The intricate challenges of delocalised wastewater treatment facilities with regards to water resource management capacity framework in South Africa

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Abstract

The project investigated the state of wastewater treatment administrative management in some of the more remote locations of South Africa, in term of the ability to realise wastewater as a potential and a viable water resource in a semi-arid land. The primary objectives centred on the element responsible for the delivery challenges within the wastewater treatment spaces, towards integrated water resource management efforts. Findings suggested that some of the more pertinent challenges emanated from shortfalls in the implementation of legislative policies, and the lack of sufficient drivers within the water resource environment. Results from most of the locations of interest showed various limitations, including the lack of adequate water treatment infrastructure, insufficient operation and maintenance schedules, limited technical skills and training, and poor management capacities. The analytical approach applied in this study was that of a wastewater management capacity framework. A workable capacity framework is proposed and discussed. The capacity framework takes into account the intricate and unique environment within a South African context, both socioeconomically and in the natural setting.

Keywords: Wastewater; Resource; Capacity; Management; Framework

Introduction

The narrative of scarcity of natural resources in the planet has become one of the major positive drivers regarding the current consciousness surrounding the manner in which waste is managed. At the centre of this narrative are economic value systems that are responsible for the global shift in perspective. Wastewater disposal has traditionally been a nuisance activity through out human history, with exception of a few applications mainly as a source of nutrient recycling. Wastewater management now forms part of what is formally termed, a circular economy. Principles outlined in the circular economy advocate for the maximum use of any resource. Wastewater has been realised to be an important resource, both in the traditional view of nutrient recycling and as a major water resource, especially in the water scarce parts of the planet. Wastewater is also a renewable energy resource; the implications of this application can be directly linked to economic functionality. Many studies have documented the economic value of wastewater with regards to the potential to offset costs associated with treatment (Song et al. 2018; van der Hoek et al. 2016; Burn et al. 2014).

For such reasons, wastewater reuse has drawn increasing attention worldwide as a potential resource that can be part of the integral water resource management plans. In addition, economic considerations are becoming increasingly important amid the introduction of market-based mechanisms of environmental and water resource management (Yang and Abbaspour 2007). Sustainable water management systems have thus become an important goal of sustainable development plans of many countries including South Africa. Government authorities and the land development industry are increasingly seeking to use alternative sources to conserve drinking water supplies and minimise the stresses of high levels of water consumption. Wastewater has become a potential reliable water source; there are, however, many crucial aspects that must be revisited before this goal can be realised. Reclaimed wastewater has been used as an additional source of non-portable water supply in many parts of the world; only recently has attention and research efforts shifted towards domestic reuse. There are, however, many facets of wastewater reuse that must be addressed before strides are possible to make, most of which include the feasibility in different settings. The more pertinent of the strides requiring making would be the legislative, policy, and regulation hurdles. The South African legislation at present on wastewater and the discharge of treated water was built on the Water Act of 1956, and currently by the application of the National Water Act (NWA) of 1998. The NWA remains the primary space that enforces and regulates effluent quality requirements and effluent disposal options.

To meet demand shortages in modern consumerism-driven societies, the alternative has been to privatise water services. This has resulted in steady-price increases of portable water procured from private enterprises. In developing countries, the purchase of portable water is not a sustainable method of delivery and promotes inequality for those who do not possess the means. This has led to investigations into alternative sources of water, including reuse capacity in the forms of wastewater recycling and reclamation. Wastewater reuse options are diverse and can be implemented at different demand levels (Vojtěchovská-Šrámková et al. 2018; Asano and Levine 2007). The concept of wastewater reuse does not only facilitate for portable and domestic water purposes, and non-portable water purposes can be unlimited when implemented accordingly. Some application practices of wastewater reuse such as agricultural irrigation of crops have been in place for many decades. The primary concern in the reinvigorated reintroduction of wastewater as a portable source concept is mainly public health, as wastewater is considered largely unsafe for human health. A clear analysis and understanding of pollutants that make wastewater unsuitable for beneficial use is, therefore, essential. To achieve water quality requirements and realise wastewater reuse potential, the implementation of valid and binding legislation that sets clear policy for wastewater reuse would be pivotal.

In recognition of this, provisions to conserve water, energy, and financial resources are being explored by municipalities and public offices. The use of wastewater to improved scarce water sources has been evaluated in a number of studies including those by Tran et al. (2016), Bluefield Research (2015), and Schwabe and Connor (2012). There are many facets of an integrated water resource management (IWRM) that would need to be addressed before strides can be made, most of which include feasibility in different settings. The more pertinent strides include and not limited to legislative, policy, and regulation hurdles within unique environments and in different systems. In semi-developed and developing countries, the focus of the wastewater environment has resonated around the design and construction, operation, maintenance, and management of wastewater systems. Though these components are very much still important, other more downstream elements of water and wastewater treatment facility's may require immediate attention if inclusive water management plans are

to be realised as a tangible water resource and asset in the near future. This research project was conducted to investigate and assess some of the prerequisites for the incorporation of strategic water management framework in the country's water environment, and to determine the elements to be considered, especially in terms of the existing water spaces.

