DEVELOPMENT AND PILOTING A RISK-BASED DECISION SUPPORT TOOL FOR THE PRIORITIZATION OF BULK SCALE WATER REUSE IN METROPOLITAN MUNICIPALITIES

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WATER RESEARCH COMMISSION

TT 915/23

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Report to the
WATER RESEARCH COMMISSION

by

C WALTERS[1], L NDLELA[1], I BANOO[1], F LEHUTSO[1], M THWALA[2], B GENTHE[3]

[1] Council for Scientific and Industrial Research (CSIR)
[2] Academy of Science of South Africa (ASSAf)
[3] Independent Collaborator

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Water Research Commission
Bloukrans Building, 2nd Floor
Lynnwood Bridge Office Park
4 Daventry Road
Lynnwood Manor
PRETORIA

orders@wrc.org.za or download from www.wrc.org.za

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EXECUTIVE SUMMARY

BACKGROUND

South Africa's already strained water resources, will become even more stressed in the near future as a result of unprecedented population growth, climate change and increased pollution. In 2017 the Department of Water and Sanitation predicted that by 2030 water demand will reach 17.7 billion m^3, exceeding the volume that is available to allocate. According to the National Water and Sanitation Master Plan (DWS, 2018a,b), agriculture was the biggest user of water at 61%, followed by domestic water use (27%) and Industry (7%). Globally, industry is the second largest user of water for development, consuming 22% of water (UN Water, 2018). In Europe and North America, industrial water use accounted for half of their total water use in 2009 in contrast to the 4-12% in developing countries over the same period. Industrial water use is however likely to increase as a result of industrialisation in developing nations, adding to the pressure on already stressed water resources (WWAP, 2009).

Responsible and efficient water management is fast becoming a pressing reality for domestic users, agriculture and industry alike. The need to reuse water in order to secure the future of the country is evident. In face of the ever-growing demand for fresh water resources globally, there is a need for a paradigm shift in wastewater management from 'treatment and disposal' to 'reuse, recycle and resource recovery". Wastewater is increasingly viewed as a potentially sustainable source of water, from which many economic benefits could be derived. The UN World Water Development Report (WWAP, 2017) suggests that improved wastewater management could facilitate the achievement of the UN's 2030 Sustainable Development Goals (SDGs). South Africa's National Water and Sanitation Master Plan (DWS, 2018a) is aligned to the UN's Sustainable Development Goals' (SDGs) (UN, 2015) unique vision for a better future for all as set out in Goal 6 which stipulates: "to ensure the availability and sustainable management of water and sanitation for all". SDG-6 specifically has a target to reduce the proportion of untreated wastewater by half by 2030, while sustainably increasing water recycling and safe reuse (WWAP, 2017).

Reclaimed water is still not extensively explored as an alternative reliable source of water supply in South Africa. Even in literature, information about water reuse in South Africa is scarce. Most of the examples of reclaimed water are related to agriculture (Jiménez et al., 2010), with a few exceptions (Eckart et al., 2011; Adewumi et al., 2010). Treated domestic wastewater has long since been reused for various purposes such as irrigation of sports fields and crops as well as for reclaimed drinking water (e.g. Atlantis managed aquifer recharge plant). More recently wastewater has been treated and used directly for drinking (e.g. Beaufort West). While there is still much more that can be done with domestic wastewater, the value of industrial effluent is yet to be realised. This is shown in the GreenCape's Market Intelligence Report (2018) where the total Gross Value Add (GVA) for moderate and highly water intense users in the Western Cape Province in 2016, excluding agriculture, was calculated to be R155 billion (Quantec, 2017). Water reclamation in industry is already practiced around the world, supported by advanced treatment technologies. Gulamussen et al. (2019) recognized the need to identify industries with potential for use of reclaimed wastewater, and the evaluation of industrial water use locations and patterns. In addition, sewage flows available for reclamation should be identified to find links for incorporation of water reclamation in urban and industrial planning.

The South African economy largely depends on mining and other large industries. According to the National Water Resources Strategy 2 (DWA, 2013a), the mining sector, with an estimated demand of about 5% of the country's available water, is a significant user of water. Many of these mines are located in water resource scarce catchments (e.g. the Lephalale and Steelpoort areas in the Limpopo province) where the availability of water can become a significant business risk. Water availability should however not be a limiting factor to growth in the country. Water resources management and development should prioritise availability of water to industry. Similarly, implementation of water conservation and water demand management (WC/WDM) measures within the mining sector is required in order to minimise this risk (DWS, 2016).

An assessment of the industrial effluent reuse potential of the country will assist in identifying where water can be made available for development. Industrial companies are increasingly exploring the reuse of their effluent (wastewater) streams. An example of direct reuse of treated effluent delivered directly to an industrial water user is Mondi Paper in the southern part of eThekwini municipality which receives treated domestic effluent from the Southern Wastewater Treatment Works, freeing up sufficient drinking water for approximately 300 000 people (eThekwini Municipality, 2011). Internationally, there is a general move towards zero liquid discharge, and several industries in South Africa already reclaim and reuse significant amounts of wastewater, such as the mining and sugar sectors. In June 2018, Nestlé South Africa announced the launch of its R88 million zero-water dairy manufacturing facility in Mossel Bay, in the Western Cape. It was estimated that the facility would allow Nestlé to reduce the factory's water consumption by more than 50% during the first year of implementation by reusing the water recovered from the milk evaporation process, saving 168 million litres of water a year. It is estimated that Nestle will eventually reduce its municipal water consumption to zero (Engineering News, 2018).

With only approximately 14% of wastewater reused in South Africa, in combination with the water stressed situation we find ourselves in (a 17% water deficit anticipated by 2030), it is crucial that alternative water sources are identified. Wastewater reuse is an important potential water source and ways of identifying and illustrating the availability of these sources is needed. A previous analysis of water use and wastewater generation highlighted that industry used the greater amount (55%) when compared to mining (23%), power generation (20%) and the food industry (2%). Effluent generation from the industrial sector has an even larger % with 74% generated by industry compared to 10% by mining, 9% by power generation and 7% by the food industry.

Both the National government and private sector, as well as the United Nations (UN) are calling for wastewater reuse to unlock alternative water sources. In response to this, the CSIR initiated a study to identify and map the major water users and effluent producers to identify opportunities for wastewater reuse. We have created a database focusing on the larger water users and wastewater producers, and are collaborating with local government municipalities, namely the eThekwini, City of Durban, City of Ekurhuleni, City of Tshwane (with additional cities in discussions) to fine tune the data. The quality of effluent and its fitness for reuse can be assessed through a biomonitoring programme to identify development opportunities in areas where previously little or no water was available.

This project deals with developing detailed scenarios and to pilot the risk-based decision support tool to identify potential wastewater reuse and to assess the best fit-for-use, and to support reuse as suitable alternative water supply option. This funding from WRC will support the next phase of the project, i.e. testing the decision support tool and it is anticipated that the wider role out of the DSS tool will have significant impact in supporting Municipalities to consider wastewater reuse as a viable alternative water supply source given the water deficit challenges currently facing SA.

AIM

The sole aim of the project was to develop and initiate piloting of a risk-informed decision support tool for metropolitan level municipalities to enhance wastewater reuse for industrial purposes.

METHODOLOGY

Task 1: Multi-species toxicity bioassays to assess fitness for use of water / wastewater
A desktop review of international literature on multi-species toxicity bioassays is in progress to summarise available toxicity assays, their advantages and disadvantages, as well as international best practices and legal requirements associated with wastewater treatment, use and reuse. These will include but will not be limited to those bioassays accepted and applied by the OECD and US EPA. As a second step to this task, a national assessment of available multi-species toxicity assays available locally will be summarised. A list will be made

of the types of assays available and who the organisation or institution is that can do these assays. If it is commercially available as well as the legal and ethical considerations in doing these assays in South Africa.

Task 2: Final DSS for wastewater reuse potential and possible trade-offs.
A web-based DSS tool will be developed for identifying optimal opportunities for bulk wastewater reuse for industrial purposes within metro municipal boundaries. Water purity risk assessments, as well as a review of the minimum legal requirements for water quality for different uses is required. The DSS will be developed where the wastewater quality and volume will be input values and the decision support system could assist with possible reuse scenarios. Included in this tool will be criteria to:

1. Approaches to assess wastewater sources.
2. Evaluation of needs assessment as informed by water supply: water demand ratio.
3. The identification of best-fit water reuse potential in industry as informed by wastewater chemical and toxicological properties.
4. Estimation of economic and technical feasibility for the implementation of industrial water reuse schemes.
5. Recommendations for implementation in identified priority industries.
6. Policy recommendations to decision-makers to incentivise water reuse by the private sector (in line with recommendations of the UN WRR-2017 report).

RESULTS AND DISCUSSION

A web-based DSS tool has been developed by the project team using data obtained from eThekwini Metropolitan Municipality (MM).

GENERAL

The project's sole aim, to develop a risk-informed decision support tool for metropolitan level municipalities to enhance wastewater reuse for industrial purposes, was achieved. The prototype of the tool is currently in its testing phase.

CONCLUSIONS

There is tremendous unexploited potential to improve water efficiency and augment or partially substitute freshwater supplies in South Africa. Reuse of treated wastewater to augment water supplies and improve water security as a result of climate change and drought, will allow more water to be available for potable uses. Decision support systems are valuable tools that strive to assist decision-makers in metropolitan areas with complex and important drought risk management decisions. Decisions for reuse are not linear and depend on various factors – such as stormwater management, aquifer protection, and industrial development. Integrated management of water resources is in line with sustainable development and the recent drive to a circular economy. This calls for targeted collaborative effort form all parties involved within and enabling environment to improve water reuse and decrease water security issues, while managing risks.

