	
Statistic	Value
Minimum	0,0004083
Maximum	0,0066562
Mean	0,0022701
Std. Deviation	0,0009101
Variance	8,283E-007
Skewness	0,6713
Kurtosis	3,4306
Median	0,0021605
Mode	0,0019939
Left X	0,0009714
Left P	5%
Right X	0,0039024
Right P	95%

Figure N. HQ for carbamazepine (CMZ) for scenario 3 using raw water raw water intake in Sesmylspruit River for the population adults.



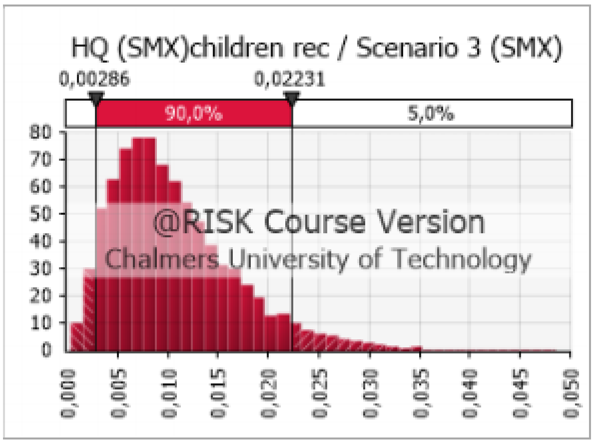
Summary Statistics	
Statistic	Value
Minimum	0,02474
Maximum	0,69507
Mean	0,14285
Std. Deviation	0,06338
Variance	0,004017
Skewness	1,3368
Kurtosis	6,2528
Median	0,13063
Mode	0,10588
Left X	0,06379
Left P	5%
Right X	0,26100
Right P	95%

Figure O. HQ for diclofenac (DIC) for scenario 3 using raw water raw water intake in Sesmylspruit River for the population children.



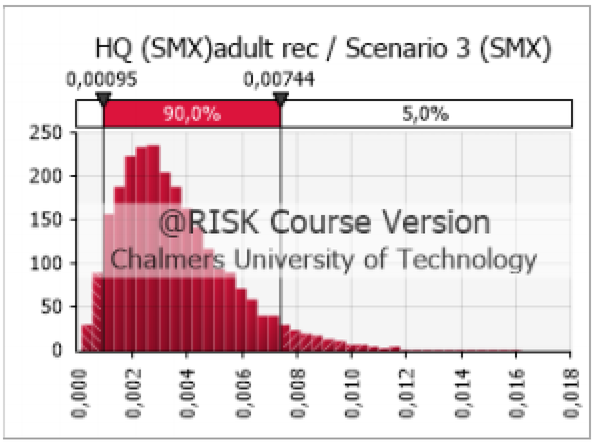
Summary Statistics	
Statistic	Value
Minimum	0,008246
Maximum	0,231690
Mean	0,047618
Std. Deviation	0,021125
Variance	0,0004463
Skewness	1,3368
Kurtosis	6,2528
Median	0,043545
Mode	0,035293
Left X	0,021263
Left P	5%
Right X	0,086999
Right P	95%

Figure P. HQ for diclofenac (DIC) for scenario 3 using raw water raw water intake in Sesmylspruit River for the population adults.



Summary Statistics	
Statistic	Value
Minimum	0,000409
Maximum	0,048572
Mean	0,010578
Std. Deviation	0,006122
Variance	3,748E-005
Skewness	1,1001
Kurtosis	4,5839
Median	0,009359
Mode	0,008347
Left X	0,002860
Left P	5%
Right X	0,022308
Right P	95%

Figure Q. HQ for sulfamethoxazole (SMX) for scenario 3 using raw water raw water intake in Sesmylspruit River for the population children.



Summary Statistics	
Statistic	Value
Minimum	0,0001363
Maximum	0,0161906
Mean	0,0035259
Std. Deviation	0,0020407
Variance	4,164E-006
Skewness	1,1001
Kurtosis	4,5839
Median	0,0031195
Mode	0,0027822
Left X	0,0009532
Left P	5%
Right X	0,0074360
Right P	95%

Figure R. HQ for sulfamethoxazole (SMX) for scenario 3 using raw water raw water intake in Sesmylspruit River for the population adults.

Appendix 12

<u>Interview 1</u>

First we want to know a little bit of who you are. Can you describe a little bit of yourself? What is your occupation etc? My name is XXX, I work in the western cape government and live in Capetown.

How long have you been living in this region?
Okey, well Hmm, huuuu, I am now back in this region for 17 years, I was born here but I lived away in between. Is that answer alright?

Yes, perfect.. What does your household look like? apartment, villa etc. and how many people?
So there are three of us living here, there is me, my husband and my son. And we live in a house.

Now we will ask you about your water knowledge and your drinking water behaviour..
Do you know where your tap water comes from?
Yes, I know, yes. Haha, My water comes from actually.. Do you know what? I tell you what.. Honestly, I have been trying to find out exactly where my tap water comes from and I have been trying to find a map of it and actually I have been very struggling but I think because I know of.. You know table mountain? You can look up the university of Capetown and the mountain is close to there. Just above there. I think that my water comes from reservoirs
on Table Mountain. That is where I think my water comes from. I am not 100% sure but I think so, but you need to remember that all the pipes in and around Capetown are interconnected so they can even change direction of the water, they are all linked together.

Do you know how the water cycle works where you live? wastewater, drinking water etc?
Okey, well, generally the water are mainly falling.. I will send you a very nice map of this area, and that map show you where the most rainfall is and.. most of the rainfall falls in the mountain just between Berg and Breede catchment area and then they are feeding damms further down and out to different towns basically in the area.

And like the urban water cycle? Like what happening with the waste water, we are looking after what happening there. When you drink the water and use the water, what is happening then?
Okey so, the waste water that I am using from where I live goes from me to Waste water treatment works and amm.. honestly I am not exactly sure which waste water treatment works and what it goes to. There is one.. hmm.. You really caught me out now haha. Hmm, this bigger system but I was trying to find that out so I think there is a waste water treatment works which is near Muizenberg which is in the southern side where the beaches are. It might go there. You are giving me some homework now haha.

And do you know or have any idea where it goes later when it is discharged from the waste water works? Hmm, I.. mm.. So all of our waste water treatment works goes into the sea as far as I know. And we are not really reusing much of it at this stage, jaa..as far as I know.

How do you use your tap water at home, what do you use it for?
We do not bath in our house, we have like two different baths and once you have been through a drought period of 3 years it almost becomes like a sin to bath. So you become psychologically trained that you.. that it is something you don't not really enjoy anymore so.. You know we have a shower in our house and we try to have quite quick showers and we use the water for washing our clothes, washing dishes and yaa..

Do you use it for drinking and for preparing food?
Yes obviously we use it for food, yaa. But you know I always try to not let the tap run over the food so

instead I use a basin and put the vegetables and so on in it and then rinse it in there. So we have quite a low water usage. Do you want to know our consumption?

No, thank you it is okey.
Okey, no worries, but we know exactly what our water usage is so that is good.

Okey, nice. And we are also curious if you drink it straight from the tap?
Yes, we drink it straight from the tap

Do you sometimes use other water sources for drinking water (beside the tap water in your household)?
No, I don’t, never

Do you anytime feel doubts that the tap water is safe to drink?
No, because I know that where I live, because different parts of Capetown get their water from different places and I know that my water I get is one of the cleanest in the world. This because that it comes directly from a reservoir from the mountains. It is very, very clean water. And it also have very low chemical contamination or anything like that. Not water is not from a river at all, thats why.

Okey, so next one. You have in some way already answer this but.. What is your feeling about the water situation and scarcity in South Africa today?
Well you cant not really generalize because different parts of africa get their water from different places, so you need to get very local on site. So I feel that the city I live in, which is the city of Capetown I know the people quite well who are in charged of bulking water to the city of capetown and I have an extremely high regard for them and they are very competent engineers and I feel that.. of course we will be taken by surprise if even more drought and as a city we have tended to rely on our rainwater. I would say that we need more backupwater like boreholes and so on.. but at this time we have already 70 boreholes in the city of capetown. So I feel that they will manage the water situation and I don't feel that we will ran out of water, I mean I cant say 20, 50 or hundred years from now but also we learn during the time of drought that people can react very positively and we really did everything. People were very very committed to what they were doing and making sure that they use a low amount of water, as possible

Okey, so lets go over to the concept of water reuse. Are you familiar with that, what does it say to you?
Okey now.. honestly, If i lived in a city like London and I knew my water were passing many times through people bodies I think I would purchase water from a spring. At least to drink. The water I get here is equivalent to spring water, the water I get in my home. So I would say major concerns of example different drugs and psychiatric drugs passes through the water waste works systems and we are then worried that these drugs.. I know that the female contraceptive drugs passes through the wwtp and that are of major concern since it impact the sperm production etc.. infertility etc. Also obviously there are main potentially other kind of drugs that I would be concerned about.