The preferred approach to the investigation was that of evaluating the worst performing regional locations. The thought process was that a proper reconciliation effort would put into perspective the realities to consider for a successful IWRM strategic framework. It should also be recognised that there is generally a correlation between locations of water delivery underperformance and socioeconomic hardships. In the current scope of developing countries, the lower income and poorer economic groups are the most affected by environmental factors (Hanif and Gago-de-Santos 2017). In South African, the rural environment and decentralised municipalities suffer the most severely in terms of service delivery, and the challenges regarding access to safe and usable water are most predominant in these regions.

The Green Drop system is used in South Africa as a means of tracking the performance of wastewater treatment facilities (WWTFs). The Green Drop process measures and compares the results of the performance of Water Service Authorities (WSA) and their Providers, and subsequently rewards (or penalises) the municipality upon evidence of their excellence (or failures) according to the minimum standards or requirements. The Green Drop regulation programme seeks to identify and develop the core competencies required for the sector that if strengthened, will gradually and sustainably improve the level of wastewater management in South Africa. This form of incentive and risk-based regulation holds the intent to synergise with the current goodwill exhibited by municipalities and existing government support programmes to give the focus, commitment, and planning needed (DWA 2011). Ntombela et al. (2016) provide a more comprehensive analysis of the green drop system in South Africa.

Wastewater as a resource forms part of most inclusive integrated water resource management programmes (IWRMP). One of the challenges with regards to the subject of integrated water resource management (IWRM) is the different definitions that are used in different environments. Supplementary studies conducted on the concept of wastewater management capacity framework revealed that different stakeholders understood IWRM in many different ways. These findings were similar to those articulated by Agyenim and Gupta (2012) and Biswas (2004) where many integrations of the IWRM concept are used in different sectors. South Africa established a strategic frameworks towards IWRM in 1998, this was the platform established for national governance protocols, where the implementation of policies and legislation regulatory measures is set (Ballweber 2006). This study focused on the challenges of delocalised wastewater treatment facilities with regards to water resource management capacity framework in South Africa.

Materials and methods

Study location selection criteria and identification

Suitable regions were selected using informed data from Green Drop Report (GDR) and related supporting documents from the Department of Water and Sanitation (DWS) and Department of Environmental Affairs (DEA). The thought process was that a proper reconciliation effort would put into perspective the realities to consider if wastewater reuse is to be a viable alternative. It should also be recognised that there is generally a correlation

between locations of water delivery underperformance and socioeconomic hardships. In the current scope of developing countries, the lower income and poorer economic groups are the most affected by environmental factors (Hanif and Gago-de-Santos 2017). In South African, the rural environment and decentralised municipalities suffer the most severely in terms of service delivery, and the challenges regarding access to safe and usable water are most predominant in these regions. The primary goal was to acquire a complete assessment of the project objectives; moreover, the acquisition of as much information as possible with regards to the impeding factors in the delivery of adequate wastewater treatment was paramount. This information was extensively analysed and evaluated in efforts to identify the factors contributing to lack of delivery of reusable water. Thorough examination of the GDR from different evaluated cycles in the previous medium-long term showed that some of the severely impeded locations with regards to wastewater treatment and water service delivery are located in the regions with severe economic hardships.

The selection was informed by the evaluation of the Green Drop Reports (GDRs). The criteria preferred was based on comparative analysis, where:

- The worst performing regions were selected.
- The worst performing district within the region was selected.
- All treatment facilities could be accessed, with duo authorisation.

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Study locations identified

Thorough examination of the GDR from different evaluated cycles in the previous medium–long term showed that some of the severely impeded locations with regards to wastewater treatment and water service delivery are located in the region presented as blue and red in Fig. 1. For the purposes of this articles, these locations of interest will be identified as location B and location R. Location R is one of the five districts in the province. District R's settlement pattern is largely rural, with women in the majority. The district has a relatively limited supply of both ground and surface water resources. The water schemes that are currently in place are old and were intended to serve a smaller population. The vast majority of the population resides in rural areas and do not have access to potable water. Location R has the second lowest access to infrastructure amongst districts in the province. In accordance with Green Drop evaluations, location R is part of the Province producing the bulk of systems that are in critical and poor performing positions. Collectively, wastewater treatment plants (WWTPs) in location R registered amongst the worst performing facilities in the country.