ACKNOWLEDGEMENTS

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The project team also wishes to thank the following people for their contributions to the project.

Reference Group	**Affiliation**
Ms Tamsyn Grewar	Mintek
Dr Jo Burgess	Isle Utilities
Dr Edward Archer	Stellenbosch University Water Institute
Prof Natalie Aneck-Hahn	University of Pretoria
Mr Patrick Milio	Department of Water and Sanitation
Mr Kevin Meier	Umgeni Water
Dr Mthokozisi Ncube	African Development Bank
Dr Kelly Reynolds-Clausen	Eskom
Others	
Teddy Gounden	eThekwini Metropolitan Municipality
Dhevan Govender	eThekwini Metropolitan Municipality
Vishnu Mahabeer	eThekwini Metropolitan Municipality
Ashan Nundlal	eThekwini Metropolitan Municipality
Sydney Masha	eThekwini Metropolitan Municipality
Megan Dharmalingum	eThekwini Metropolitan Municipality

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ACRONYMS & ABBREVIATIONS

DPR	Direct Potable Reuse
DSS	Decision Support System
DWS	Department of Water and Sanitation
gva	Gross Value Add (GVA)
IPR	Indirect Potable Reuse
SDG	Sustainable Development Goals
UN	United Nations
WC/WDM	Water Conservation and Water Demand Management
WWAP	World Water Assessment Programme

GLOSSARY

Wastewater. Water that has been used in the home in a business, or as part of an industrial process.

Water reuse. Beneficial use of reclaimed water.

1 BACKGROUND

1.1 INTRODUCTION

This WRC Report details the work completed between March 2021 and November 2022 on Project No. C2021/2022-00502 entitled: "Development and piloting a risk-based decision support tool for the prioritization of bulk scale water reuse in metropolitan municipalities". The research programme has been undertaken in the research context of global data which suggests that over 80% of worlds wastewater is currently released into the environment, untreated (WWAP, 2018). In high-income countries, as much as 70% of municipal and industrial wastewater is treated; 38% in upper-middle income countries; 28% in lower-middle income countries; and only 8% is treated in low-income countries (Sato et al., 2015). In South Africa, approximately 14% of wastewater is reused according to estimates provided in the National Water and Sanitation Master Plan (2018). In face of the ever-growing demand for fresh water resources globally, there is a need for a paradigm shift in wastewater management from 'treatment and disposal' to 'reuse, recycle and resource recovery". Wastewater is increasingly viewed as a potentially sustainable source of water, from which many economic benefits could be derived.

The UN World Water Development Report (WWAP, 2017) suggests that improved wastewater management could facilitate the achievement of the UN's 2030 Sustainable Development Goals (SDGs). South Africa's National Water and Sanitation Master Plan (DWS, 2018) is aligned to the UN's Sustainable Development Goals' (SDGs) (UN, 2015) unique vision for a better future for all as set out in Goal 6 which stipulates: "to ensure the availability and sustainable management of water and sanitation for all". SDG-6 specifically has a target to reduce the proportion of untreated wastewater by half by 2030, while sustainably increasing water recycling and safe reuse (WWAP, 2017).

Target 6.3: "By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally."

Target 6.A: "By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies."

This project has contributed towards unlocking development opportunities and creating an enabling framework for industrial wastewater re-use opportunities across SA. A decision support system (DSS) which assists to identify the potential for industrial wastewater re-use opportunities has been piloted, refined and enhanced in this financial year and this has been a key milestone achievement of the project. In addition, a DSS prototype has been designed and developed, which allows for industrial water consumers and wastewater emitters to be geographically mapped and then provides recommendations for a risk informed approach to assess the potential and fitness for wastewater re-use, on a case-by-case basis. Some of the research outputs from the investment include popular articles and book chapters and presentations made by the project team at local and international forums which were in support of the roll out of the National Atlas for the Potential for Wastewater Reuse in SA which was developed by the project team (refer to knowledge dissemination section).

Initiatives for water reuse in the municipal sector include reclamation plants in Beaufort West (direct potable reuse (DPR)), George (indirect potable reuse (IPR)) and Mossel Bay (reuse for industrial purposes). Direct potable reuse options in Durban (eThekwini Municipality), Port Elizabeth, Cape Town and Hermanus are at an advanced planning stage, and occur at many other municipalities, and therefore opportunities for wastewater reuse exist across sectors.

An assessment of water use and effluent generation in South Africa undertaken in 2010, highlighted the following:

1) Consumption: the water consumption fractions of industry, mining, power generation and the food and beverages industry are 55%, 23%, 20% and 2%, respectively. In the industry sector petroleum, ferrous metals, and pulp and paper are dominant at 42%, 41% and 14%, respectively, whereas in the food and beverage (2%) industry breweries comprise only 15%.
2) Effluent generation: the order was industry, mining, food and beverage, and power generation are 74%, 10%, 9% and 7% respectively. Pulp and paper and the petroleum industry at 57% and 34% respectively dominated the industry sector, whereas 18% of the effluent generated in the food and beverage sector was from breweries.

The water use for the different users and wastewater producers are summarised in Figure 1.1 below:

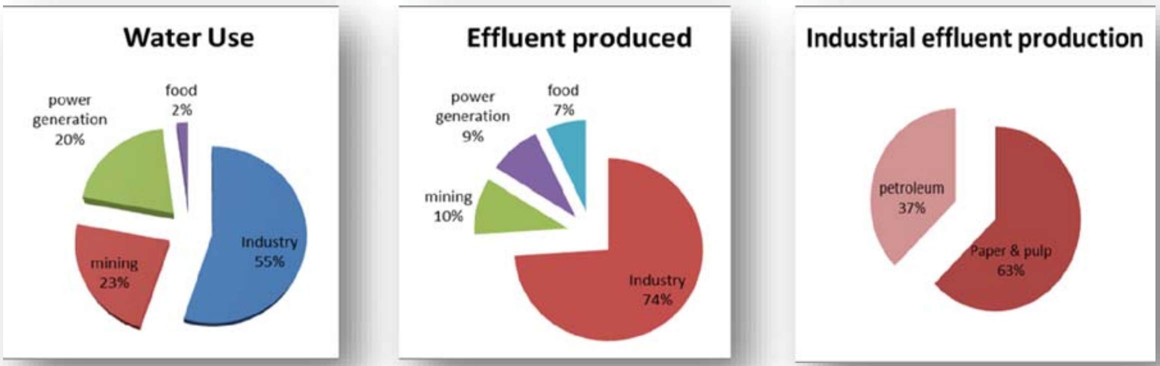

Figure 1.1. Water use and wastewater producers

Therefore, based on the assessment by Cloete et al. (2010) there is potential to reduce demand in the industry sector since it generated more than 74% of the effluent. However, the profile of industrial effluents differs considerably. For instance, from a hazard perspective (effluent chemical composition), the mining sector poses the greatest potential risk followed by the food and beverage sector and then power generation.

The private sector is also investigating alternative water sources (reuse being one and demand reduction another). For instance, the National Business Initiative and Strategic Water Partners Network are amongst those calling for wastewater reuse solutions in industry. Furthermore, globally there is high emphasis on wastewater reuse and in 2017 the United Nations launched a report in South Africa (Durban) which is aimed at unlocking wastewater reuse opportunities (WWAP, 2017).

The current study undertakes a more refined/detailed identification of wastewater reuse opportunities in South Africa involving industrial (not residential/domestic) water consumers and wastewater emitters, and a risk informed approach to assess fitness for reuse. The limitation to industrial reuse (rather than domestic/residential) is deliberate to achieve maximum impact for the effort involved, as it implies a smaller number of higher-volume users rather than a larger number of low-volume users. The removal of domestic/residential consumers removes the blanket assumption of the requirement of the water to necessarily be of potable quality.

As stated in the National Water and Sanitation Master Plan, a 17% water deficit (or between 2,7-3,8 billion m^3 per annum) is expected by 2030 (Figure 1.2). This project will assist in identifying opportunities for development purposes by making water available through bulk reuse, not relying on existing water allocations. Reuse potential at nearby industries will be identified through creating a Decision Support System tool after identifying and mapping the volumes of effluent production at bulk industrial producers. The quality of effluent and its fitness for use will be able to be assessed through a qualitative analysis programme.

Industry is the second largest user of water for development, consuming 22% of water globally (UN Water, 2018). In Europe and North America, industrial water use accounted for half of their total water use in 2009 in contrast to the 4-12% in developing countries over the same period. Industrial water use is however likely to increase as a result of industrialisation in developing nations, adding to the pressure on already stressed water resources (WWAP, 2009).