How would you feel if you were living in a area that was taking raw water from a river? And that is also retrieving treated waste water further upstream, such as Berg river.
Hmm, I would say I would use the water for the shower and so on, you know, and if I am wealthy enough I would purchase my water instead on drinking that water than. I would purchase spring water instead. Just for drinking. If I knew this about reuse. I would do that instead.

So if you travel to other places in south Africa how do you do then?
Hmm, not really that I buy water then, when I am traveling I always go to mountain areas and nature reserves etc so the water there is really clean but if I go to a city in Europe I may prefer to buy bottle water, yes, for example. And I also ask advice from the people that live there, if they buy bottle water or..

Do you feel that you have enough knowledge about water reuse to decide if it is safe to drink?
Yes, definitely

Do you have trust in water cleaning technologies? And also if you could think as one scenario like when you are in a situation of when you need to use water reused water.
I do have trust in cleaning technologies. But always water treatment works are tending to, mainly many of them using procedures like using chlorine and chloride and I don’t really like that because you can get tetrachlorides. You know molecules and atoms that have potentially links to cancer. So that I don’t want but if I knew the water have been cleaned with ozon I would feel that that is a more reasonable technology and then I would more be okey to drink the water.

So if it would be a conventional treatment plant with coagulation, flocculation, sedimentation and chlorination, you would not prefer it?
Yes, I would not be so keen then, especially when they use chlorine. But having said that you know, if I am out in a native area and I need to get water, of course, then I need to drink it, you know.

Do you have trust in your authorities such as municipalities or others working with water in your region?
Yes, remember I live in Capetown, in the city of Capetown, and they are the best performing municipalities in the country. And also remember we are wealthier, we have more wealth in the city so we can put betten procedures in place, we are not a municipality that struggling and we have competent engineers. I would say that our water cleaning processes are world class, you know. It depends very much from municipality to municipality.

You said that if you go to London or Europe for example you don’t have that much trust in the water and that it is clean, Can you think of anything in these cases that could help increase your trust in water reuse for drinking water?
I prefer to know that ozon have been used in the cleaning process

..
Thank you for your participation!

Appendix 13

Interview 2

Can you describe a little bit of yourself? What is your occupation, where do you live?
I'm xxx, I am unemployed, I have a biological son and an adoptive daughter. I am staying in Paarl, in Drakenstein municipality. I stay with my mum in my fathers house. I took in an uncle of mine that was living in the streets, he is 62 years old. Before lock down I was working with council meetings but because of lock down there are no longer council meetings.

Okey. So how many people live in your household?
Five people: it is me, my mum, my uncle and the two children.

Do you live in an apartment, or villa or house?
It is a house.

In which region (municipality) do you live and how long have you been living in this region?
I was born and raised in Paarl.

And now we will ask you about water and your drinking water behaviour..

Do you have knowledge or an idea of where your tap water comes from?
Honestly speaking, no! I do not have an idea.

Do you have any idea of how the water cycle works where you live? **What happens when you drink the water?**
In Drakenstein there is sometimes when the water does not taste fine. 80% of the time the water is fine. I think that when it is a cut off of water then, I don't know. There are times when the water doesn't taste right for me.

So sometimes it does not taste good?
Yes.

How do you use your tap water at home?
Usually if I do have finances I buy bottled water. Or I boil the water most of the time.

Did you say boil the water?
Yes, boil the water.

So you never, or do you drink the water straight from the tap?
Most of the time I do.

So, when do you boil it?
When it doesn't taste good.

Okay, so it is the taste?
Yes yes.

And you said that sometimes you used other water sources for drinking water?
Yes, I buy myself water. Especially when I'm in other regions. Or maybe I'm in eastern cape. Because that water sometimes gives me stomach cramps, and I will have a running stomach.

But when you are at home in your own house then you drink from the tap?

Yes, yes.

Do you ever doubt that the tap water is safe to drink?
Not always safe, but 80 % of the time I do drink it like I have said. Okay.

When you feel the doubt, what is that based on? Like what are your worries?
To get sick is my worry. So then I will boil the water. or if I have money I will buy bottled water from the shop.

What is your feeling about the water situation and scarcity in South Africa today?
First of all we had a shortage of water in South Africa. They came to us and said it was a drought. And we must use water, we must not waste water. They did not come back and the water level dams are up. They are using the same rate now as when it was drought.

The dam is at the same level as when it was drought?
It is higher now. But the rate that they are charging people is still the same as when we had drought.

Would you say in your region is there a problem with scarcity often? At this moment when I am looking at the dams level they don't have a problem now. They had a problem in the past.

Have you heard the term water reuse? Are you familiar with that?
Eh, no. They don't educate people about that, honestly.

Because our project, our master thesis, is about water reuse. That means that we have treated wastewater that will be discharged to rivers. So the treated wastewater is discharged into rivers and then it is treated again for drinking water.
For drinking water. okay. alright.

How would you feel of knowing that you… does it feel okay for you to drink reused water?
You know. Honestly, I don't feel right. But if they are testing it and would be 100% sure that won't affect our lives, you see. I'm not an expert on that field, I don't know the things that they are using, what they can do, what harm they could do to our human body. You see, if those things can be 100% sure I would not have a problem. Honestly speaking, there is one thing that worries me, are those things, those chemicals that they are using 100 percent for our body?

So you are worried about the chemical that they are using in the water treatment?
Yes, what side effects does it have in the human body? Your organs, your kidneys, your lungs. Because it is chemicals that they are using.

Like chlorine? Yes.

Would you say that you are more afraid of chlorine than of wastewater?
I am afraid of both. Because I don't know if that wastewater is 100% clean. If that chlorine can kill all the bacteria in that water. They don't educate us about that. That chlor can clean 100% that water. Honestly, sometimes when we drink that water straight from the tap you can taste, it is not a good taste. It is a different taste.

If you get educated in this, and if they spoke to the people more would you feel more safe than?
Yes, so that people can understand. yeah, if the political and people**..** Yes.

In general, do you have trust in water cleaning technologies?
Honestly speaking, I do not even have trust in people cooking in the restaurants. People can make big mistakes.

Can you say if you have trust in municipalities where you live? Do you think that they clean the water properly?
I would say 80% trust, and a little bit of doubt.

Would you say that you have trust in the authorities?
Even them. You know, in our country you don't trust anything anymore. Because they are doing things for them. They are no longer doing things for the community. So you do not know if they want to save the news, to keep us from things, so we can get that water. I will be honest with you.

Is there anything that could help increase your trust in water reuse for drinking water?
They must be, what is this word, they must be open with the people, transparent with the people.

So, open up for information and maybe would you say that you would need more health tests, health impact tests? Yes yes.

Appendix 14

<u>Interview 3</u>

We would like to start with, Can you describe a little bit of yourself? What is your occupation, where do you live?
I live in Piketberg in the side of the town in Berg municipality. I work at Berg municipality and are senior protechnician so I do everything that is regard to water such as purification, sewage treatment.

Maybe you will be kind of an export on what we will ask you about later then.. but that is also good so we will have a spread range of people and knowledge.

How long have you been living in this region?
2 and half years I have been living here and before that I lived in Capetown

Did you move for work?
yes, I did.

What does your household look like? apartment, villa etc. and how many people?
Normal 3-bedroom free standing house, and it is me and my fiance living there. Ya, that's all.

And now we will ask you about water and your drinking water behaviour..

Do you have knowledge or an idea of where your tap water comes from?
haha, yes. All water gets diffracted from the Berg river that it goes from purification works or treatment works and comes up/pumped up to reservoirs going out to the network down to the households.

And later, what happens then? asking about the wastewater cycle.
Okay, okay. Obviously the wastewater moved down to the waste water treatment work and get treated there and then in Piketberg it goes to our irrigation dam. Treated wastewater are pumped to the irrigation dam and is then used to water the golf, the sportsfield and some gardens and open areas.

It is not discharged to the Berg river?
No, no. If the irrigation is full we discharge to a small street but it does not happen often.

Never to Berg River from your nearest waste water treatment plant?
No, no.

That's interesting for us, and news for us. What is the name of the WWTP?
Piketberg WWTP

How do you use your tap water at home, what do you use it for?
I use it for the normal, drinking and preparing food and also washing myself and clothes etc. and i recycle a lot of water from the washing and reuse in the garden. what else? use it in the garden if i have enough already used.

Did you say that you don't have enough recycled water?
Yaa, from time to time it depends on how much washing I do. I catched water in tanks and take it to the garden but from time to time it gets very hot and in Piketberg in the summer you need to water every second to keep your garden growing.