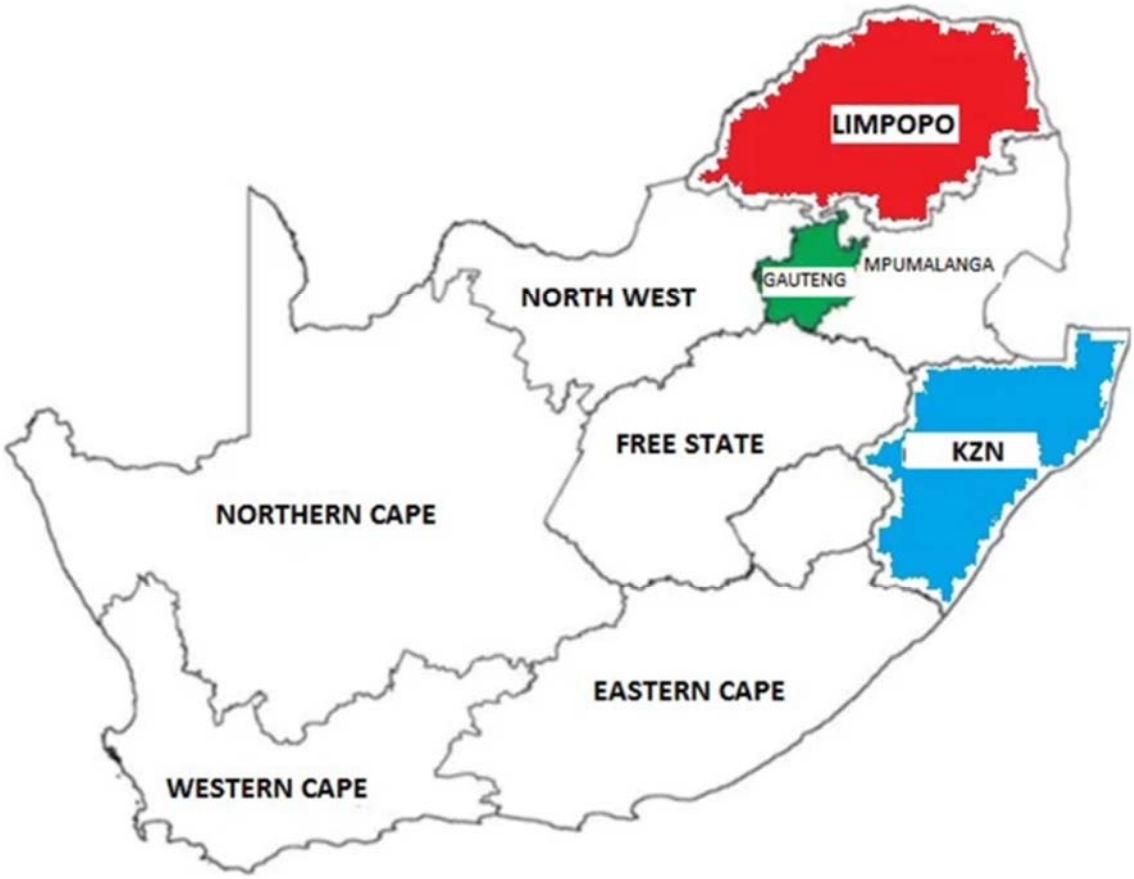

Fig. 1. Map of South Africa showing the provinces with the worst performing regions (red and blue), and the country's economic hub (green)

Location B is largely rural, with significant sanitation backlog being the major infrastructural challenges facing the region. All local municipalities in the district have been classified in the category of most vulnerable. District location B oversees the worst performing wastewater treatment facilities in Province, and most of the worst performers in the country.

Data collection

Informative questionnaires were prepared and used to acquire details of WWTP's operations and performance from the onsite technical staff and operation management. The effort was to gauge their perspectives of how they viewed the operation. The questionnaires were designed to specifically address areas around challenges faced by each WWTP's operations, capacity, and constraints. Infrastructure details and potential developments for growth opportunities were also be included in the questionnaires.

Similar questionnaires specifically aimed at acquiring information from a municipality stand-point were prepared and used in the field surveys. The directive of this information was to determine how the technical management office views WWT capacity in its entirety, the challenges faced from a delivery perspective and the requirements to achieve compliant delivery, and above board operational performance for all treatment facilities under municipal management.

The published Green Drop Reports, integrated development plan (IDP) reports, municipal technical reports, and more sources were used to evaluate the many WWTPs within the set criteria to identify the district and regions where the studies were conducted. The published GDR and various repositories from Department of Public Works (DPW) and the Department of Water and Sanitation (DWS) were used for information and details of operational performance, compliant status, areas of concern, as well of the quality of water discharged.

Data were collected from many sources within the water and wastewater environment. The targeted respondents included the following area operation:

- Water and wastewater division management (administrative).
- Facilities managers.
- Process controller.
- Operational staff.
- Human resource skill development officers.
- Technical service manager.
- Water service manager.
- Supervisors.
- General staff.
- Regional offices.

Results

Wastewater capacity framework

This study investigation pertains to how wastewater treatment can be made efficient in a South Africa context towards total resource management. In light of the study findings to be discussed, and the insights gathered from the overall evaluation of the state of wastewater treatment and delivery in delocalised regions, a working framework will be proposed. An analysis of the water and sanitation institutional delivery structure will be evaluated, informed by data acquired from field research. The main objective being to assess methods through which efficiency of delivery can be improved, leading to a functional system that is able to realise the provisions outlined in the National Water Act and Water Services Act with regards to wastewater. Available treated wastewater has the potential to impact positively to the country's growing economy, through the many roles that could be fulfilled within the different sectors of the South African economy, including recycle and reuse for households and residential areas, agriculture, industrial activities, and recreational usage. A complete analysis of an effective framework evaluated and proposed has the potential to be applicable and has relevance to some of the economic drivers in the Southern African region.