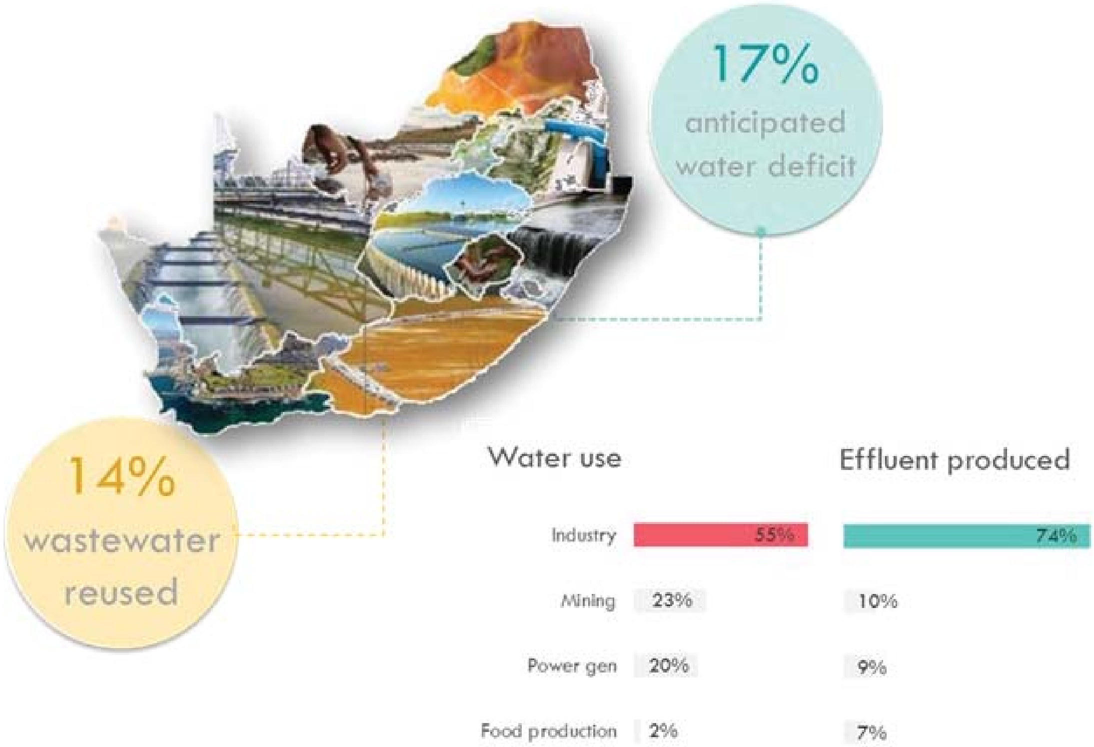

Figure 1.2. Summary of water use, water reuse and effluent produced

South Africa's already strained water resources, will become even more stressed in the near future as a result of unprecedented population growth, climate change and increased pollution. In 2017 the Department of Water and Sanitation predicted that by 2030 water demand will reach 17.7 billion m^3, exceeding the volume that is available to allocate. According to the National Water and Sanitation Master Plan (DWS, 2018a,b) agriculture was the biggest user of water at 61%, followed by domestic water use (27%) and Industry (7%).

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Responsible and efficient water management is fast becoming a pressing reality for domestic users, agriculture and industry alike. The need to reuse water in order to secure the future of the country is evident. In face of the ever-growing demand for fresh water resources globally, there is a need for a paradigm shift in wastewater management from ‘treatment and disposal’ to ‘reuse, recycle and resource recovery”. Wastewater is increasingly viewed as a potentially sustainable source of water, from which many economic benefits could be derived. The UN World Water Development Report (WWAP, 2017) suggests that improved wastewater management could facilitate the achievement of the UN’s 2030 Sustainable Development Goals (SDGs). South Africa’s National Water and Sanitation Master Plan (DWS, 2018a) is aligned to the UN’s Sustainable Development Goals’ (SDGs) (UN, 2015) unique vision for a better future for all as set out in Goal 6 which stipulates: “to ensure the availability and sustainable management of water and sanitation for all”. SDG-6 specifically has a target to reduce the proportion of untreated wastewater by half by 2030, while sustainably increasing water recycling and safe reuse (WWAP, 2017).

Reclaimed water is still not extensively explored as an alternative reliable source of water supply in South Africa. Even in literature, information about water reuse in South Africa is scarce. Most of the examples of reclaimed water are related to agriculture (Jiménez et al., 2010), with a few exceptions (Eckart et al., 2011; Adewumi et al., 2010). Treated domestic wastewater has long since been reused for various purposes such as irrigation of sports fields and crops as well as for reclaimed drinking water (e.g. Atlantis managed aquifer recharge plant). More recently wastewater has been treated and used directly for drinking (e.g. Beaufort West). While there is still much more that can be done with domestic wastewater, the value of industrial effluent is yet to be realised. This is shown in the GreenCape’s Market Intelligence Report (2018) where the total Gross Value Add (GVA) for moderate and highly water intense users in the Western Cape Province in 2016, excluding agriculture, was calculated to be R155 billion (Quantec 2017). Water reclamation in industry is already practiced around the world, supported by advanced treatment technologies. Gulamussen et al. (2019) recognized the need to identify industries with potential for use of reclaimed wastewater, and the evaluation of industrial water use locations and patterns. In addition, sewage flows available for reclamation should be identified to find links for incorporation of water reclamation in urban and industrial planning.

An assessment of the industrial effluent reuse potential of the country will assist in identifying where water can be made available for development. Industrial companies are increasingly exploring the reuse of their effluent (wastewater) streams. An example of direct reuse of treated effluent delivered directly to an industrial water user is Mondi Paper in the southern part of eThekwini municipality which receives treated domestic effluent from the Southern Wastewater Treatment Works, freeing up sufficient drinking water for approximately 300 000 people (eThekwini Municipality, 2011). Internationally, there is a general move towards zero liquid discharge, and several industries in South Africa already reclaim and reuse significant amounts of wastewater, such as the mining and sugar sectors. In June 2018, Nestlé South Africa announced the launch of its R88-million zero-water dairy manufacturing facility in Mossel Bay, in the Western Cape. It was estimated that the facility would allow Nestlé to reduce the factory’s water consumption by more than 50% during the first year of implementation by reusing the water recovered from the milk evaporation process, saving 168-million litres of water a year. It is estimated that Nestle will eventually reduce its municipal water consumption to zero (Engineering News, 2018). Figure 1.3 and Table 1.1 provide examples of the different ways that water can be re-used in South Africa.

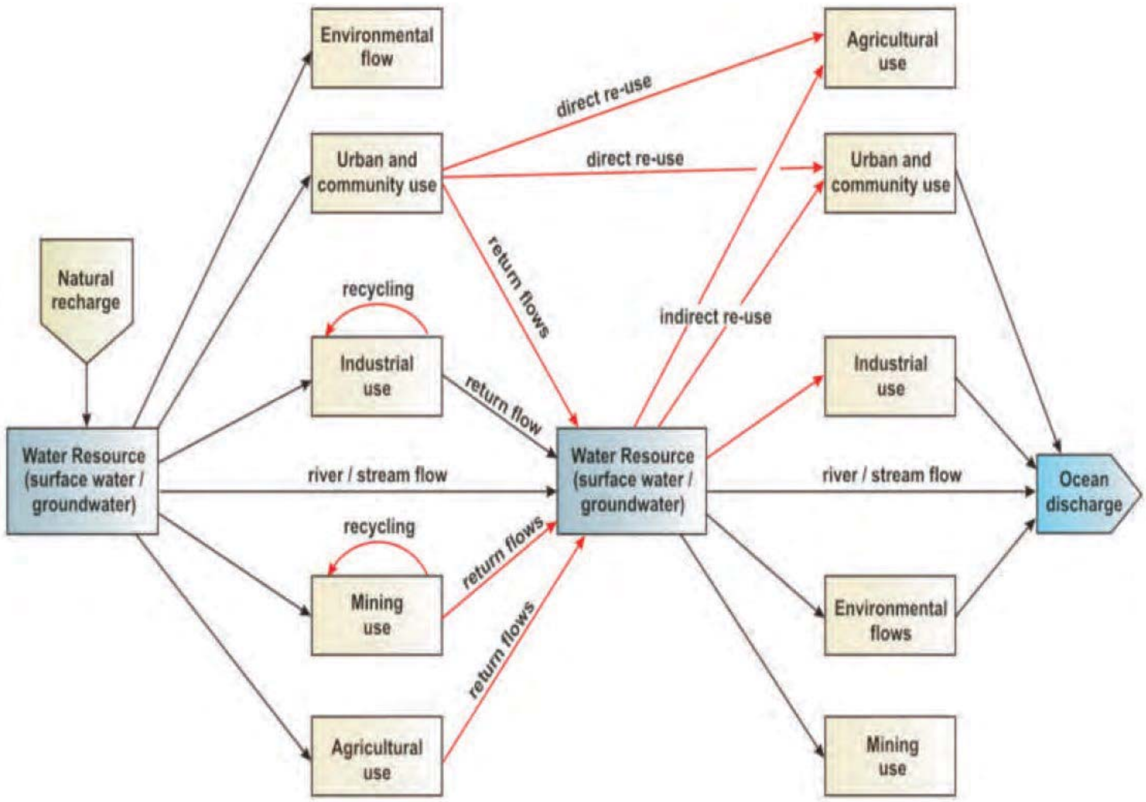


Figure 1.3. Non-exhaustive illustration of different ways that water can be re-used

Table 1.1. Examples of water reuse projects in South Africa (Niekerk and Schneider, 2013)

Source of Reclaimed Water			Reclaimed Water User	
Water Services Authority	**Facility**	**Level of treatment**	**Institution**	**Category of use**
City of Cape Town Metro Municipality (CoCT)	Potsdam WWTW	Secondary, tertiary	Organization	Industrial, process water
City of Johannesburg Metro Municipality (CoJ)	-	Secondary, disinfection	Kelvin Power Station	Industrial, cooling water
City of Tshwane Metro Municipality (CoT)	Rooiwal WWTW	Secondary, disinfection	Rooiwal Power station	Industrial, cooling water
eThekwini Metro Municipality (EMM)	Southern WWTW	Secondary, tertiary	Mondi Paper Company	Industrial, cooling water

It is envisaged that the project's research outputs will now enable several SA municipalities and industry partnerships to be fostered more coherently in terms of wastewater reuse. The projects investment has inputted into the water value chain within the SA water sector and a graphical representation of the project value add, is presented in Figure 1-4. In this regard, the project team has been actively involved in multiple stakeholder engagement initiatives and activities with the intent to partner and further develop pilot studies using the DSS.