Are you allowed in South Africa to take as much water as you want for gardening and stuff or is it a limit?
For these moments we are allowed to use as much as we want obviously you get to pay for as much as you want. The bills workes exponentially so more water you used to use, the higher the tax. At the moment we

are not in a drought situation but we have times where we are not allowed to use to water you garden etc. For two years from now we were in a situation when we were not allowed to garden etc.

Do you drink it straight from the tap?
yes, I drink it straight from the tap

Do you anytime buy water from other sources? Buy water for drinking?
No, no. But only if I am traveling somewhere I do that. Otherwise no. Because I work with it and I know that the water quality is good it feels good. And on a weekly basis I know that the water is safe.

If you travel in south africa you always go for the tap water?
most of the time, yes. I have a bit of a area that I can't drink the water because I know of these problems.

You never feel doubts then that the tap water is not safe?
No, no. I have a area that I have to fear for the water but most of the time it is good water

Your already said that it is not a drought season or period now but, what is your feeling about the water situation and scarcity in South Africa today? how is it for you?
I can speak of my own experience from Berg river we are in a situation because of that the berg river running through a area and then we have a couple of mountain stream and the groundwater are fairly minimum and is of a lot of treatment so yaa, we are fairly unsure that the water is not wasted and we monitor it a lot to ensure that it won’t be a problem in the future and what we in that case should do.

Would you say that it is an increasing problem?
yes, definitely. I think east of south africa and even in the whole world. we will get to a point where the water is going to be a..

Is the people living in Piketberg are encouraged to reuse their water in their homes, do you know if other people do it?
Definitely, just before we had the drought situation here in the wester cape area where we reached the 4 day zero for the water and it becomes more and more and it comes more methods to keep and catch water harvesting and minimize the usage and get water smart etc. Maybe put plants that don't need a lot of water in the garden etc. So yaa, we have reached that we are over the limit after the drought. But now in not drought we are within the limit in this situation. And you can see that the water reuse is a lot less after the drought season and people become not that good anymore..

When we are saying water reuse, What does it say to you when you hear water reuse?
Water reuse is all about the water you can reuse after treatment and thats what I see water reuse as. Thats mainly..hmm.. we have many people reuse the water from washing clothes etc and use it in the garden and that is fairly straight forward and it is not required and then no treatment processes are used either.

And using water reused water for final drinking water, what does you say about that?
Yes, I know we have a couple of pilot plans etc in south africa and I know also capetown looking at it and I know sewage treatment plant need a bit of update or upgrade in the aim to reused for potable drinking and I am not sure all the people or everyone in south africa would preferably buy into reused water but yaa, for me, that something we are looking in to the future and the mostly of our water treatment works the quality is now fairly good. SOme of the other town use springs and storage dams so if that waters was the normal raw water before treatment for potable water it would be reused and that would be good.

For you, how would you feel about drinking reused water to avoid water scarcity?
Yaa, because I know I don’t have any doubts that the quality of the water are good and safe to drink

So do you think that the reason for you is that you have much knowledge from your work and life within this topic?
Yaa, for me it going to be easier than a normal person not working with it and not having all the knowledge

it would need more compensating and yaa.

Maybe it could be harder for other people, and if they know that their raw water could sometimes consist of a high amount of treated waste water - do you think it could be more difficult for them?
Yaa

Do you have trust in your authorities such as municipalities or others working with water in your region? This question is a little bit of "do you have trust in yourself" haha..
Haha, Yeah I have trust for me and for all municipality workplace and people I know. If we need to go to reclaim or reuse we will be able to perform and deliver. And I know some other municipalities in South Africa that are not that safe in my area and in my municipality. So i feel very safe here. In my area, my municipality at least and we will be able to deliver.

If you think for yourself and also for other people in your surroundings, Is there anything that could help increase your trust in water reuse for drinking water? like further cleaned, more knowledge spread, further health impact tests etc, study visits or anything you can think of.
Yaa, I think if you can show them the result and that is out and that is no problem. I think that inform them more and spread the knowledge, maybe campaigning and showing them that the water is actually safe and that is how your normal raw water is and some raw water is even worst than treated waste water. People need to the science and the studies they need to see that it is proven that it is no problem and safe to drink. It can be sure, it can be proven.

Is you perception that ordinary people not working or having extra knowledge about this that they tend to accept or reject water reuse for drinking water or would you think that they would go "uucchhs" and yuck-factor so disgusting of getting the knowledge of this?
Ah, yaa, I have a situation like that from my own experience. my parents live in capetown and that area are covered of three plants that have outbreaks and reuse water and we had this discussion with my parents and they said that they would rather buy water for drinking than use and drink reused water. As I said, everyone need a bit of education around and maybe we need campaigning and showing that we can ensure safe water. For me, it is not disgusting if it is treated and correct and according to all quality tests that we do and that we understand that it is no problem with reused water.

..
Thank you so much..

Appendix 15

<u>Interview 4</u>

Okay so first, we would like to know a little bit about you. What do you work with? What is your occupation, where do you live in South Africa?
Okay, so at the moment I am not working, I'm not allowed to work because of my visa situation. aaaahm, we live in Paarl which is about 55 km outside of Capetown city. It is along Berg river. Uhm, so the state where I am living is , uhm, bordering Berg river, so if we walk just outside of this state we would come to berg river, and we can go and swim there as well.

What did you work with before you moved to South Africa?
So, in Sweden I was a travel agent. I was working for big swedish travel companies and was working mainly with group travels. So, conferences, large groups of families, the main market was more or less europe. Uhm, yes.

How old are you?
I was born in 1984, 37 years old this year.

How long have you lived in your region?
Since August 2019.

What does your household look like? apartment, villa etc. and how many people?
This is a free standing house on a small plot within a state. We have a free standing house. It is Me and my husband and my son. He is five years old.

Now we will ask you about water and your drinking water behaviour..

Do you have knowledge or an idea of where your tap water comes from?
I believe our tap water comes from a big dam outside Franschhoek, which is called tierowats cloak.

Do you have any idea of how the water cycle works where you live? wastewater, drinking water etc? After using the water for flushing what do you think happens with it?
Actually not. I can't. Not here. Absolutely no idea. I don't know if it is being recycled or where it goes, I have zero idea.

How do you use your tap water at home, what do you use it for?
In the kitchen, we use it for cooking, and then the tap water for brushing teeth and in the shower, and the water that we… We always use a bucket in the shower and the water that is left in the bath we use outside for the garden. And I.. it is the same water we use all around the house. The same in the taps, and then also the sprinkler system is from the same main tap. I am not sure about the toilet water, but I believe it could be the same.

You never mentioned if you drink the water?
We do sometimes. We actually recently started to drink the tap water more frequently. Because before, we feel like it is safe, but it doesn't taste very good. So we recently started buying bottled water because it tastes better for us. So whenever we fill up our water bottle we take plastic bottles. But if I'm thirsty and I quickly go to the kitchen I drink from the tap. And all of the water for cooking, we take from the tap.

It is never that you treat the water before drinking if you drink it from the tap?
No. never.

It is the taste? Is it chlorine? or what is it? I would call it more earthy. It feels like it.. i wouldn't say… I can't taste chlorine, I can't taste iron. If I refer to swedish houses that has their own well you can taste the iron in the water, but I can't taste that iron here. I would just say that it is very earthy. It doesn't taste very good.

Is it any colour? can't look bad?
No it looks very good actually. It looks cleaned, and not discoloured.

You've already answered this, but sometimes you buy water? Or, you buy water mostly? Yes, Yes.

And you do that because of the taste? Only because of the taste. I prefer actually not to buy water, because I don't want to spend the money and I don't want to spend money on plastic. But it is just because it tastes better. Whenever we fill up our water bottles.

If you drink the tap water, do you ever have doubt that it is safe to drink?
I would say, uhm, sometimes yes. I know that the state that we live in has had some issues with water supply. I can't tell you why, but sometimes it comes out discoloured. So sometimes I can see that it has some kind of brownish tint to it. And then we don't drink it. Or we flush it so it looks clean again. But that does not happen very often, I think maybe five times in a year and a half.

What is your feeling about the water situation and scarcity in South Africa today overall? Would you say it is bad?
I would definitely say it is bad. I would say that everyone knows about this problem. But very few people actually take action against it. Uhm, a lot of people still talk about the south africa summer of 2018 which had a serious drought. I remember that, because we were here on holiday and the swimming pools were not taped up. The taps in the bathrooms in public places and shopping malls were closed. So I do remember it, and people talk alot about the problem that there is not a lot of water, but they dont do anything about it so to speek. The still shower, they still bathe, and so on.

And would you say that even if it is not drought now, would you say it is an increasing problem in your region?
Definitely, I think so. And I think it will get worse.

Are you familiar with the term "water reuse"? What does it say to you?
What it means to me? Uhm, i'm not very familiar with it. But I maybe think that uhm, all of the water that we use is somehow being cleaned and we can use it again. Very basic.