Challenges with regards to wastewater treatment

Implementation of wastewater treatment policies

One of the challenges with regards to wastewater aspects in South Africa is the implementation of wastewater treatment policies across the board. This prominent feature has been identified from many previous and present investigations, through systematic scrutiny, that were applied in efforts to fully understand the major contributing factors to the impeding challenges in the water delivery spaces in the country. Despite big strides and major improvements with regards to drinking water supply in South Africa, adequate wastewater

treatment has lagged behind. Literature analysis suggested that this situation is not unique to South Africa, there seems so be a pattern of this sort worldwide (Ardakanian et al. 2018). In attempting to understand the situation in South Africa, findings indicated that there were major issues of governance which were primarily responsible for many drawbacks in the wastewater spaces, such as lack of adequate knowledge by those in decision-making positions, and severe financial mismanagement in public delivery offices.

Though a negative situation is evident in many of the public forums, for institutions within the academic environment who are familiar with the wastewater and water intricacies, provided that they are adequately informed and have competent assessment capacities; the scarcity of water is not such a grave issue; solutions are known and available. There real challenges being faced are largely related to the non-recognition of, either (i) the sources that possess the tools to deal with the problems, or (ii) implementation of the available solutions. Both these scenarios point to governance as the main culprit. Though this view-point will naturally spark disagreeability from some public office spaces in responsible, during the investigation inquisitions, the most common reasons provided in effort to maintain deniability and transfer responsibility by higher up management responsible for delivery was the "lack of funding from higher orders of office". True, this may be at some levels of operation, but in the overall South African context, it is difficult to comprehend and correlate the relatively progressive economic reality of the country versus the atrocious state of affairs for the more desperate of the nation's citizens. The analysis of the country's situation being presented by no means suggests that simply issuing policies naturally guarantee the expected performance shifts, there have been many cases internationally where well-designed governance systems did not automatically deliver the expected outcomes; some of these are reported in the study by Birkland (2011). There, however, exist a serious concern with regards to the implementations of policy with regards to wastewater downstream applications in South Africa. Whilst South Africa boast a large number of WWTPs, a lot of these facilities are not being operated efficiently, and many have infrastructure challenges. The current national strategies do not directly speak of nor address turn-around plans, even though enormous importance is placed on the Green Drop Cumulative Risk Rating (CRR) System to manage wastewater facilities. The analytical reconciliation of the Green Drop System itself revealed that it barely achieves positive results at the fundamental operational levels. The CCR system seems to be a tool only capable of assessing and adjudicating, without tangible enforcement. Most facility operation managers interviewed in the study did not even understand how the CRR system is meant to address issues faced by WWTPs. The fundamental failure of the Green Drop system can be viewed as testament to the current underperformance with regards to environmental policy implementation in South Africa.

Skills and training in the wastewater treatment environment

Another major drawback with regards to the efficiency of wastewater treatment in the country was identified to be the severe lack of skills and training at all levels of the wastewater and water environment. Global studies have concur that promoting education and training for water technicians and professionals have been a challenge (UNESCO-UNEVOC 2012). South Africa as a growing player in the global market still puts a lot of emphasis on skilled labour directed towards the industrial sector; this somewhat indirectly undermines and to some extent renders emerging sectors neglected in this regard. Schutte (1998) wrote an article highlighting the need for high-level water and wastewater treatment operators in the South African water environment. Though there are professional and effective training institutions available designated for treatment plant operation vocations, the concern is that

these institutions are under-utilised. Other key elements that were identified as some of the challenges included staffing and available infrastructure, and these tended to be an issue across the wastewater delivery sector.

Key components that require regulation

The Constitution of South Africa assigns the responsibility for provision of water services to Local Government, whilst oversight and performance monitoring duties are delegated to Provincial and National Government. The Department of Water Affairs is responsible for the regulation of water services as dictated by Section 62 of the Water Services Act (Act 108 of 1997). Without taking much away from the outstanding acts and policies developed and adopted by South Africa, it must be admitted that somewhere in the current water framework lacks the tools to comprehensively apply these provisions to an extent where compliance is enforced without secondary strings. Currently, the discharge of treated effluent of very low quality is an operationally acceptable practice country-wide. The GDR is evidence to the reality that a significant number of the treatment plants in South Africa operate well below facility permutations. All such plants still remain in operation and continuously discharge close to toxic effluent in some places. Though it is accepted that exclusion of such treatment facilities from the overall treatment grid cannot be afforded, it must, however, still remain the priority of regulation tools to ensure that the health and safety of South Africa and all its inhabitants are of primary concern. The environmental polluting from devices that installed to curb and remove pollution should, therefore, be unacceptable.

The DWA and DWS do define components that require regulation from their set policies that are meant to address and deal with issues of conformity and compliance. At the current implementation rate of policies, as indicated earlier, South Africa is not even close to meeting these standards. There, perhaps, should be paralleling enforceable regulatory measures that are put in place to strictly deal with functional incapacity of WWTPs. These measures can police the functional integrity of infrastructural elements and their ability to perform designated wastewater designed operational functions. This policing platform of monitoring would supersede the false authority afforded to the Green Drop Cumulative Assessment Rating system without compromising its content, but adding a complementary and independent layer of regulation that is meant to primary uphold constitutional provisions whilst fundamentally protecting. The key components that should be regulated in the wastewater treatment space, even without the proposal of the above-mentioned additional platform, are briefly outlined below.