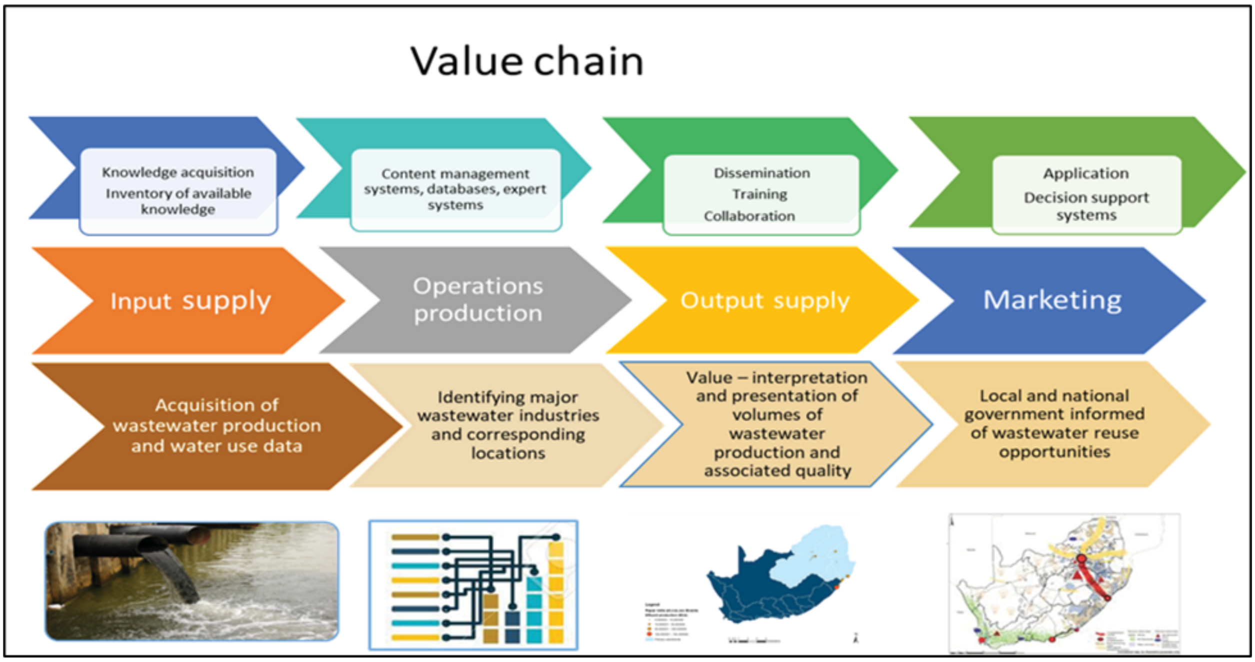


Figure 1.4. Bulk Water Reuse Project Value Chain

Project execution was negatively impacted and logistics and travel challenges were compounded during the COVID-19 mandatory lockdown periods, during which project team members were unable to undertake any lab analysis, fieldwork or host planned stakeholder workshops. Despite the challenges encountered, the project team has still managed to achieve all key milestones and has delivered on all the planned research outputs.

1.2 PROJECT AIM

The aim of the project was to develop and initiate piloting of a risk-informed decision support tool for metropolitan level municipalities to enhance wastewater reuse for industrial purposes.

1.3 PROJECT TASKS

The identification of wastewater reuse opportunities involving industry was done by partnering at the first tier with three local government municipalities, namely the City of eThekwini, City of Ekurhuleni, City of Tshwane, in order to obtain water use and effluent generation at urbanised industrial settings. The outcome of that exercise was specific identification of sectors and industrial organisations where there is potential based on demand volumes and effluent generation (to map the producers and users to enable the production of a glossy atlas for industrial wastewater reuse opportunities).

To assess and ensure the quality of the effluent planned for reuse (fitness for use) it is necessary to show that it will not cause adverse effects to either the environment or to human and animal health. We proposed adopting a risk informed approach rather than a hazard-based approach. South Africa is already developing the Water Quality Guidelines under the framework of risk. Furthermore, the Waste Discharge Charge System which is currently hazard based (water pollution levy) presents an opportunity for development towards risk-based, to consider water resource classification and catchment vision in a geographical boundary. The risk informed approach adopted involves the testing of suitability and relevance of toxicity bioassays to the effluent and planned reuse.

Treated wastewater contains a multitude of organic chemicals, including pharmaceuticals, hormones, and pesticides continuously introduced into aquatic ecosystems. Simultaneous exposures to multiple chemicals can exert additive, synergistic, or antagonistic effects; equal to, greater than, or less than the sum of the independent effects of each contaminant, respectively. Appropriate bioassays should include relevant effects or modes of action, such as mutagenicity, genotoxicity, endocrine disruption (e.g. androgen, oestrogen, and glucocorticoid receptor activation, modulation, and thyroid hormone disruption), oxidative stress, neurotoxicity, immuno-toxicity, cellular integrity and cell or tissue damage. Biological tests can be used as a screening and prioritisation tool for subsequent chemical analysis using biological measures of exposure or biomarkers. This option is also in line with the Direct Estimation of Ecological Effect Potential (DEEEP) approach (DWAF, 2003), followed by the National Toxicity Monitoring Programme that was initiated by DWS, and is the current tool for effluent discharge compliance (licensing).

Briefly, detailed scenarios were evaluated for potential reuse, making use of a risk-based approach; thus, developing a glossy atlas for the different metros to unlock water in wastewater reuse scenarios for instance, will extend beyond industrial treatment processes, to neighbouring ecological infrastructure, agriculture and communities. Reuse potential was investigated at a small-scale approach (e.g. adopt a catchment/municipal/city) – hence municipal boundaries which are also practical for the magnitude of the current project. This can identify an impact at a specific site as well as influence a more widely based demand management programme, for instance, municipal strategies, business and general society, to stimulate public-private partnerships within a geographical location. The framework developed can be tailor-made for different locations or scenarios, thus a potential value offering by the CSIR tool to the local water sector.

2 DEVELOPMENT OF RISK-BASE DECISION SUPPORT TOOL FOR WATER REUSE

2.1 INTRODUCTION

The identification of wastewater reuse opportunities involving large industries, was initially identified by making use of the Department of Water and Sanitation's, WARMS database. This step was also refined by partnering at the first tier, with local government municipalities, e.g. eThekwini Municipality, City of Ekurhuleni and City of Tshwane to obtain data and access publicly available information relating to municipal water usage. This was done in order to obtain water use and effluent data at the urbanised industrial context within the metros. The outcome(s) of that exercise was a specific identification of key sectors and industrial organisations where there was greatest potential for wastewater re-use. This was also informed by analysing demand volumes and effluent generation of industrial operations. Through this data collection and analysis, various GIS based maps of the producers and users were completed and this then enabled the development the National Atlas for industrial wastewater reuse opportunities in SA.

At the second tier, many stakeholder engagements were undertaken with identified priority organisations in order to undertake a more robust case-by-case wastewater reuse analysis to the support the objective of tailored wastewater re-use solutions, including an assessment of the fitness for re-use, by adopting a water quality risk-based approach. The data analysis included results from parameters such as water quantity and quality, water use location, and (where available) billing rates.

In order to assess and ensure the quality of the effluent planned for reuse, it was necessary for the project team to consider adverse effects to either the natural environment or to human and animal health. The project team therefore adopted a risk informed approach rather than a hazard-based approach and this involved the testing of suitability and relevance of toxicity bioassays to the effluent and potential planned reuse. Based on the data analysis suggesting that wastewater contained a multitude of organic chemicals, including pharmaceuticals, hormones, and pesticides which are continuously introduced into aquatic ecosystems, appropriate bioassays were then included which had direct relevance to the effects or modes of action, such as mutagenicity, Geno toxicity, endocrine disruption (e.g. androgen, oestrogen, and glucocorticoid receptor activation, oxidative stress, neurotoxicity, immuno-toxicity, cellular integrity and cell or tissue damage.

Biological tests were also used as a screening and prioritisation tool for subsequent chemical analysis by utilising biological measures of exposure or biomarkers. This option was in line with the DEEEP approach (2003) as followed by the National Toxicity Monitoring Programme that was initiated by Department of Water Affairs in 2003, and is also the current tool for effluent discharge compliance nationally (i.e. for water use licensing). Scenarios were then evaluated for potential re-use by making use of the risk-based approach; thus resulting in the culmination of a National South African Atlas for industrial wastewater reuse opportunities in the different metros across the country and the objective of publishing the National Atlas was to unlock a research conversation on sustainable long term, wastewater re-use projects in SA. The earlier versions of the DSS were already able to assist with extending industrial treatment processes to include neighbouring ecological infrastructure, agriculture and local communities. This also allowed for the reuse potential to be investigated at a small scale (i.e. catchment/municipal/city) – hence municipal boundaries were determined to being scientifically practical for the magnitude of the current project scope and budget. The approach also assisted the project team with the identification of impacts at a specific site as well as its influence more widely in terms of water conservation and demand management programmes in SA.

The National Atlas and DSS 2.0/3.0 that have been developed from this WRC project allows for the streamlining and tailoring of alternatives as well as different options for potential wastewater re-use, across

South African metropolitan municipalities. It is proposed that the next phase of the project receives continued Water Centre are ideally positioned to lead this bulk wastewater re-use research programme, nationally and increase the project impact through the development of CSIR Technology Demonstrator.