Do you think for yourself then? or is it public use?
Uhm, I would maybe think on a larger scale. Ideally would be on a larger scale.

Because this is kind of what we work with. We already said to you that we are working with pharmaceuticals in rivers. But also, we work with water reuse in rivers. And that means that a lot of the treated wastewater will be discharged to rivers, and sometimes during drought it consists of really really much wastewater, but of course treated wastewater, and then in a next step it is also cleaned in the drinking water treatment works. It happens all over the world, especially in some places in South Africa and there is a lot of research on it now. So that's why we work with this.

You said that, your definition of water reuse. Do you know where you got that information from? friends, family, tv?
No, I don't hear anyone talking about it here. It is just something that I got in the back of my mind. Especially from Sweden. I don't hear about it on the news. I don't read about it. And don't hear neighbors talk about it, or friends talk about it.

How would you feel about drinking reused water? Like taking water from Berg river that consists of treated wastewater?

Uhm, yes and no. I think the idea does not suit very nice with me because thinking that it is someone else's dirty water. Than I also see the bigger picture that we need to do. Uhm, so, I mean I trust science and if it has been proven that it is fine I would definitely do it.

“...the idea does not suit very nice with me, because thinking that it is someone else's dirty water. Then, I also see the bigger picture that we need to do….and if it has been proven that it is fine I would definitely do it.”

So it is a mixed feeling?
Very much.

Do you feel that you have enough knowledge about water reuse to decide if it is safe to drink?
No.

Do you have trust in water cleaning technologies?
Yes I do.

Do you have trust in your authorities such as municipalities or others in your region?
Uhm, not so much.

Okay, Why? Well, this is a bigger discussion. South Africa is very known for being corrupt. And money not being dealt with in a good way and people, uhm, not handling money that has been given to them for a specific reason. Like they dont use it for that specific purpose. They might use some of the money for that purpose, but then there is always money disappearing. There is Always money disappearing. So I dont have a lot of faith, maybe in the municipality. Sadly thats how it is here.

But would you say that this would risk your and other peoples health, because maybe some money goes to wrong places? Yes I would say so. I think that a lot of people would feel hesitant if there is something that would be especially handled by government money. I think a lot of people would feel differently if it was, uhm, somewhere from the private sector.

Is there anything that you could think of that could help increase your trust of water reuse? Like more knowledge, education about the cleaning technologies, open thinking from authorities, study visits?
Uhm, I think just sending out information. As I said I believe in science and someone talking about it, showing the effects and proving how it works and stuff. For me that would be good.

So the most important for you would be like, get more information from the bigger picture?
Yes, which is not the municipality actually.

More from private sectors or?
Yes

So if the, let's say a drinking water treatment works would be private and you buy water from that place. Would you say that feels more safe for you?
Yes

Appendix 16

Interview 5

Can you describe a little bit of yourself? What is your occupation, where do you live? How old are you?
I will start with the age, I am 36 years of age. An I am 36 years of age, and I live currently in a little place called emuqleny which is in Paarl, in berg river district, i drakenstein. My occupation: I am a household aid in Paarl hospital currently.

How long have you lived there in that region or in paarl?
I have stayed here for the past 22.. I think 23 years, from 97. 25 years, yes 25 years.

Can I ask you, what is your occupation, what are you doing in the hospital?
I am a household aid. I take care of patients needs.

How do you live? Do you live alone or with family? In an apartment, villa?
I Live in an apartment with family.

How many are you that live in your household?
It is a small family of three.

Okay, yes. Do you know where the tap water comes from?
Uhm, I am not sure where the tap water comes from. I am not well informed about that.

Do you have any idea of the water cycle in your city? Like when you flush the toilet, where does the water go? When you shower and the water goes through, goes down, where does it go? Do you have any idea what happens with the water?
No, I don't have any idea where the water goes. Ehhm, shower and tap water combined, i don't have any idea where that water goes.

Do you have any guesses? Could you guess where it goes? If you use your imagination?
uuuhm, If I can use my imagination. I have seen a water filtration system, in a XXX: I would guess that it goes there. More specially, when you consider the pipes system that the toilettes and the a shower system use I would guess that it goes there.

If we are thinking of drinking water, like your tap water. Would you guess that that water originally comes from the mountain, the river, the ocean, do you have any idea? In Paarl where you live?
If I can guess from that as well, our main system, or if I can say, I see the water runs through is the berg river. So my guess would be that it comes from there. I have also heard the spring waters, coming from the mountains.

How do you use your tap water at home, what do you use it for?
Tap water use it mainly for drinking, I drink mainly from the tap. I use it for cooking as well and for washing dishes and stuff.

Do you always drink it straight from the tap?
Yeah, I always drink it straight from the tap.

Do you sometimes buy water from other water sources?
Yes, sometimes. Sometimes I buy from the shop, like bottled water, spring water.

When do you do this?
Occasionally. Not always, saying that we are under a bit of a cash shortage, whenever I get a bit of cash I buy a bit of bottled water.

So if you had like no limit you would always want to buy?
If I had no limit, yes I would always buy.

Why is that? Why would you rather buy than drink from the tap?
haha, uuhm. I have noticed a bit of inconsistency in the water. When it comes to colour. I would assume that the authorities, or the municipality are using some kind of water cleansing chemical. SO that water cleansing chemical usually leaves like a different colour to water. Normal water is clearer. but then you get water, But Sometimes we get the water coming out, a bit of a greyish colour, a bit of a yellowish colour. So when it comes to that, I don't drink it straight from the tap, and i definitely need to take it from the tap and then heat it up and cool it off.

Do you anytime feel doubts that the tap water is safe to drink?
Yes.

When you have this doubt, what are you concerned about? When you see this bad colour or something, what are your concerns?
When I see that, my main concern is uhm, the health implications that will come with that colour, or that uhm change in the water. It is all.

Would you say that it is mostly health implications and issues, or could it also be taste? or is it mostly the health?
It is mostly healthy. Sometimes you can feel the taste as well.

And that feels unsafe?
Yes. If I can go to the hospital part, I think they use boreholes. I have heard that they are using boreholes.

For groundwater?
Yes, for groundwater. So the taste of it, you can taste the differences between them. The water that we get at home, and the water that we get from the hospital. And, many people have complained about runny tummies, like diarrhea when they are drinking from that water. So they avoid drinking from the hospital water as well.

Aha, okey. But this you say that they got diarrhea from the ground water? From the hospital water?
From the hospital water.

Okey, so the hospital got tap water and the groundwater is besides?
Yes.

Okey, so next question then. Like, what is your feeling about the water situation and scarcity in South Africa today?
Scarcity of water is a big issue. Mainly because, if and whenever the municipality or the government decides to close down the water because of the water is scarce, and they put up flierce that there is a scarcity of water and then suddenly the water is cut of for one or two days. So for that 1 or 2 days that the water is cut of, what do you do? That main, water is our main, uhm, source. I don't know if you understand.

Yes, I think we understand.
We use it for practically everything.
We drink from water, we drink it, and then we have to cook, and we have to wash ourselfes as well. If there is no water, we struggle.

Does this happens often?
It happens ahh, it happens often, but it has not happen in the past two- three months. But it does not happen everywhere at the same time., it happens in different regions at different times.

So it is like, now we lack of water and they they reach to the public to save and then just turn it off?

Yes, definitely.

Have you heard about "water reuse"? Are you familiar with the term "water reuse"? What does it say to you?
Water reuse.. I think i heard about the term but not in full detail. For me for instance if i were to wash my dishes and then not flush it out, and then I take the same water and use it again, maybe in the toilet system again.

That could be water reuse in your household?
Yes, yes.. water reuse yes.

Can you also think of water reuse for public and municipal use?
Hmm, public and municipal use.. no I have not. Those of the things that you come across.

I think it is different to different people of course but kind of the definition of it is when people using treated waste water that is discharged to river or other surface water such as lakes etc, then in a later step is treated again for final drinking water. So it is a cycle of water, water reuse.
Oh okey I understand, It is recycling it. I get it now.

If that would happen or be the case where you live in your region, how would you feel of drinking reused water? And also to avoid scarcity? Would that feel okey for you?
Yeah, that would feel okay. If that is fact and figure that it is safe to prove that it is safe. Then I would be okay to reuse it in such a way.

How could it be that it feels safe to you?
For me, if the campaigns and municipality could come to the people and the community and inform them, that would feel better. Giving illustrations of it.
Yes, sounds good to me too.

Do you feel that you have enough knowledge yourself (that's why you want the campaigns etc that you mentioned) about water reuse to decide if it is safe to drink?

Yaa, I feel that there is a lack of knowledge given to the public. Maybe the government and municipalities need themselves to think that they are giving people information but they are not, they need to give them knowledge and informt them, they put up posters but one-o-one of the people don't have the knowledge. We need better understanding of the processes and at the same time make them feel okay that it is safe to drink.