Authorisation to discharge

There should be a regulatory certification process where all wastewater treatment plants and related facilities in operation are cleared to operate within the public delivery and service space. This process should not be related or be misinterpreted for the certificate of operation that is applied for and acquired before a plant is deemed ready for operation with predetermined set parameter limits of compliance.

Authorisation to discharge would be an on-going process that would be primary aimed at detecting operational defects that would be indicators of the facilities readiness to perform the required tasks. These indicators would be focused on the physio-chemical elements of the WWTPs, assuming that the facilities had the capacity to perform the operation duties and attain compliance as required in the permits. What this process would also indirectly negate is

the design and development of new facilities that are unable to operate and perform functions as expected. The situation indicated above may be one of the reasons many facilities are failing, whilst the brunt of responsibility is shifted towards the final users.

The authorisation to discharge process would ultimately protect the product end users from systematic deviation of passively applied regulatory measures such as the CRR, whilst providing information and insight regarding the genuine state of operational health of the facilities themselves. Where deviations occur and/or the system reveals signs of less than optimal performance, an opportunity arises to intercept and deal with the issues as required before the correcting measures amount to exorbitant costs. The study findings indicated that the majority of WWTPs in the regions identified went unchecked or maintained for long periods of time. At which point the many accumulated defects amount to full-scale salvage mission projects requiring enormous funding. The authorisation to discharge competency would require certain complementary protocols to be implemented that would form part of a broader effort of monitoring.

Total monitoring protocols

Most wastewater treatment plants in South Africa operate blindly. The context of this statement is that most of these facilities have no tools with which to interact with to determine the manner of their operation. It is not quantitatively possible to determine or adjudicate operation performance of a facility without appropriate measurement tools and related indicators. It should be noted that an authorisation to discharge protocol that is backed by verifiable data would be a major regulatory and enforcement tool, whilst also an important monitoring tool.

A total monitoring protocol would make up an important pillar in the authorisation to discharge competency assessment, and only in exceptional circumstances will it not necessarily be the final limiting variable. To elaborate slightly, systematic failures that are not detected using their respective monitoring tools, or when the total monitoring process is absent altogether, resulting in the failure of water quality tests would not mean that the whole operational process is a failure. In such cases, water quality failures would function as single-point failure indicators and more importantly, they would serve as systematic alarms. Currently in the South African wastewater environment, with the exception of major mechanical failures, the only tools used to assess and inform total performance of WWTPs are the liquid fractions of effluent water at discharge points. This is clearly not an adequate tool for the assessment of the complex processes involved in wastewater treatment. A comprehensive effort of total water monitoring would include:

- Water sampling, which would encompass biological and chemical analysis. The importance of these measurements cannot be overstated and this aspect of water monitoring needs little justification. In accordance with the standards practices for water and wastewater treatment, this should be a continuous practice, if not, it becomes a limiting tool. Water should be analysed at as many process break-points as possible, such as at these following treatment process stages; inflow, post-primary clarification, post-secondary clarification, post-conventional tertiary treatment, and prior to discharge where advanced tertiary processes are present. The parameters analysed should be representative of those analysed for water treatment. Permit limits for wastewater discharge in South Africa currently require only a few parameters to be available, which do not necessary reflect the real state of toxicity.

- All malfunctions and related failures need to be logged and monitored, this is directly related to water analyses, and when coupled accordingly, the data could be an effective tool to correlate and/or pinpoint operational flaws, systematic where failures are imminent.
- All unscheduled wastewater bypass activities in the facility and within operations should be recorded, and treated attentively. Most importantly, wastewater bypassing should be avoided, even during routine maintenance unless unavoidable.

These three monitoring tools are not complex, nor do they require nuisance schedules or operational interruptions. In fact, monitoring of these tools is already part of the requirement for good operations practice in the water and wastewater environment. When combined and interpreted accordingly, a total monitoring protocol of such a simple nature would prove more effective than very costly and complicated monitoring computing systems. Closer scrutiny of the tools outlined shows that the (i) infrastructure and mechanical operational aspects (wastewater bypass) are monitored, (ii) malfunctions and related failures [design capacity and control process (skills and training) failures] are monitored, and (iii) water quality (the product) is monitored. In addition, no additional training or complex equipment is required.

All WWTP stations in South Africa are regulatory supposed to have onsite laboratory services or have quick access to these facilities. Upon a complete assessment of the simple total monitoring protocol that informs the authorisation to discharge competency process, if authorisation requirements are not met, enforcement actions that are authorised towards rectification of the failures must be applied with immediate effect without deviation or the plant operation should be suspended. It becomes the governing municipality's responsibilities (financially) to deal with all aspects identified for rectification in the treatment plants. This will essentially obligate the municipality to take action when a problem arises oppose to the current situations where the liable public offices look the other way, knowing that the administrative system is ill-equipped to deal with transgressions requiring specialised skills and knowledge. Whereas if the governance structures through the authorisation to discharge protocols lead the solution efforts by providing the required tools to deal with underperformance and non-compliance. The municipal technical and finance offices would them take the process to completion, without complacency playing a part.