A web-based Decision Support System (DSS) has been developed which will enable municipal and industry partners, and water quality managers to make informed decisions for possible reuse options. It aims to directly assist by linking industrial effluent volumes and quality to fitness for use, with specific industries. The tool will be able to determine the suitability of available bulk wastewater for reuse by nearby water consuming industries. As such, there is a need for a decision support tool that can assist in identifying the water reuse potential, examining the feasibility, economic viability, ecological compatibility and social acceptance of alternative service water supply solutions.

2.2 DEVELOPMENT OF A WEB-BASED DECISION SUPPORT SYSTEM (DSS) TOOL

The DSS v 2.0 tool itself is a user-oriented, simple, and efficient interactive web-based (and mobile app) tool developed to directly assist by linking industrial effluent volumes and quality to fitness for use and linking it with specific industries in the geographical vicinity based on industry specific water quality and quantity requirements (refer to Appendix A). It users various input data, largely effluent and water use data sourced directly from the municipality (i.e., eThekwini MM) can be applied prior to a more detailed feasibility study in order to assess possible water-reuse options and it shows decision makers and other stakeholders that implementable solutions are available which comply with local requirements. A prototype to the web-based DSS tool (Figure 2.1 and Figure 2.2) was developed for identifying optimal opportunities for bulk wastewater reuse for industrial purposes within metro municipal boundaries. Water purity risk assessments, as well as a review of the minimum legal requirements for water quality for different uses is required. The interactive visualization of water reuse potential dashboard was developed.

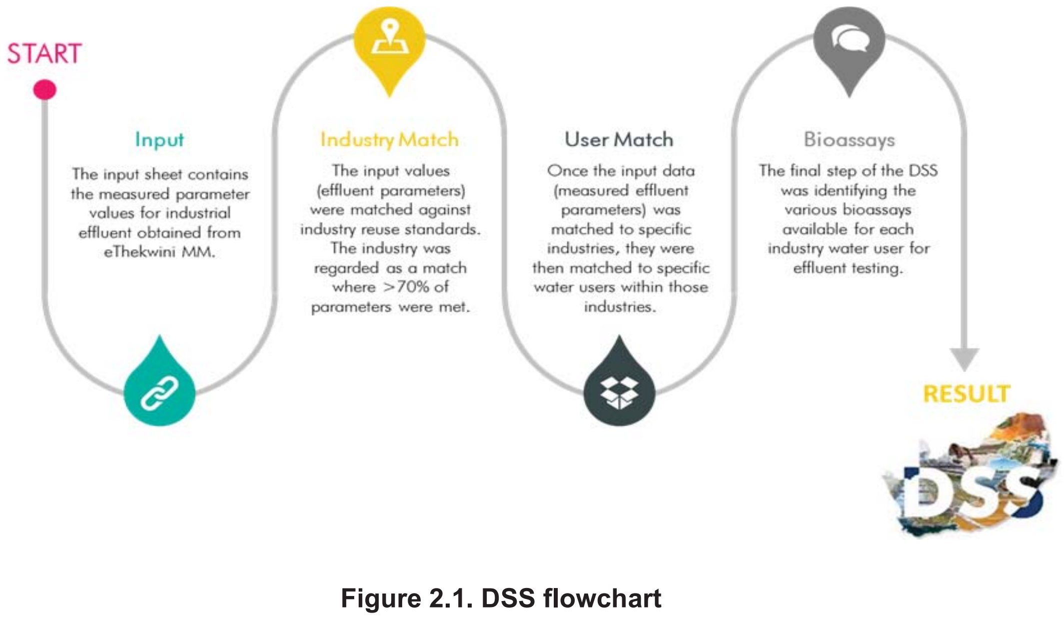


Figure 2.1. DSS flowchart

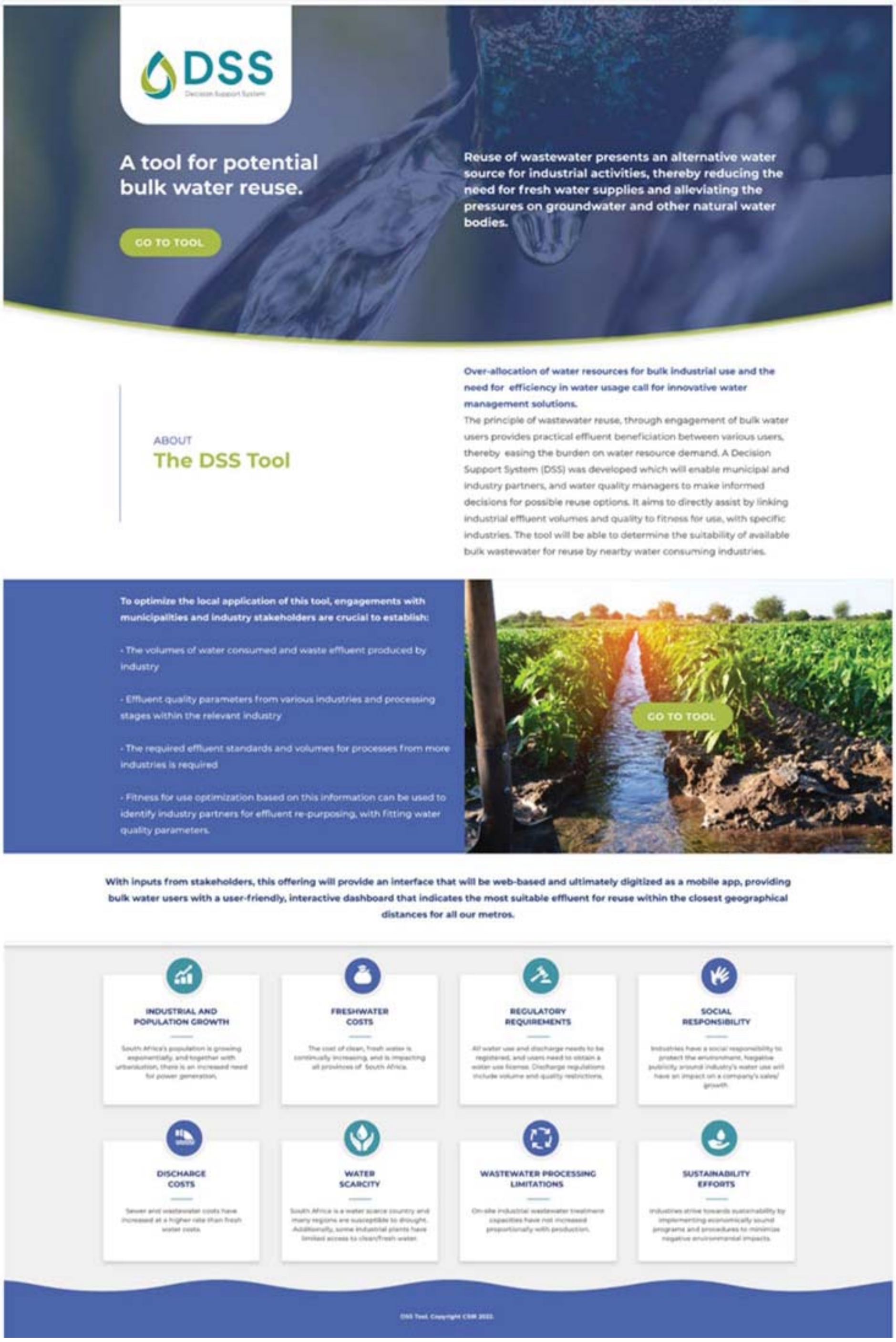


Figure 2.2. Screenshot of the web-based DSS

The DSS will be developed where the wastewater quality and volume will be input values and the decision support system could assist with possible reuse scenarios. Included in this tool will be criteria to:

1. Approaches to assess wastewater sources.
2. Evaluation of needs assessment as informed by water supply: water demand ratio
3. The identification of best-fit water reuse potential in industry as informed by wastewater chemical and toxicological properties.
4. Estimation of economic and technical feasibility for the implementation of industrial water reuse schemes
5. Recommendations for implementation in identified priority industries.

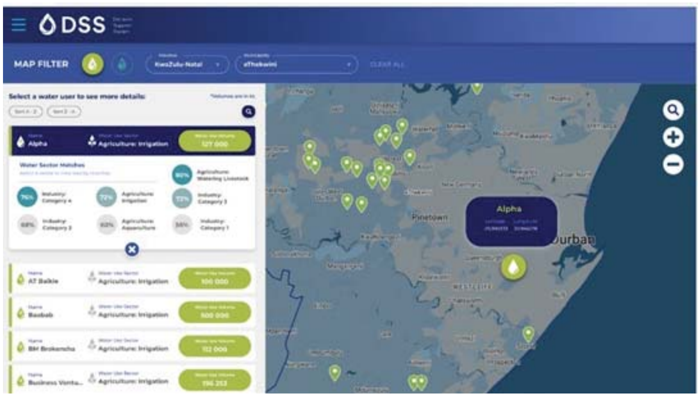
6. Policy recommendations to decision-makers to incentivise water reuse by the private sector (in line with recommendations of the UN WRR-2017 report).

The underlying systemic approach of the tool makes it intuitive also for users with limited prior knowledge in the field to identify most adequate solutions based on multi-parameter inputs. This should help to promote water reuse and spearhead initiates for more detailed feasibility and design commissioning for implementation of water reuse schemes. A "walk-through" of the DSS tool is given in the sub-sections below.