Do you have trust in water cleaning technologies in general?
Ahhh, I would say 50 %.

Some techniques you have trust in?
But the cleaning technologies itselfs I do have 100% trust, but for some extent I dont have the performance of it I don't have. How the people are performing the task. It is not that suitable for consumption.

Would you say that you have trust in some techniques and some not or is the only thing you worried about is the part of performing, the human error?
Yes, only How they perform it yes, It is nothing wrong with the technique. I trust it 100%. It is more of human error.

So maybe it is more about the next questions then, like.. Do you have trust in your authorities such as municipalities or others working with water in your region?
Haha, I do not have trust for them.

Not at all?

In a way I do, but sometimes you get that doubt in yourself that it is something going wrong, something that they are not doing right. But at least they are trying, but they can really do better.

What is this feeling based on? Have you had the same feeling most of your life or is this a new thing for you having this feeling?
No, I have not. But as you go along you see a nixx going on.

Nixx? What do you mean?
Impurities so to speak. People having flaws. You see flaws, and human error. Everybody has errors, but if you do them and you get used to them and then get a part of you - that is the difference what it was before. You see. That's the same with the water, even if it was clean before and you notice and you did something to change the color and taste and then you get used to that change and that color and taste. And then you don't notice the difference.

Is there anything that could help increase your trust in water reuse for drinking water besides what you already mentioned such as campaigning etc?
Personal involvement i would say. That would increase my trust. If I as an individual and maybe the next person can be involved in those processes, you don't have the knowledge and the qualifications to perform those tasks but at least to expose us to those processes!

And would you say that the biggest aim is to ensure people that their drinking water is safe to drink, and it would not have any health impacts on them drinking the water?
Absolutely yes. Because if the water is safe to consume the people will consume it without any doubts.

And one last question, the knowledge you already have yourself, where have you got this from? work, family friends, internet?
Honestly, it is not research or anything but the Internet helps. I come across a lot there. I can find what I want.

..Thank you so much..

Appendix 17

Interview 6

Can you describe a little bit of yourself? What is your occupation, where do you live?
My name is XXX and I am living in Paarl working for a company named William Mark company and it is a measuring company, I started study marketing and management at college, currently I am doing my internship with sales, retail, promotion also selling products, special, selling in products, introduce the product and what is the difference to my competitors etc.

How old are you?
I am 27 years old.

When will you be done with your studies?
I am in college, I studied for 18 month and then I go for internship, so now is my internship period. In total the diploma is for 3 years. 18 theory + 18 month practical work. I will finish next year around january. Usually it is only graduation in june so I need to wait until June for the real graduation and get my diploma.

How long have you lived in Paarl?
I have lived since 2014, from eastern cape.

So you grow up in Cape town?
Yeah, Yeah I grow up in Paarl, I grow up in Cape town.

What does your household look like? Do you live in an apartment or villa etc, do you live with family or friends or by yourself?
I live with my family in an apartment, we don't stay together all of us, I have four brothers. Now we only live me and my 3 brothers together. My mother and and father.

So at the moment you are 6 people living together in your household?
Yeah, 6 persons.

Now we will ask you about your water knowledge..
Do you have knowledge or an idea of where your tap water comes from?
Oh I know, It come from municipality sites, I just forgot the name of that place, I was once there. What they are doing there, the water I am using at home, the water I use for flushing the toilet etc they recycle and reuse again, it is from them... And another thing, sorry for cutting you, but I got to think of an other thing. The water is from the river and then they have cleaned it, empty the pool/river and clean it and then they send it to us, the people. To our home, that is how we get the water in our taps. That water we use to clean our staff they also goes back to them to their sites and they clean it again from their site and then we drink it again and we reuse it again.

So then you explained what we were supposed to ask you now, but you are on step a head! haha. Great! Okey..

What do you use your tap water at home for?
I am use my tap water when I want to drink, when let’s say when I am washing the pot or whatever dishes. But mostly, when I want to drink water I use it. And maybe to bath, sometimes old model that we use, that you get the water from the tap and warm up the water a little bit and you put on kettle you see..

So sometimes you warm the water?
Yeah, I do before I bath.

You never warm it up before you drink it?
Lets say, maybe if i having a flu, if I am powerless etc I am doing my own thing, I am warming up the water and put sugar and salt and then drink it.

Aha, okey. When you drink it and want cold water, you always drink it straight from the tap? Or do you anytime treat it?
Yes, I drink it straight. Sometimes I put on the fridge and drink from there.

Ok, thanks. Do you sometimes use other water sources for drinking water (beside the tap water in your household)?
When I am on the road or I am traveling to somewhere, then I buy water. Like now, I am in town and I am far from home and obviously I need water so this time I will buy. It I am thirsty, I am going to buy water.

When you are at home you never buy?
No, when I am home I always drink directly from the tap.

When you warm the water and put sugar and salt in it, is that because it feels good for your flu and leave a good feeling in your through or is is because of health based that you want to clean the water further?
No, when it is warm I don't drink it, I wait for it to be cold. I cant not drink it when it is warm, it is like coffee.

Okey, so it is not like you boil it for the reason that you want it to become more clean?
No, I never do that. It is just for me, because no, I trust my authorities, my municipalities that that it is clean. That is no need for me to clean it further. More verification I don't need, I already seen it and I have been there and people are know what they are doing and they did it infront of me, I saw it with my own eyes.

Ah, where are you on a study visit?
Yes, I don't need to purify myself, It is already clean.

So you never feel doubts that the tap water is safe to drink?
No, I never. Because I saw them, I saw how they cleaned the water so I trust them a lot and they are very professional. They took the water from the location and they showed us put on the material they are using and they put it there in front of us so we saw how they cleaned it, they showed us the whole process and I saw it and I believe that they really know what they are doing.

When was this study visit, was it a part of your education in class?
I went there with ARA Ngo and they taught high school kids so we took them to that site in the aim to get them to know where and what their water goes to. They showed us that the water you are using to flush your toilet we take it again and we clean it and then send it back to them and you reuse this water. We take it back and send it back. It is not that it is going away, we reuse it. They teach us how this is happening and they also teach us how important it is to keep the rivers clean, and our environment clean etc and they were teaching us all these things. You see. They also show us the river the process there, how we use the water in the toilet and goes to the cleaning. And now we are aware of what we can and not can put in our toilet.

Wow! great input and great to hear that.. What is your feeling about the water situation and scarcity in South Africa today?
It’s really scaring me. Because some people out they don’ t take it seriously. Out in the township you will find taps that are leaking, nobody paying attention, no one is calling the municipality to fix it. Nobody looking after these taps. It is scaring me that other people don't take it serious. It is a serious issue that we must work on, that we need to look at it as a problem, people don't care, you cant be educated enough about water. I our country it is very important, we are nothing, it is so important, we can do nothing without water, cant live, cant cook.. nothing we can do without water. the veggies we eat, they need water, but you know.. people lack knowledge about that.

It is everyone's responsibility to do their part of course..
Exactly, exactly. Some people throw stuff and garbage just into our river, and they are killing our river by doing that. You see.

You have already mentioned this but I want to ask you if you are familiar with the term "water reuse"? What does it say to you?
For me, Hmm, I don't know if I understand the questions exactly but I will try to answer it, the water reuse means that the water we use like now for example washing etc and will be dirty, and then I will throw it away, on the, what to call it, the drain on the toilet. That water is damage or will not work again until it cleaned. But that water is then going somewhere to be cleaned. When it reaches its destination they will purify and then send it back to me. And I will be able to drink again and use it for other stuff. That what is means for me.

Yes, Perfect. And this information and this view you described, where have you got that information? From what source, mostly, is it based on for you? (School, family, friends or internet etc)
It is from friends. Mostly friends. Yeah

How would you feel to drink water that originally comes from wastewater?
Okey, Because what I told you before, I really trust these people working with it and purify these water, they went for school to study that and know they are doing it practical - i trust it a lot. I really trust ut to be clean 100%. Because I saw how do they did it. I feel safe, because you can also see that it is clean. You see they take away everything.

Would you that you have enough knowledge about water reuse to decide if it is safe to drink?
Yes

Like you already mentioned, do you have trust in your authorities such as municipalities or others working with water in your region?
Yes, 100 I do have 100 % trust in all municipalities so far. I went to other places like cape towns like you see locations around in cape towns, if you taste that water from around there our water is not the same. It does not taste the same, I don't like their water and their taste of it. If you go to Khalilisha, close to the sea, that water is completely different to ours. Our water is so nice and I really trust my municipalities, 100%.