Wastewater capacity framework

A wastewater capacity framework could be adopted to specifically deal with wastewater as a resource within the more comprehensive integrated water resource management programmes. The wastewater capacity framework (WCF) would be intended as a guiding document around the management of wastewater in all treatment facilities, in efforts to actively encourage the reuse and recycling of treated wastewater in the greater water and sanitation community. The Framework will attempt to provide a platform that can be used towards viable utilisation of a continuously available resource within the operations of the Department of Environmental Affairs (DEA) and the Department of Water and Sanitation (DWS) in South Africa. The central components of this framework would be the processes through which wastewater is generated, collected, and treated. Following which the final stage being a sustainable reuse scheme instead of the predominantly unchecked direct environmental discharge.

The proposed framework would be developed using inputs from a variety of sources including informed findings from research studies deliberately aimed at the evaluation of

wastewater reuse for portable water capacity improvements. This was one of the studies conducted in a parallel investigation by the research team; the activities conducted as part of the study included:

- Conversations with key figures in the public delivery administrative offices of wastewater at the identified municipalities.
- Discussions with technical department's representatives at management levels where relevant pitfalls were identified with the general state functionality from policy.
- The assessment of the WWTF at municipalities where total failures were reported, the purpose was to acquire a better understanding and ascertain the real challenges.
- Interactive interviews with WWTP operation office representatives.
- Review of the identified municipalities water and wastewater delivery practices and organisational cultures.
- The assessment of options that can be applied to the intricate realities within South Africa with regards to wastewater resource optimisation.

Though it is accepted that the South Africa delivery spaces for wastewater are primarily focused on technical aspects and related issues of improvements in water quality and operation performances. Limited attention has been given to maximising the potential use of wastewater as a resource through which economic and social benefits exits. Studies of the nature reported in this project suggest that South Africa is becoming aware of the potential of such resources. It is, however, important that the value chain mechanism put in place recognises the importance of research with regards to wastewater a potential resource. The proposed framework will be centred on aspects such as (i) legislation and related requirements, (ii) financial systems, and (iii) technical delivery.

The analysis of the framework will follow a wastewater delivery protocol, by recognising the physical pathway through which wastewater is sourced, inflow, treated, and discharged. This process allows for a logical flow plan that is better able to capture the framework capacity. It has been reported in literature that the emphasis on different phases of this pathway depends on the level of development in the regions. As regions become more developed, they concentrate on factors further down the pathway. This is an expected development phase process; very few regions would be expected to behave differently. South African as a whole, its regions, and regions within it regions depict similar formations.

Legislation and policy-related requirements

Policy and related components would be required to support, facilitate, and drive the implementation of the framework. In recognition of the current passive enforcement tools in implementing policy, legislative requirement would need to be aligned accordingly to enable actionable enforcement. At the core of this function would be the public offices (municipalities), who would require positive derivers.

Municipalities' relevant departments would be tasked with the responsibility of conducting and facilitating all activities relating to the delivery and implementation of the WCF. This would include the initiating and follow-through of all processes regarding and related to compliance, and the updating of legislations with regards to Acts such as the Municipal Systems Act. This, of course, would require the municipality to be familiar with WCF to competently achieve these mandates.

The National Water Act and the Water Services Act would also be affected by the WCF, most importantly would be the legal provisions required for implementation of the framework, with key emphasis on the enforcement tools. The aim of this proposal is not to dwell on the inner working of such initiative, but rather on the principal aspects.

Components that would be required to develop an effective framework for wastewater resource management as a whole would need to consider the socioeconomic facets. The potential impacts factors to the regional economic systems as well as the social environment of operation. Some of the components identified are:

- The physical systems:
    - Wastewater collection infrastructure
    - Wastewater treatment infrastructure
    - Wastewater reclamation infrastructure and upgrading in facilities
    - Sources of wastewater and sewage pipes
- Performance:
    - Monitoring tools
    - Effluent water quality
    - Wastewater treatment technology and processes.
    - Assessment criteria
    - Data facilities
- Social factors:
    - Attitudes of water handlers
    - Attitudes of end users
    - General water and wastewater awareness
- Technical factors:
    - Training and education for administrative and management skills
    - Education and training to develop competent plant operators and process controllers
    - Consulting and advanced solutions
    - Research
- Economic
    - Municipal budgets
    - Water charges
    - Subsidies
    - Business environment
- Existing frameworks
    - Existing water and wastewater legislation and policy
    - Water-related organisational and institutional structures.

Listed above are some of the many components, of which some are delicate and have intrinsic functionality within the scope of water and wastewater. There still exist the potential for conflicts of interest between and within the many stakeholders, some which may be pertinent are:

1. Disharmony in policy implementation between the policy enforcers and authorities involved in planning, water supply and the environment, and inadequate community consultation on the issue (PMSEIC 2003).