2.2.1 Input values

The identification of wastewater reuse opportunities involving large industries, was initially identified by making use of the Department of Water and Sanitation's, WARMS database. This step was also refined by partnering at the first tier, with local government municipalities, (e.g. eThekwini Municipality) to obtain data and access publicly available information relating to municipal water usage and effluent quality. This was done in order to obtain water use and effluent data at the urbanised industrial context within the metros. The outcome(s) of that exercise was a specific identification of key sectors and industrial organisations where there was greatest potential for wastewater re-use. This was also informed by analysing demand volumes and effluent generation of industrial operations. Through this data collection and analysis, various GIS based maps of the producers and users were completed and this then enabled the development the National Atlas for industrial wastewater reuse opportunities in SA. In addition, the user is also able to input the site-specific aspects such as monthly water consumption volumes, wastewater quality and quantity generated, and geographical location through a user-friendly interface.

2.2.2 Evaluation



Effluent quality is matched against standard water quality guidelines as detailed in the South African Water Quality Guidelines Volumes 1-6. If more than 70% of effluent parameters fall within the water quality guidelines, a potential match is considered. The water user is selected from the list a specific effluent matches for each water sector is made within a geographical area (10 km). However, the end user is able to expand on the geographical radius of up to 50km.

In order to assess and ensure the quality of the effluent planned for reuse, it was necessary for the project team to consider adverse effects to either the natural environment or to human and animal health. The project team therefore adopted a risk informed approach rather than a hazard-based approach and this involved the testing of suitability and relevance of toxicity bioassays to the effluent and potential planned reuse. Based on the data analysis suggesting that wastewater contained a multitude of organic chemicals, including pharmaceuticals, hormones, and pesticides which are continuously introduced into aquatic ecosystems, appropriate bioassays were then included which had direct relevance to the effects or modes of action, such as mutagenicity, Geno toxicity, endocrine disruption (e.g. androgen, oestrogen, and glucocorticoid receptor activation, oxidative stress, neurotoxicity, immuno-toxicity, cellular integrity and cell or tissue damage.

2.3 MULTI-SPECIES TOXICITY BIOASSAYS TO ASSESS FITNESS FOR USE OF WATER / WASTEWATER

A desktop review of international literature on multi-species toxicity bioassays is in progress to summarise available toxicity assays, their advantages and disadvantages, as well as international best practices and legal requirements associated with wastewater treatment, use and reuse. These include but not be limited to those bioassays accepted and applied by the OECD and US EPA (Figure 2.3). As a second step to this task, a national assessment of available multi-species toxicity assays available locally will be summarised. A list will be made of the types of assays available and who the organisation or institution is that can do these assays, if it is commercially available as well as the legal and ethical considerations in doing these assays in South Africa.

The value of bio-indicators is the ability of sensitive organisms to react to the totality of an environmental contaminant or unknown solution, without only testing known components (Slabbert et al., 1996). This enables a better understanding of otherwise unclear interactions and possible impacts in complex settings. An inventory of currently used assays is listed in Figure 2 and sorted according to trophic levels. There are numerous indicators, some of which exhibit similar sensitivities to common pollutants and others with specific sensitivity to other chemicals/pollutants. Recent assessment of bio-indicator sensitivity for example showed a specific sensitivity of freshwater shrimp to algal toxins as opposed to lettuce in a battery of bioassays (Ndlela et al., 2020) although testing for the sensitivity of *Lactuca sativa* to wastewater polluted with heavy metals indicated its suitability as a bio-indicator, with reduced germination reflecting the toxicity of the water, therefore based on the current literature, the suitability of bioassays for various effluents will be proposed.

Bio-indicator response can be unique to various pollutants. Organisms can have (Markwiese et al., 2001) varying tolerance levels, which is important to note when investigating environmental impacts. The testing of only one or potentially resistant indicator compromises the assessment of toxicant impacts. There is currently an inventory by (Cloete et al., 2010) which provides the general characteristics of wastewater from the major industries. From this and additional literature, the characteristics of wastewater have been listed and based on these, suitable bio-indicators selected based on their sensitivity and previous reported testing of specific effluents and sensitivity. Although literature may provide one or two commonly indicated organism, testing across different trophic levels is recommended to have a more holistic assessment of effluent impact. Additional assays to determine cell stress/death or oxidation can be conducted for a better understanding of the basic cell/organism changes and can provide more insight on the mechanism or particular effect the effluent components may potentially have on the organism, i.e. environment.

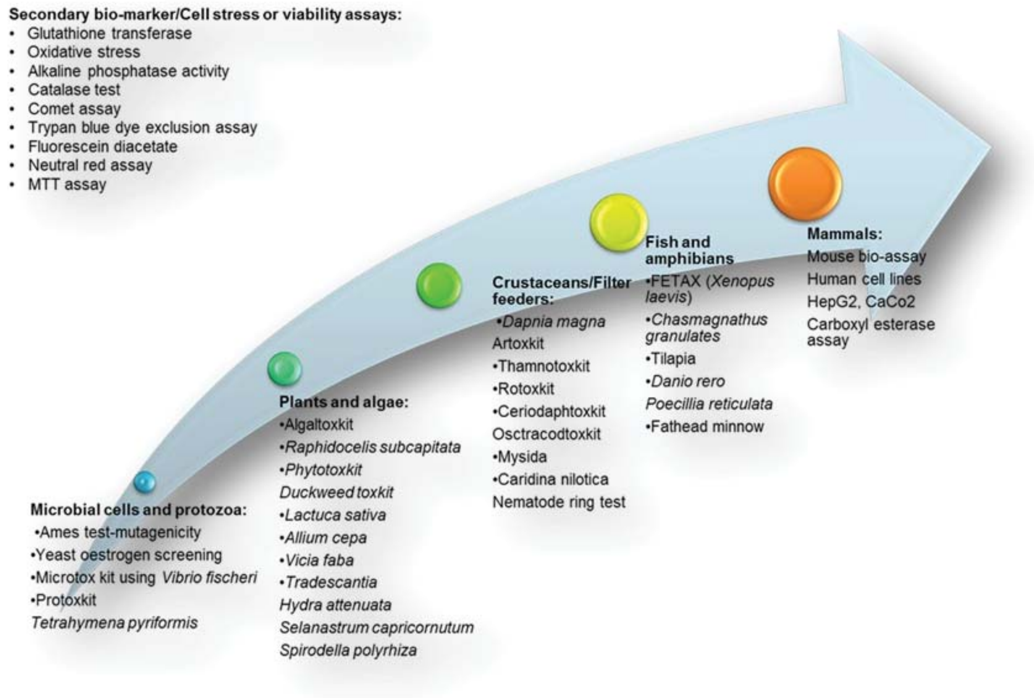


Figure 2.3. An inventory of available and currently applied bioassays at various trophic levels.

To increase the appeal and uptake of effect-based monitoring as an integral part of water quality testing, the consideration of bioassay requirements is crucial. As a key component of the tool, the availability of resources, skill and time need to be considered in the assays recommended. In cases where sophisticated skills and equipment are required, it needs to be clear where stakeholders can obtain or make use of such services. With an array of assays available, the criteria of indicator sensitivity, ease and robustness have been applied as far as possible in the tests recommended.

Over a time, a baseline response is envisaged for the indicators to various industry effluents when a match is made within the tool. This will not only provide guidance on single dose-responses but provide an adequate background on when action should be taken based on the indicator response trend. So a holistic assessment of effluent matches can provide meaningful insights and potentially avoid further adverse environmental impacts from proposed reuse applications such as this decision support system.

Efforts to inform toxicological risk assessment through the organization of biological information has led to the development of several pathway frameworks. The Adverse Outcome Pathway (AOP) framework (https://aopwiki.org/) describes the progression of a toxicity pathway from molecular perturbation to population-level outcome in a series of measurable, mechanistic responses. An AOP follows the events of a toxicity pathway in measurable mechanistic steps, beginning with a Molecular Initiating Event (MIE) that describes an action on a specific biomolecule, through a series of causally-linked Key Events (KE) representing downstream effects at the levels of molecular, cellular, tissue, organ, individual and population-level response, leading to some Adverse Outcome (AO).

Further collaborative efforts with the University of Pretoria (WRC Project Number C2020/2021-0047 and through the support of the WRC the Global Water Research Coalition (GWRC)) investigating the feasibility of an effect-based monitoring in water safety planning) have established a stronger baseline for available assays, the level of skill and equipment required. With this foundation, it is important to note the factors of consideration in the effective implementation of this component in the decision support tool. For one, although an expanse of knowledge has been gathered in terms of industrial effluent characteristics and proposed assays, the dependence of bio-indicator recommendation is interlinked with water quality information. Water quality data of effluents is an area where knowledge gaps may affect how suitably bio-indicators are recommended. Furthermore, there is a need to consider the feasibility of assays applicable from a time, skill and cost perspective. This is of particular significance in the appeal of this tool to industrial stakeholders and will also carve out a method of practice for an autonomous fitness for use matching.