And are you also have trust in water cleaning techniques?
Yes, because I saw it and they showed me. I saw how do they do all the process, and I belive in them a lot, and also what I noticed they really care about our safety. They really care about our safety and I really noticed this about them, they really educated us about how important that is. Like to keep our rivers clean etc and how important it is to reuse the water. If we do so, if we can keep our rivers clean and stop damage our drains and stop trowing in the dams and rivers. They will do their simple job, we give the a hard job. We will help them to eliminate this hard work and do what we can to keep the rivers clean. And not flush unnecessary stuff down our toilet etc. They know what they do, and they care a lot about our safety.

Yeah, would you think that your knowledge because you know this and have been on study visits etc, but if you imagine people don't have the same knowledge like you, would you think that could increase their trust anyhow? if they know more or if they feel that they were involved more for etc.?

Exactly, they could very much increase their trust if they had more knowledge I think. Our municipalities I trust them a lot, but overall people are lacking knowledge in our townships and I think this is something of an issue. Maybe one day a week they something like here maybe the water short cause on the community wall, but know they can not because of covid19. But I think they should try to get people involved, get them information, get them educated about the water and how important water is in our lives and how important to keep our rivers clean and always there is a need to educate the public. Now when we are facing this pandemic it is impossible to take everyone on study visit, maybe later, hand them flyers. People tell them and try them to understand how important the water is. Personally I use the information I have and I spread the knowledge I have, I try to share the information and get it around in the community and really try to talk about the challenges we have in the community and try to solve it together. Issues the facing and rise the challenge we have and how to overcome it. People always rise the issue of crime but always we need to talk about this, we need our water to be clean, we need our rivers to still be clean. Example, people using the rivers like garbage. They go to the parks and drink alcohol and then they take the bottle and throw it in the river. In that situations I really try to share the information I have and try to educate them that they can take it home and put it where it belongs.. in the bins. There is no need for us to throw them in the river. I share the information I have. And I think that all municipalities should do the same, share the information they have.

Would you say that your friends are as engaged that you are in these questions? Also inform other about these issues?
Especially my family and my friends. I live at home with my brothers, and you know we also have issues of unemployment and I always try to share my information. With my brothers, And you use water - you pay rent. I educate my brothers to keep water, safe water, don't waste water, keep the water clean.. My people and my family are engaged but especially my family and friends. I live with them, I spend a lot of time with them. I always educate them of what I know. It is so important to our lives.

..**Thank you so much..**

Appendix 18

<u>Interview 7</u>

Can you describe a little bit of yourself? What is your occupation, where do you live?
First of all my name is xxx, I am from Linguini, I learn at XXX school, yes i am 16 years old living in Greyton.

How old are you did you say?
16 years old

How long have you been living in this region?
About 16 years

Ah okay, so you where born and raised?
Yes

Do you live with your family or how do you live? in an apartment?
Actually I live with my family
How many people are you that live in your house?
uuuuuuhm, my guess is about 10 or 8, 10 I am not sure, but it is to many of us.

How many siblings to you have?
about, 6 even 7, one coming baby.

Did you say that you are a student now?
Yes, I am a learn-up…

Do you have an internship or what does it mean with learn-up?
No, actually I am learning at a public school where we go from primary school to high school.

So it is kind of the same as we have here in Sweden, we finish school when we are 19, 18 something.
Yes

What was the name of the city that you live in or the area that you live in?
It is winguini…

Linguini?
Wuinguini

And now we will ask you about water and your drinking water behaviour..

Do you have knowledge or an idea of where your tap water comes from?
Yes i think I do know where the water comes from

Where does it come from?
Berg river dam of course. And also XX damm, and a few other damms

Okay, good. Do you know where the wastewater goes, the toilet water and the dish water? do you know where that goes?
Yes, I know where it goes.

Can you explain the cycle?

From here it goes to, through the pipes to linguini pump station there they pump the water first, they take it, i forgotten the name, where they pump it to a tank where things with high density goes down and water goes up, from a tank to the lab where it can be investigated, to see if it is clean or not.

So the wastewater goes to a lab and is tested there and treated?
Yes

Do you know where it goes after that, when it is treated?
Yes, it goes to… Im not sure but I think it is a cleaner station by XX damm, but I don't know if they are pumping water there or.

How do you use your tap water at home, what do you use it for?
Use it for drinking, of course for washing our bodies and clothes, mmmmm my brother has an assignment where he should plant a peanut, so trying to grow crobs, ehhmm we also use it for other stuff, washing dishes and also in the toilette.

Do you drink it straight from the tap?
Yes, or from the freezer.

Is that because it taste good?
I do it because it is hot summer.

Do you sometimes use other water sources for drinking water (beside the tap water in your household)? Do you buy water or?
Buy water... Yes, actually sometimes I do. But a most of the time I drink from the tap.

When do you buy water?
When I am interested in buying it, when I am in the town or something like that.

Do you anytime feel doubts that the tap water is safe to drink?
Yes, I do

What is that doubt based on?
Because sometimes it is too much chlorine in the water, which makes the tap water white. And that scares the hell out of me.

Does that taste ill or are you scared it is not safe or is it, are you afraid of the chlorine or is it bacterias?
I am afraid of the chlorine actually

What is your feeling about the water situation and scarcity in South Africa today?
The thing is, first I know the water is reused. I know it for it to be free, but also a bit scared. The reason I am scared is because they are reusing and the water also comes back, and I am also scared that the water will be going away, and maybe that other stuff will be changed and new bacterias will come and can affect the water. Also rising sea levels.

You mentioned water reuse there, before, what do you mean with water reuse when you say it, do you mean for municipal use? What does water reuse mean for you?
Okey, water reuse for me means that the water we use and then through it in the toilettes or anything comes back to you again, and this is going repeatedly

The knowledge you have, where did you get information about this? Is it from school or family and friends or internet?
Actually, most I would say form the eco club because first of all, school in africa right they don't take us out and like show things and reaching information, but eco club do. We learn about other things but not this

things, but this information I got from the eco club and what they have learned from others, I think also politicians.

So can you please explain, how does it work with the eco club? Are they like a spread community?
Sorry can you repeat again.

Yes, you mentioned the eco club, how is it working with them, how do they work, is it a big community/company? What do they do?
Actually I think it is, they are based on.. it is more of an organisation which is small but really trying to make a difference, They go from school to school teaching us and children for a better tomorrow.

They teach you about the environment and stuff, and you heard about water reuse here?
Yes, exactly. Yes they told me about water reuse. Without them I would not have this knowledge I have right now.

That's really good. Thank you for sharing this with us!
Okey, how would you feel of drinking water that originally comes from treated wastewater?
I feel relieved, and I am not scared for the last 15 years because I have been drinking the same water, no 16 years of my life, I don't have a problem, I would not have a problem with that

Would you be encouraged to drink reused water in the aim to overcome the water scarcity? Should that add something for you, would you be more motivated?
Sorry, repeat.

Would you feel encouraged to drink reused water in the aim to help the environment and help the situation with water scarcity?
Yes, I would be encouraged of that yes, And also because I feel it is okey even before

Do you feel that you, yourself have enough knowledge about water reuse to decide if it is safe to drink?
Hmm, actually I do have a think, but I don't think the entire knowledge of it, yes

Would you like to have more knowledge in this?
Yes, I would like more knowledge, yes

Do you have trust in water cleaning technologies in general?
yes, I do, actually I do,

And in the region you live, the cleaning technologies there? Do you know which they use?
Yes, I do know about the techniques here and I do trust them

Do you have trust in your authorities such as municipalities or others working with water in your region?
yes, I do, Actually I really really do

Is there anything that could help increase your trust even more in water reuse for drinking water?
hmm.. I don't know

like further cleaned/treated water, more knowledge/information from authorities such as study visits, cheaper water, further health impact tests.. Can you think of anything that would help your trust?
The truth is. Yes, that would really increase my trust. My trust would be further developed if I got these, yes.

But also, like it is like now, you have no problem with reused water?
I would drink it, yes.. okey.. hmm.. I would drink reused water because I think I have enough information so I can say that I trust it, that feels good for me.

How do you think it is among your friends, what perception do you think they have?
I think they have the same perception that I have. Because I share the information with them and when I have shared the information and then I drink the water in front of them, they trust me. There is no problem. And we share the information between each other and we educate each other.

The eco club that you talked about, are you yourself engaged or involved in any project there?
Actually, I don't have much information, I am just a selected student so I am not much involved in the eco club but I am there whenever I want, and they are really good in education in these topics.

..Thank you so much for the interview, it has been very interesting to interview you. So much great input to our work.. Thank you so much for your participation..

Appendix 19

<u>Interview 8</u>

Can you describe a little bit of yourself? What is your occupation, where do you live?
My name is XXX, I worked for the department agriculture for all my life. I am a civil engineering and within technicians, worked for 30 years as a designer for subsurface drain system after that I worked in little Karoo with ocean structures and stop water systems. And later for 5-6 years management and last 10 years now I have been working with new sustainable agriculture resources.