2. Lack of trust in the technology by stakeholders, in opposition to using reclaimed water.

3. Social factors, wastewater as a water resource does not automatically warrant the acceptability of wastewater recycling.

4. The business environment has been reported to have had the greatest concern when wastewater reuse was the subject. Some of the reasons are maintenance of markets, and continued access of commodities at set prices price.

Legislative and policy-related requirement for this type of framework is paramount. All stakeholder involvement through consultative platforms would need to be encouraged, but central to the WCF would be an active process that would drive the implementation of all and related policies.

Financial systems

Potable water is classified as a rival good, this means that once appropriated by a household, it is not unavailable for another. For this simple factor, it can, therefore, be priced like a private rival good. Wastewater is mostly generated as a by-product of the potable water service, and generates substantial external costs. Most municipalities and water service providers (WSP) internalise the wastewater external cost into user's decision-making, to incorporate wastewater cost into the potable water service tariffs. Water-related tariffs that are charged to average households are exorbitant for many South Africans in the lower end of the income spectrum. The selling point is simple; efficient reuse of wastewater can substantially reduce the cost of water service systems and in-turn benefit the end users.

Many municipalities in the country are facing challenges related to cost recovery related to the provision of water and sanitation service. Costs recovered from the provision of water services through wastewater recycling tools can be redirected to improve the status of the existing infrastructure in terms of operation and maintenance and/or even replacing the old/non-functional infrastructure.

There are very few sources of funding for infrastructural development for struggling municipalities within the South African context. An efficient WCF would generate a regenerative stream of funding that could be focused on all phases of wastewater treatment and water reclamation. Following which surplus financial resource could be used to develop facilities incorporating advanced technologies.

Technical systems

An effective WCF would require knowledge of the entire wastewater treatment cycle. This would include:

- The theoretical understanding of operational processes that are involved
- The mechanical works
- Operational process and control
- The implications of system failures or compromises to effluent quality
- Recovery and relevant corrective measures required
- Preventative protocols.

Figure 2 shows the four phases of wastewater flow. The different pathway phases would require isolated and overplaying technical skills and knowledge. Each phase of delivery has

unique features that may require different skills sets. Intricacies of the different phases are briefly discussed below.