3 PILOT TESTING AND CAPACITY BUILDING RELATED TO THE RISK-BASE DECISION SUPPORT TOOL FOR WATER REUSE

3.1 PILOT SITE

The average water demand in the eThekwini Metropolitan Municipality is 963 ML/day and is supplied from 10 potable water treatment plants. The Municipality purchases most of its water from Umgeni Water and a small portion the water is supplied from water treatment plants that are owned by the Municipality. However, recently erratic climate conditions and rapid urbanization have drastically increased the City's water demand, such that as recently as 2015/16 water restrictions were affected. Recent studies by the EWS, project the Inner City Water Demands to be approximately 65 ML/day; outstripping the supply of 50 ML/d, and thus the need to augment the supply by 15 ML/d by 2020.The recycling of water for potable and non-potable use has been identified and presented in the Water Reconciliation Strategy for the KwaZulu-Natal Coastal Metropolitan Areas as an important potential water resource for the eThekwini Municipality. The EWS has a goal of producing 20% of its own water supply in 10 years' time (EWS Security of water supply, 2017). According to the Umgeni River System water balance and reconciliation strategy; reuse of treated effluent is amongst priority options to reconcile the water requirements in the years immediately prior to the implementation of the Smithfield Dam. Approximately 500ML/day of wastewater is disposed of daily within eThekwini (AADF flows provided by EWS for the various WWTW, 2017). The Municipality is planning to further implement several reuse projects over the next few years to meet its additional water demands.

Therefore, the WRC funding for this project supports the CSIR in its DSS refinement activities as it concurrently supports the EWS endeavours in implementing an effective wastewater reuse project. More specifically, the research will assist the Municipality to develop appropriate and site-specific water re-use guidelines for a novel Remix Plant Project located in Durban. Further such studies are expected to be done at each of the proposed Municipality led wastewater reuse projects in the future. For each project, a particular focus will be placed on examining and analysing contaminants of emerging concern as several contaminants are not currently addressed in South African water quality policies and guidelines.

Additionally, the CSIR is also aiming to assist in reuse projects and programmes in other parts of South Africa, for example, in Gauteng, the IVRS which supports most of Gauteng's water demands is about 98% to full allocation with the majority water use (79%) being the metro municipalities, namely CoE, CoJ, CoT (DWS, 2018). Collectively the metros account for approximately 3 388 and 2 206 Ml/d water use and wastewater generation respectively from a population of 12 million and associated industrial activities. Considering the looming water security risk (social and economic) faced by Gauteng; water demand reduction interventions such as bulk wastewater reuse are a priority need for all Gauteng metros. Therefore, the current project funding further supports the establishment of research collaborations with all Gauteng metros, that will be tailored for effective implementation by further refinement and application of the DSS tool.

3.2 STAKEHOLDER ENGAGEMENTS AND WORKSHOPS

Several meetings have been undertaken with stakeholders across the country. More structured meetings have been had with pilot partners (i.e. eThekwini MM) to obtain available water use and effluent data of various industries registered as water users within the eThekwini MM. The data obtained will be used in the current version of the DSS in order to refine and augment the data utilised from WARMS in the current DSS. The technical project team meeting took place between the CSIR specialist team dealing with the bioassay assessment and DSS development and refinement and thus far important data has already been obtained and reviewed by the CSIR.

A stakeholder workshop between the CSIR project team and eThekwini Municipality took place on 8 December 2021. The aim of the workshop was to demonstrate the applicability of the data obtained in the current DSS, and also to identify the advantages and limitations of the current Version of DSS with a view to update the DSS with the requirements from eThekwini MM. The tool was well-received and extensive brainstorming between the project team and the municipality on the DSS applicability was achieved. A second workshop was held at WISA 2022 (September 2022).

3.3 COMMUNITY AND INSTITUTIONAL EMPOWERMENT

Collaboration between CSIR and municipalities (i.e. specifically eThekwini MM) are in place and include sharing of data and demonstration of the tool.

3.4 STUDENT CAPACITY BUILDING

3.4.1 Overview

A studentship agreement has been signed between the CSIR Water Centre and the Institute for Water and Wastewater Technology housed at Durban University of Technology (DUT). Mr Prince Manyepa has registered for a Masters in Engineering (MEng) degree. The registration of the student has been completed and the PG2 Masters study application process was initiated in May 2021. PG2 has been since been approved. The primary aim of the study is targeted at evaluating any potential human health risks impacts that maybe associated with bulk reuse of waste and desalinated water within the City of Durban. A pilot technology plant has been identified for the study (i.e. EWS eThekwini Remix Plant). The study objective is focused on analysing the effectiveness of the proposed Remix technologies in ensuring the safety of the water for further potable use. The 'fitness-for-use' aspect specifically, in terms of water quality is amongst one of the top priority aspects which reuse schemes or projects such as these, need to address. In line with this need, and in the context of bulk water reuse for potable usage, the application of the 2017 WHO Guidelines for Drinking Water Quality will be used in the Masters study to assess health risks associated with effluent reuse from the Remix Plant (Figure 3.1). The WHO framework includes three key components and can be summarised as follows:

- Health-based targets: These are risk-based measurable objectives that define the safety of drinking-water. They include performance targets to achieve microbial safety and numerical water quality targets for chemical and radiological parameters.
- Water safety plans (not to be included in study).
- Independent Surveillance – depending on future funding availability

The study essentially covered the following overarching research objectives:

- Examining the existing data for emerging contaminants measured in the influent and effluent.
- Prioritising the most relevant compounds based on persistence, bioaccumulation and toxicity (and other impacts such as endocrine disruption)

- Modelling or predicting expected concentrations based on detailed literature review and technology configuration.

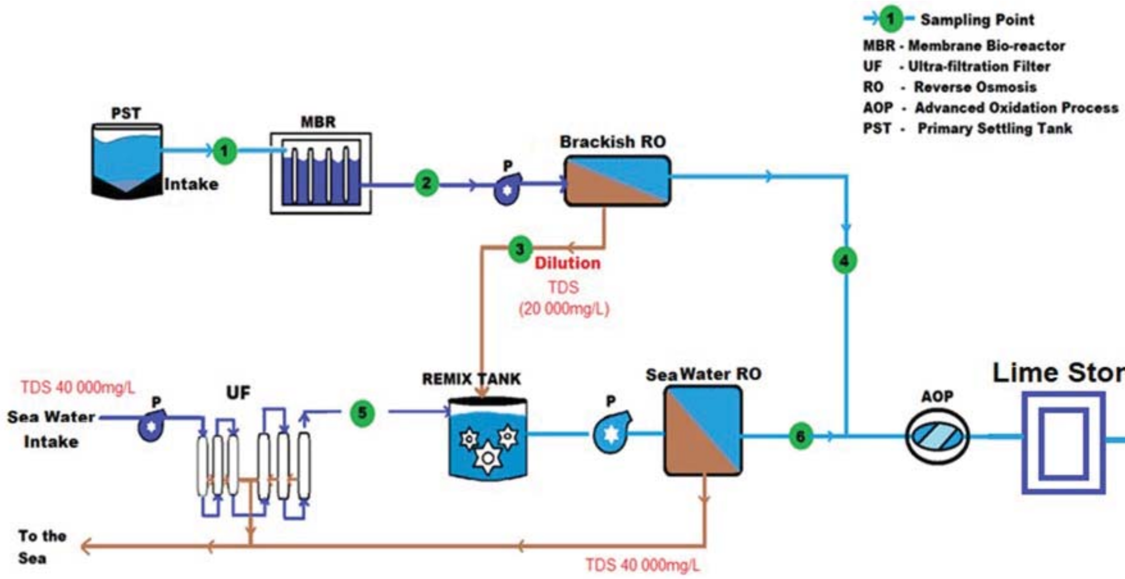


Figure 3.1. The schematic diagram of REMIX Water Treatment Plant

The student has managed to successfully complete his registration and PG2 application for the study at DUT IWWT within the first year of the study. Unfortunately, due to COVID-19 lockdown regulations which were in effect for much part of 2021, scheduled fieldwork and sampling could not take place. In this period the student worked on sourcing relevant literature sources for the study as well as finalising his sampling plan and list of analysis/parameters that will need to be analysed in the study. Figure 3.2 below indicates the study sample points and a list of analysis that will be undertaken for emerging contaminants, Heavy Metals and general water chemistry.

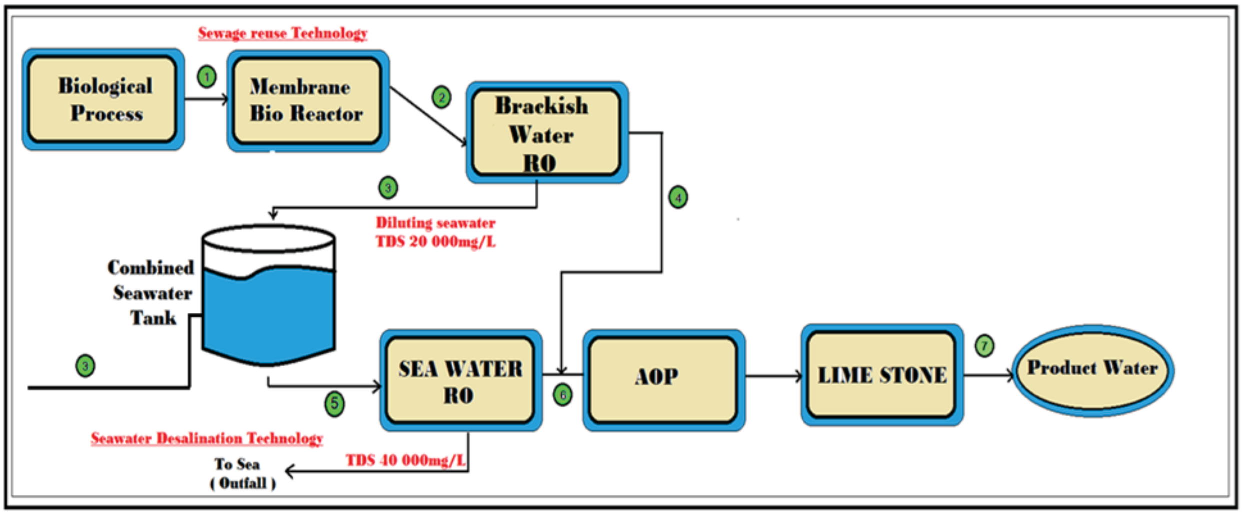


Figure 3.2. Study sampling points

With the easing of Lockdown restrictions at the beginning of November 2021. The first of 4 on-site sampling runs was conducted and the samples were successfully collected, transported and subsequently prepared for further lab analysis. The project team will be utilizing accredited laboratories located within the CSIR and

University of Stellenbosch to carry all the analysis required for the student study. The first batch of samples will be sent to the labs at the end January 2021 and subsequent samples from the 3 remaining sampling runs will be done during the first 3-6 months of the 2022 calendar year. Overall, the study has been good progress but some time has been lost due to COVID restrictions.