Where do you live?
I live outside Piketberg, next to the berg river, next to the river, in seven cross, on a farm. I am not a farmer myself but we operate one area of the farm.

How old are you?
Haha, old, 57

What does your household look like? apartment, villa etc. and how many people?
We are four, my wife and 1 live in a house, my daughter and her son, but they live in a separate house. 2 seperate houses.

How long have you been living in this region? I was actually born on that farm but I lived in the grandmothers house (which my daughter lives in know) but we have not lived here for 40 years. Came back the last years. Really benefit all the farm gives us. 1 hektar land. A big garden area and plants and trees etc. Some infrastructure on the farm.

And now we will ask you about water and your drinking water behaviour..
Do you have knowledge or an idea of where your tap water comes from?
yes, haha, we pumped from berg river out of river into reservoar,
then for household water we filter with a defilter and chlorination and filling up the tank next to the tank. 10.000 litres of household water. this water for dishes, dishwasher, flush the toilet whatever..

So you always do this, you never buy municipal tap water? Are you connected to the municipal network?
No, we are not connected. We have our own system. My drinking water and my household water have two separate systems. The drinking water also have tap, but we have two taps. One line is for drinking and one line is for household water.

What treatments steps do you do for your drinking water?
the household water: from berg river, pumped to a reservoar, settle, used for irrigation etc..
I put sometimes in a little damm around the trees, save the water there. From this system I take some water and filter and chlorinate for household use. And i fill up the tank for the house, and then I have a 50micro-filter before it goes in the house. These tanks I clean every five years.

What is the material in the microfilter?
just a normal 50-micro-filter, just to clean out the most of the solids the turbidity in the water such as salts etc.. fine, algies.. this is the reason I also do the chlorination because otherwise it would be blocked. It is not a lot of pressure. Pressure pump and then I have and other filter 50-microfilter. It is like a paper filter, solinder, 5-micro for the household water. That water is better and little bit clean, but it is not drinkable in my view. I don’t drink that water. I also use chlorination tablets in a floater. I have some sort of sanitation of bacteria and flocculation of all the fines. It is so much fines in the Berg River. It is so much mudd. I can send you photos of these.

Thank you, we would love to see it.

But for you drinking water, how do you do?
Yes, I dont use that water for drinking. For drinking I use water from my gutter. We harvesting rainwater from the sky. Later I filter leaves and stuff out. We don't got so much rain but it it enough. 300mm per year, not a lot, but it is more than we can use in our household coming from my roof alone. I only harvesting from my house.

Do you treat it further?
Yes, I filter it in the gutter before the tank. Settles in the tank and later I filter again in two steps. The water is fairly clean, I don't run it through dry osmosis or anything like that.
I believe it is clean to the standards we want. It must be some sort of chemicals still in the water the water is like battery acid haha.

So after this steps you feel that it is clean, or do you sometimes boil it etc?
The water we use for cooking and coffee etc of course, but we also drink it straight from the tap, yes. Have not been a problem. All farmers here do the same. The groundwater here is unusable here so we need this source. And you can run the ground water through osmosis.

If there would be no rain, how would you feel if you got forced to use the Berg river as a source for drinking water?
haha, yaa, the chances of no rain is very small, in the driest seasons we still have water. In the dry period 2015 in ages, we never ran out of water. We have 10 times too much. It overflow on daily basis. I don't think we will run out of water. Then I harvest from more roofs.

If you were forced to take water from Berg river, how would that feel for you to treat and drink that? How would that feel, because of the quality?
I would need to run it through reverse osmosis at least and put chlorination and filter etc. Whatever technologies there is but we need to clean it to a much better standard than rainwater. The current drinking water in the municipality is available in the office from the Withoogte system, and after that we run it through reverse osmosis. To get the real standards and that we know that it is clean. If you go upstream Berg River, the closer you go to Drakenstein or Willingtone area, the more suspect in my view I should be of the water quality. I know a couple of people that go kanoe on the river and certain time they have seen waste water treatment works are open and raw sewage goes into the berg River. These overflows on WWTP are there, The management there must be better, you can clean most of the stuff out of the water but hormones and stuff, antibiotics, in the end of the day that would be accumulated in the river. Especially if it is not sorted out before. Within the river and it is in high flow, the river must be very contaminated and transport it further downstream.

Do you anytime feel doubts that the water you have is safe to drink?
Yes, I have control, because I drink my rain water up to a standard up to a level I am comfortable with it. Also because I filter it, I know my water is not full of hormones and chemicals and so on.

If you were forced to use municipal tap water, how would you feel then, would you have doubts that the water is clean?
Yaa, I would have to treat it myself to the standard to at least I feel safe to drink it. To the standard we do in the office. I would not brush my teeth in that, actually. I use my own drinking water to brush my teeth. And I would like to have ozmosis there if I need to use the tap water on the office. Originally basis.

What is your feeling of the situation and water scarcity in south africa right now?
Yaa, we have a huge problem in the Western cape here. My view is that the management is not good. They need to manage better and utilize waste water and grey water better. Also, most of the water comes from outside, big dams etc. They don't contribute to the amount of water. The city doesn't utilize their stormwater, ther rainwater to a great extent, that is not good for me.. they just let it run into the sea. They don't harvest it

like they could. For instance, they don't harvest the drinking water at all. just let it go into the sea. Don't even use the springs.. I really think they could utilize the water much better!

When I say water reuse, I mean municipal water reuse, what does that say to you, what does it mean for you?
Hmm, I would say.. If you want to reuse your water. I would say that you should split your water. To keep safe drinking water and the other water for other uses. Great runoff water, keep that seperate. Try to seperate pee from poop and so on.. You will end up in less water in your waste water works and the systems will be more efficient.

What do you think of the concept of water reuse such as Berg River, where they have WWTP discharging their treated wastewater into the berg river that is later used in the drinking water treatment plant?
Yaa, at this stage we are already at that point. We have so much overflows etc.. and little towns upstream. Even Piketberg. They have it circular. At this stage, we are already at that point that we already reuse water but we don't reuse it as good as we can. We should have better wastewater systems with this splitting thing I described earlier, I would think that could help. You only treat what you need to treat. Less water to flow into the natural system. Use your grey water for irrigation directly for example. So much more safe. Less contaminants etc.

Okay, so you would say that you support the concept of de facto water reuse but you say that we would need more management, maintenance and operations to manage it well? Use different techniques to split it.
Yes, exactly what I mean. Manage the grey water better. Less water to manage.

Do you think that most people know of this concept, have heard and are familiar with this concept?
Hahah, most of the public I would say don't even know where the water comes from. If you think of the Berg river system.. Berg river dam. Misverstand dam Withoogte system.. we feed the water from one system. The lower downstream you go the more extent ineffective and affected the water will be.

Okey, so get a little better of a background of you answers here we would like to ask you..
Do you feel that you have enough knowledge about water reuse to decide if it is safe to drink?
You can never have enough knowledge, I don't have enough knowledge to clean waste water, I have to read up on it a lot, invest in systems and evaluate and test different systems to prove if they work. Look at the current water and standards and see if that water complying with the that. I don't think that Withoogte evaluates that water to that standards, I don't know..

But you would feel safe if you get more and more knowledge in these?
Obviously, yes. If needed, I would get more knowledge, because I don't have much knowledge myself. It is not my field of expertise.

So did you say that you don't have the trust that withoogte are following theirs guidelines or reference values or what did you say?
Yes, yes, I have my doubts about municipalities and the other thing is also that the source of contaminations always utilize the water. I don't know and I don't feel sure how they utilize that contaminated water and also how they draw their water because of the upstream contamination points.. In my review, I can't not rely on governments. Not at this stage. Most of them do a very good job running their processes but yaa..

What issues should you say are the most important? Is it health issues or? Why dont you dont have trust?
I don't have trust in the capacity, I have trust in the official but not the politicians, haha.

Okey, but you do have trust in cleaning technologies?
Yes, of course. I have trust in that, but not in the people

So if your self would be a expert and need to decide what kind of techniques to use and how the water was treated, would you then drink reused water?
Yaa, if there is no other water to use, of course I would do it. It is just that in my point of view there is much easier way to solve the situation.. and to clean water. harvest it from the roof etc.. So I would really use that instead to drink, and then use water from reused for irrigation and so on.

If you were visiting a city their they used reuse water for reclamation for drinking water, would you drink the water?
Yaa, if it is safe and it is clean enough and passas all test I would do that. It is not impossible to clean water, but it is very difficult if the water is highly contaminated.

Okey so for you it's more of a resource question than a health-related question?
Yes, we have rainwater coming from the sky. It is easy to harvest. We can clean it much easier because it is not that contaminated.