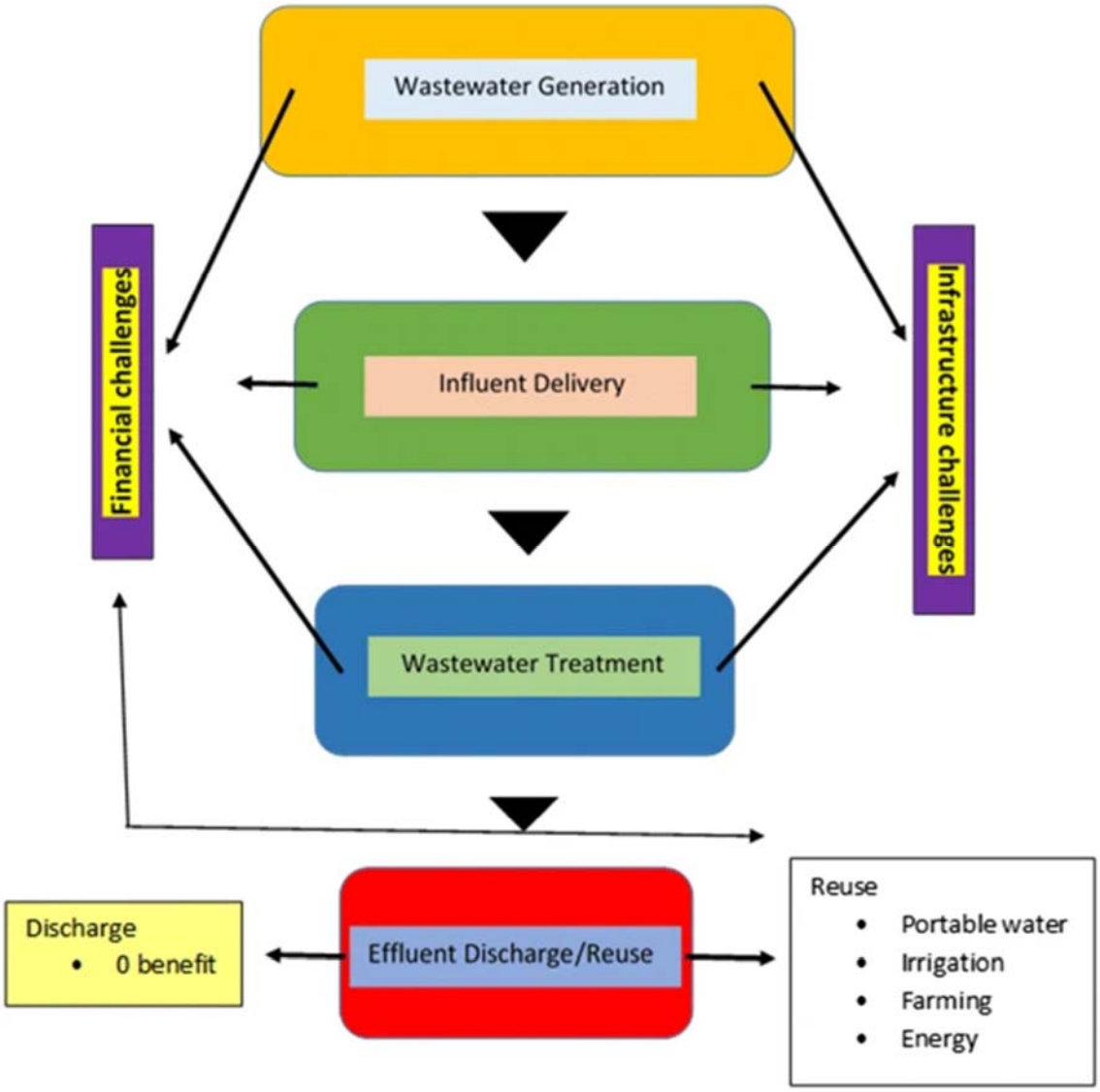

Fig. 2. Wastewater flow pathway representing the stages of the cycle

Wastewater generation and wastewater delivery

Van Vuuren and van Djik (2011) published a report directly dealing with the components of these two phases. The report specifically deals with the waterborne sanitation, operations, and maintenance guide when dealing with wastewater delivery protocols. This document comprises of section sections dealing with:

- Types of maintenance
- Equipment required for maintenance
- Maintenance requirements and frequency
- Operational requirements
- Safety measures and practices

- Inspection forms and checklist

This report considered many aspects of the skills and training required for successful implementation of the phases of wastewater collection and delivery. Such information should form the basis of training tools that are aimed at empowering the delivery of the WCF and related capacities.

Wastewater treatment

There are many training platforms that deal with applicable knowledge towards efficient handling of wastewater facilities. Most of these are aimed at the proficiency of plant operation. The South African Qualifications Authority (SAQA) endorses training and skills development such as the National Certificate: Water and Wastewater Process Control. Acquisition of this qualification is the most popular amongst those with qualifications directed at competency in operational processes at WWTPs. It has been observed and documented, including in this study that there were very qualified WWTF onsite staff at many of the locations investigated. The other concerning issue is that the skills levels boasted by the qualification towards WWTF and WTF offered in the type of qualifications mentioned above do not embroil the knowledge required to effectively deal with the type of challenges faced with the current state of affairs of the wastewater treatment environment in South Africa. To deal with the kind of WWTP challenges reported in this study and others, some form of theoretical background is required. Unfortunately, there are not very many public institutions that possess the teaching tools of this nature, those that are available are in private spaces, which the municipal and public delivery structures do not generally opt for. The wastewater and water treatment fraternities within South African and the relevant stakeholders should be encouraged to utilise advanced training and skills development programmes.

Wastewater reclamation and reuse

Wastewater reclamation and reuse is a relatively young endeavour in South Africa. An integrated wastewater management plan would need to be developed that would primarily view wastewater as an independent resource towards the overall conservation and protection of water in the local natural environment. The main data required for the planning of a wastewater management would include the analysis of tangibles, such as:

- The quantity of wastewater produced in the region
- The utilisation of water in the region
- The existing treatment facilities
- The treatment requirements for discharge
- The available and/or required treatment technologies

The other aspects requiring attention would fall within the typical water resources frameworks presented in reports such as the Drinking Water Quality Framework for South Africa published in 2005. SALGA (2008) also published a framework for water conservation and demand management, outlining the assessment of some of the areas requiring focus. All other considerations barring the wastewater reclamation technology would fall within the bigger water resource scope, and many literature studies and reports have been published addressing this subject. The technology requirements for successful management of the WCF

have been published in other platforms parallel to this study. With the backing of legislation and proper implementations of policy, only the end user concerns remain.

The evaluation of public acceptance of a wastewater reclamation and reuse application would not be a simple task. South Africa is a big country, and collectively, it has a diverse and complicated cultural organisational structure. A study was conducted in China by Chen et al. (2015), where, based on the participatory research method, the attitudes of stakeholders involved in reclaimed water reuse in Beijing was investigated. The findings showed that the general public's knowledge on water resources was poor, while their awareness on reclaimed water reuse was high. The general public showed a strong acceptance of non-contact and non-potable reclaimed water reuse, but their acceptance of the reclaimed water for domestic use was very low. The beneficial use of reclaimed water was admired by the knowledgeable and informed stakeholders, who strongly supported the advancement of reclaimed water reuse, while the general public were not as convinced. The study also found that the stakeholders' perception of reclaimed water was influenced by their social-economic attributes. The findings in this study may not be too different from what would be expected in a South Africa context.

Conclusion

A framework that would enable the functional capacity of the wastewater reuse initiative was argued for, and relevant factors that would drive this processes were discussed with regards mainly to the lack of implementation of policy as observed from field data. The alignment of wastewater resource planning as part of the greater water resource planning development were identified as crucial. Issues around some of the important factors requiring attention for workable wastewater framework were evaluated and discussed. Some of the more pertinent challenges were reviewed within a South African context, by taking into account some of the more fundamental challenges faced by the water and wastewater space in terms of public service and delivery.

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