3.4.2 Aim of the research

To evaluate eThekwini REMIX water treatment technology for the removal of persistent, bioaccumulating and toxic emerging contaminants, conducting a human health-based risk assessment for ensuring the safety of the reclaimed water planned for augmentation into the convectional potable water supply.

3.4.3 Objectives

1. To analyse the chosen emerging contaminants (ECs) concentrations from each treatment unit of the Remix Treatment technology on the influent and effluent.
2. To prioritise the most relevant compounds based on Persistence, Bioaccumulation, and Toxicity.
3. To predict rejection of ECs by the membrane technology along the treatment train.

3.4.4 Challenges

1. The REMIX Water Treatment Plant was shut down post the devasting floods which took place in April 2022 and this affected the original objective and the plan of the project.
2. One sampling event was conducted instead of the 4 planned sampling events. The sampling event was conducted on the 13th of February 2022.
3. Relocation of Dr Taher Abunama who was the post-doctoral research lead assisting the study with regards to the modelling and statistical analysis of algorithms.

3.5 KNOWLEDGE DISSEMINATION

The knowledge generated in this project can lead to improved public understanding of the country's available water supplies, and the full costs and benefits associated with water reuse as water supply alternatives. This in turn could lead to more efficient processes for specific projects. Overall, the information and knowledge gained in this project will ensure CSIR remains on the scientific forefront in the field of water reuse.
The various items of knowledge dissemination emanating from this project are as follows (Table 3.1):

1. CSIR Atlas of Bulk Scale Water Reuse (Steyn et al., 2021)
2. IMESA Conference and full conference paper (title: Steyn and Walters (2021) Potential for Bulk Scale Industrial Water Reuse in South Africa)
3. Popular article
4. Project brief (developed for stakeholder engagement)
5. Book chapter
6. WISA 2022 oral presentations and workshop participation

Table 3.1. List of deliverables submitted

No.	Deliverable	Status	Due date
0	Advance	Received	1 April 2021
1	Inception Report	Submitted	31 May 2021
2	Draft Decision Support System	Submitted	30 November 2021
4	Annual progress report	Submitted	28 February 2022
5	Workshop report	Submitted	30 April 2022
6	Draft report	Submitted	30 November 2022
7	Final project report	Submitted	28 February 2023

4 CONCLUSIONS

4.1 IMPLEMENTATION OF WATER REUSE: BARRIERS AND OPPORTUNITIES

4.1.1 Reuse constraints

The use of recycled water (e.g. for the irrigation of crops) has benefits in using a resource that would otherwise be discarded and wasted. The use of recycled water also reduces the pressures on the environment by reducing the use of environmental waters (UN, 2021). Morris et al. (2021) did a comprehensive review and analysis and found 56 barriers for implementing water reuse in agriculture. The following key constraints were highlighted:

1. Social and economic constraints – a general lack of knowledge and public understanding, leads to negative perceptions towards reusing wastewater in terms of human health impacts, environmental impacts and cost implications. Long-term financial burdens and short-term financial barriers were a prominent feature amongst stakeholders. Kirchherr et al. (2018) found that economic feasibility aspects of technological solutions were one of the main barriers in wastewater reuse (Kalebaila et al., not dated).
2. Governance and Policy – A general lack of regulatory barriers at local or regional levels delay investment in wastewater solutions. According to Sharma (2000) local water specifications often do not recognize the use of recycled water. Lack of political will and a regulatory framework that support reuse further impacts integrated wastewater management in cities. (Kalebaila et al., not dated).
3. Technological aspects –Technological advances and infrastructure needs to treat complex mixture of polluted wastewaters are often expensive and not economically viable (Morris et al., 2021). Fit-for-purpose treatment could solve the problem without excessive implementation costs as not all practices for reuse requires the same water quality requirements. Often tertiary treatment of wastewater could be a viable option where freshwater availability is declining. In some cases, simple green and low technologies could be effective in allowing reuse while closing the loop on nutrient recycling (e.g. phycoremediation of domestic wastewater) (Steyn and Oberholster, 2021).
4. Environmental aspects – Water reuse within a circular economy approach could pose significant risks to the environment (Hamilton, 2006; Toze, 2006; Voulvoulis, 2018). Nutrient and salinity aspects could cause real concern in agricultural areas (De Lange et al., 2008) while pathogens, or the accumulation of metals from insufficiently treated wastewater could hamper human health (DWS, 2022).

4.1.2 The future of water management

Water reuse is on the rise globally – and not just in developing nations. In 2018, the IWA Wastewater Report (IWA, 2018) found that the global market for Wastewater reuse and recycling reached almost $12.2 billion in 2016 and expressed a predicted increase against the backdrop of climate variability, population growth and urbanisation to $22,3 billion by 2021. A paradigm shift is needed where used water is no longer seen as a waste that one needs to get rid of, but a valuable resource that forms an integral part of water budgeting and planning in urban areas, industry and agriculture alike (GWP, 2009; Rodriguez et al., 2020; UN, 2021). Several key areas for effective integrated water management should include the following:

1. Planning for integration – Wastewater treatment should be incorporated into economic development agendas and planning of cities. The location of treatment (either centralized or decentralized) should be planned close to reuse sites, e.g. peri-urban farmers or industrial users. The treatment and disposal of wastewater of a city / town should be seen as part of the water management. Planning should consider the risks, e.g. pathogens, build-up of contaminants (Hamilton et al., 2006; Van Koppen and Schreiner, 2014; Van Niekerk and Schreider, 2013).

2. Sanitation opportunities – a portfolio of sanitation options and alternative solutions will enable communities and decision-makers to select the best possible option. Technical, environmental, economic, and institutional criteria will inform such decisions. In some cases, decentralized systems would best protect the environment, and avoid transfer of water over long distances (Brault et al., 2022).
3. Define fit-for purpose and cost-effective treatment options – Treatment options are often based on the effluent regulatory standards or guidelines instead of managing the performance criteria based on reducing human health risks, lessen the environmental impact or potential for reuse (which could be more effective). Planning for reuse (planning of treatment plant design) will have optimal results (Capodaglio, 2021).
4. Source of supply approach – Both centralized and decentralized water treatment options should be considered. A shift is needed where for example industrial pollutants are removed at the source instead of after it has joined the municipal sewer system. This is much more complicated, and in some cases even not technically or economically feasible. Within a circular economy approach, nutrients or pollutants should be considered within a closed-loop approach and retained within the same industry for example (Voulvoulis, 2018; Kesari et al., 2021).
5. Agriculture within an urban water treatment cycle – To take advantage of the water and nutrient recycling opportunities, agriculture should be considered as the land treatment option for closing the nutrient loop, e.g. domestic wastewater and the irrigation of fodder crops, or forest trees (Rosemarin et al., 2020).
6. Enabling environment – Paramount to the above, a complete wastewater discharge, treatment and reuse system requires an enabling environment, e.g. an integrated view and adapted legislation and institutional structures (IWRM approach) (Van Koppen and Shreiner, 2014; Van Niekerk and Schneider, 2013; Kalebaila, not dated). Political will should be strengthened and collective pro-active action from all sectors, e.g. tourism, trade, agriculture should be communicated together with the impact on poverty reduction. Water rights must be defined and clearly communicated to all users. Economic incentives for the reuse of wastewater should be defined. In-plant recycling and pre-treatment should be pro-actively financed as part of future water supply strategies. Realistic guidelines or standards should be developed for treatment and reuse that are both enforceable and affordable. These guidelines should consider local conditions (e., socio-cultural, environmental, epidemiological). Public awareness and training and stakeholder engagement should be integrated, and water quality data should be freely available and shared with customers and the general public. Where necessary, users' needs within communities should be communicated and discussed openly at multiple stakeholder participation platforms.

4.2 GENERAL CONCLUSIONS

There is tremendous unexploited potential to improve water efficiency and augment or partially substitute freshwater supplies in South Africa. Reuse of treated wastewater to augment water supplies and improve water security as a result of climate change and drought, will allow more water to be available for potable uses. Decision support systems are valuable tools that strive to assist decision-makers in metropolitan areas with complex and important drought risk management decisions. Decisions for reuse are not linear and depend on various factors – such as stormwater management, aquifer protection, and industrial development. Integrated management of water resources is in line with sustainable development and the recent drive to a circular economy. This calls for targeted collaborative effort form all parties involved within and enabling environment to improve water reuse and decrease water security issues, while managing risks. Due to its user-friendly design, a transparent valuation approach as well as the clear and comprehensible presentation of results, the end user became more aware of the strengths and weaknesses of the considered option and were able to identify the most sustainable supply system or strategy for their decision case.

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APPENDIX A: DSS INFOGRAPHIC