Is there anything you can think of that could help increase your trust authorities and municipalities in water reuse for drinking water?
Yaa, hmm, at this stage. I think the politicians must make them do a lot first.. if you look at south africa we have a big problem with corruption. Financially we have a problem. If you can't manage yourself financially, how the heck should you manage yourself of those of resources then? In my view they need to do more before I can develop my trust.

..
Thank you so much for your participation!

Appendix 20

<u>Interview 9</u>

Can you describe a little bit of yourself? What is your occupation, where do you live?
Okay, I am.. Should I introduce myself or should I say my name or?

Yes, please do.
My name is XXXX, I was born in Paarl but i currently live in CRS, I am educated in Wallington university, and also primary.

Do you have a work now or do you still study?
Yes, I am a teacher, In Wallington primary school

In what subject, do you have any specific or many differences?
I am a Mathematic teacher

What ages?
I am kind of working with 13, 14 years old

How old are you?
I am 29

Did you say that you are living in Willingtone now?
I live in CRS, but I am working in Willingtone

How long have you been living CRS?
In SRC for 7 years now.

How does your household look like? apartment, villa etc. and how many people?
I have 6 apartment house, that includes 3 rooms with kitchen, livingroom, sleeping room and a toilet.

Do you live there by yourself?
No, I live here with my wife and my little boy

And now we will ask you about water and your drinking water behaviour..

Do you have knowledge or an idea of where your tap water comes from? In your house, or your apartment?
I think it comes from crocedoo damm, I am not hundred percent sure but I am thinking that it comes from there.

Do you know where the wastewater go when you flush the toilet etc? Can you describe the water cycle?
Hmm, no, not at all, have no idea

If you use your imagination, do you have any idea?
If I use my imagination, hmm, Honestly I am not going to take the chance, I don't know

Okey, how do you use your tap water at home, what do you use it for?
For drinking, making food, washing clothes, for other purposes maybe, fill the pool etc, potable use, yaa, we tap water for everything

When you drink the water, do you drink it straight from the tap?

Sometimes I put in a bottle and put it in the fridge, usually when it is so hot, but often no, I drink it straight. During winter times I always drink straight from the tap

Do you anytime buy water or sometimes use other water sources for drinking water (beside the tap water in your household)?
Hmm, anytime when I buy water it is when I am on the road or if I am out hiking or something like that..

Do you anytime feel doubts that the tap water is safe to drink?
haha, you guys are placing a lot of doubts in my mind now haha.

Oh sorry, that is not the aim of these.
Haha, no not like that.. Honestly I don't know, but I will say, I trust the system. It is like that.

What is your feeling about the water situation and scarcity in South Africa today?
Hmm, how should I put it.. The thing is that there is a lot of people that receive water for free, and they are using it, you see, later on, It can turn into a problem.

Ah, okey, so You don't think it is a problem right now, would you say that you have enough water in south africa, you would say?
I would say yes, It was a time when red light was going off.. and it was worse, they were warning people of water cuts etc. But I think we are safe now.

Have you heard about "water reuse"?
Are we talking about the water that we are using? the water we drinking?

I mean the municipal water, connected to the municipal water system network
Is it that water that we are drinking?

Yes, exactly, that is what we are asking. Have you heard anyone talk about water reuse?
Like when we say water reuse, what pops in to you mind?
If that water that we are flushing, going down our drains, and then we use it again.. later for drinking water..

Exactly, the definition of municipal water reuse is what you said, how you described it. Like we have water, it goes to the WWTP to get treated, then it is discharged to a river, and then we take it and treat it again and after that it is safe to drink.
Yepp!

Can you think of where you have got this information? Is it from your education, or family and friends or internet..?
Hmm, probably from my education from a few years back. Or mostly it is just common sense, mam.

How would you feel to drink water that originally comes from wastewater?
The thing is that.. The water that comes out of the tap I don't know if that water is reused water or fresh water or how fresh or how safe that water really is.. So, as I said earlier I trust the system and hopefully I will not get sick from drinking it.

Yes, I see what you mean.. Would you be encouraged to drink reused water in the aim to overcome water scarcity? Like if the situation of water and drought would be much worse.. would that motivate you to use reused water?
Yes, definitely, definitely.

Would you say that you feel that you yourself have enough knowledge about water reuse to decide if it is safe to drink?
No, honestly I don't, I don't have knowledge.

Would you like to have more knowledge?
Really, I would love to have that

You said earlier you had trust to the system.. Do you have trust in your authorities such as municipalities or others working with water in your region?
Yes, I have trust for them, yes. I think that is because I have drinked water straight from the tap in 29 years now and never been sick..

And nothing happened?
Yes, so far nothing happened. That's why I feel safe.

Yes, that is a good test.. Do you have trust in water cleaning technologies in general?
Hmm, I don't think I have enough knowledge to say yes or no in that regard.

Maybe it is hard when you don't know exactly what techniques they are using?
Yes exactly, maybe if i see what techniques they are using then maybe my, how could i say, maybe then the way I see it maybe that can be changed.. I would maybe stop drinking it. For example, I don't eat meat if I can see it in front of me, then I can't eat it. The effect of it, it is okey to do it and to eat it if you understand what I am trying to say.

Is there anything that could help increase your trust in water reuse for drinking water? You self mentioned that "if I see it with my own eyes"?
Maybe a little bit more education around water and maybe more exposure to and free existed where they show how they clean it and so on, something like that, mam. Maybe something to give me a little more trust. But I am having complete trust in the whole system because I have been drinking it my whole life.

So anything else, Would you like to go on a study visit on a water treatment works or anything? Look at a movie showing..?
Oh, I would really love to do that, really love to do that. This interview was really eyeopening for me. And I would really think that would increased my trust even more.

What do you think of, do you think that your family and your friends have the same view as you have on these topic?
I think so yes, I think they have exactly the same perception that I have. Hmm, I think that because that tap water is the only water source we have, otherwise we need to go buy water in a shop and water is like a.. how should I say.. we need it! We need to invest in it. The working class maybe they will just trust the system and do whatever they have to do with the tap water…

…
Thank you so much for your participation!

Appendix 21

<u>Interview 10</u>

Can you describe a little bit of yourself? What is your occupation, where do you live? How old are you?
Okey, I am 56 year old and I am staying in Willingtone.

What is your occupation?
No, I am not working, I am unemployed. I am always at home, looking after the children.

How many kids do you have?
I have three kids, one is married and two are still living in my house

How many people live in your household now?
Four grandchildren, me and my husband and my child.

7 people?
No, we are 8

How long have you been living in Willingtone?
All my life, hehe, all my life

Is it an apartment or how does your household look?
It is a house we rent here, 3 years now. 2 bedrooms and one separate room and kitchen and bathroom.

And now we will ask you about water and your drinking water behaviour..

Do you have knowledge or an idea of where your tap water comes from?
ja, it comes from the water place. haha, I don't know the name, but jaa, from that place.

And before that, do you have any idea of where they collect water?
Nope, no idea

Do you have any idea of what happens with the wastewater after it goes from you, after flushing the toilet, shower etc?
hmmm, it going to that place to treat it, it going away

How do you use your tap water at home, what do you use it for?
I use the water for drinking, and also to wash my clothes, and wash dishes and cleaning

Do you drink it straight from the tap?
yes, most of the time

When do you don't?
When I buy water from a shop thats the time I don't use my water at home

When and why do you buy water from the shop?
When I am in town

Do you any time treat your water at home?
No, I never.

Do you anytime feel doubts that the tap water is safe to drink?

Nope, never, I feel that it is safe

What is your feeling about the water situation and scarcity in South Africa today?
Haha, oh, I really don't think about it, I never think about it, sorry

Have you heard about "water reuse"? Are you familiar with the term "water reuse"? What does it say to you? Yes, I have heard about it, but not familiar, hmm I don't know, What I have heard is that all of our popo go there and then they clean it.

Exactly, as you said. Water reuse for municipal use is what you said. The waste water will be cleaned and then discharged into the river, then we later take water from the river - clean it again and to become final drinking water safe to drink!

The knowledge you have, where did you get information about this? (television/radio, family and friends, your work, school)
Mostly from a friend

How would you feel to drink water that originally comes from wastewater?
As long it is clean and not smelling anything I don't have any problem with it.

Would you be encouraged to drink reused water in the aim to overcome water scarcity?
Hmm, can you please explain the question again, I am not sure I understand

Would it feel okay for you to drink reused water to save water? Help the environment
Oh, yes, I would

Do you feel that you have enough knowledge about water reuse to decide if it is safe to drink? Yes

Do you have trust in water cleaning technologies in general?
Yes

Do you have trust in water cleaning technologies where you live?
Yes, I have

Do you have trust in your authorities such as municipalities or others working with water in your region?
Yes

Is there anything that you can think of that could help increase your trust even more in water reuse for drinking water?
No I'm happy with the way they do it
..
Thank you so much for your participation! Have been a pleasure interviewing you..