“Insights and challenges of efficient water service provision and management”

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Insights and challenges of efficient water service provision and management

Abstract

There is a growing need to understand how the scarce water resources could be conserved and efficiently provided to the local societies. This paper examines the non-revenue water management practices in the local municipality and its impact on water service provision. The results of the study indicated that the municipality does not have sufficient capability to monitor and manage water provision and usage. Almost half of the respondents thought that the municipality does not take non-revenue water management seriously. The results suggest that the local water service provider operations and approaches to non-revenue water management is a real threat to the local government and society. The municipality needs to be proactively involved in the efforts to adapt to practices and mitigation strategies to reduce non-revenue water.

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Introduction

Although water is increasingly becoming a very scarce resource, massive inefficiencies still exist in many water service provision systems. The World Bank estimates that in developing countries, water leakage is about 45 million cubic meters per day (m3/day) (Kingdom et al., 2006). Also, roughly 30 million m3 of water per day is not paid for (Wyatt, 2010). South Africa is reported to have 37% of Non-Revenue Water (NRW), which is well within the global average of 36.6% (Mckenzie et al., 2012). However, this global average is largely dominated by countries that are not water strained. Countries with scarce water resources such as Australia have 10% of NRW (Mckenzie et al., 2012). In addition, the authors highlighted that there is high usage of water per capita in SA, which is approximately 273 litres per person per day. Moreover, South Africa is one of the developing countries with scarce water resources and there is a need for research to which facilitate in water service provision and management.

Reducing NRW is a global challenge that prompted IWA to come up with technical interventions in order to try and reduce NRW (Frauendorfer & Liemberger, 2010). The NRW water management methods are chosen based on the characteristics of the water scheme. The methods that were adopted by IWA, which are used to calculate and distinguish commercial losses from physical losses, have also played a major role in guiding the industry regarding measuring and monitoring water losses and authorised consumption as stipulated in the IWA best practice standard water balance (Farley & Liemberger, 2004; Ranhill & USAID, 2008). All these methods form part of the NRW management strategy which should be adopted by municipalities and water boards. The strategy also suggests that there should be leakage management policies in place to monitor and address water losses (Frauendorfer & Liemberger, 2010; Ranhill & USAID, 2008). Leakage management programs should be implemented in the distribution network as part of the effort to reduce NRW.

Water is an essential natural resources that is indispensable for human beings, economic development and biological diversity (Walter et al., 2011). Mistakes in the proper management and sanitation of the water sources can cause serious water losses and health problems to the society. It is therefore essential that water provision and usage should be managed efficiently in all water supply utilities. Therefore, the purpose of this article is to get an understanding of the water provision services and the challenges of reducing NRW. As such, a survey was conducted in KwaZulu-Natal (KZN) a province of South Africa[1]. The following section focuses on the theoretical aspects of the study. The review discusses previous literature on the strategies to improve NRW management.

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[1] The township wishes to remain anonymous, as explained in the methodology section of this paper.

1. Literature review

Managing and creating awareness of the NRW is a mammoth task. Unlike in the developed countries, there were no standard procedure and terminology for NRW for most developing countries (Frauendorfer & Liemberger, 2010). This was up until the national associations adopted an International Water Association (IWA) standards and terminology (Frauendorfer & Liemberger, 2010).

1.1. Strategy to reduce NRW. Real losses (physical losses) and apparent losses (commercial or administrative losses) have synergetic negative impacts on the overall performance of the Water Service Provider (WSP) (Ranhill & USAID, 2008). While real losses cause increase of the operating costs and larger investments, the commercial losses reduce the utility revenues. Ranhill and USAID (2008) have illustrated this in their vicious and virtuous circles, as depicted in Figure 1 below.

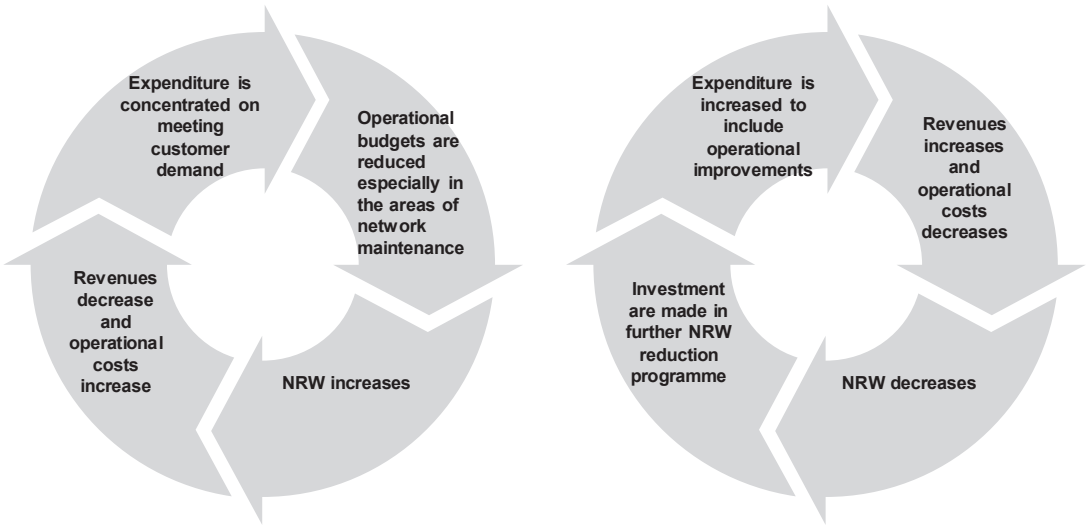

Fig. 1. NRW circle

Source: adapted from Ranhill and USAID (2008).

The vicious circle shows that increasing NRW level would lead to more production cost and simultaneously, less revenues, while this in turn causes increased spending of the current budget to meet high demand on the cost of maintenance of the system (Ranhill & USAID, 2008). Improper maintenance causes NRW to increase and so forth; this remains a challenge for the WSP, whose main purpose is to transform the vicious circle to the virtuous one (Ranhill & USAID, 2008).

Research by the United State Agency for International Development (2013) has shown that USAID is planning to tackle global water challenges in close cooperation with non-governmental and civil society organizations that assume the critical frontline obligation of developing and executing water programs. This would involve forming a working relationship between advocacy groups that carry both knowledge and passion.

1.2. Water balance: How much water is being lost? The IWA, through its task force, has developed a standard method to be used throughout the world to do a water balance, and this answers the first question, which is: "how much water is being lost", as shown in Fig. 2 (Farley & Liemberger, 2004). The development of a water balance is naturally based on a rough appreciation of the apparent losses and a direct evaluation of real losses by measuring the minimum night flows (the top-down approach and the bottom up approach). This method normally produces good results if the information required is available to measure the minimum night flow (Vermersch & Rizzo, 2008).

Ranhill and USAID (2008) describe NRW as the total amount of water flowing into the water supply scheme from a water treatment works (the 'System Input Volume'), minus the total amount of water that industrial and domestic consumers are authorized to use (the 'Authorized Consumption').

NRW = System Input Volume – Billed Authorized Consumption

This equation assumes that:

- System Input Volume has been corrected for any known errors.
- The billed metered consumption period for customer billing records are consistent with the System Input Volume period (Ranhill & USAID, 2008).

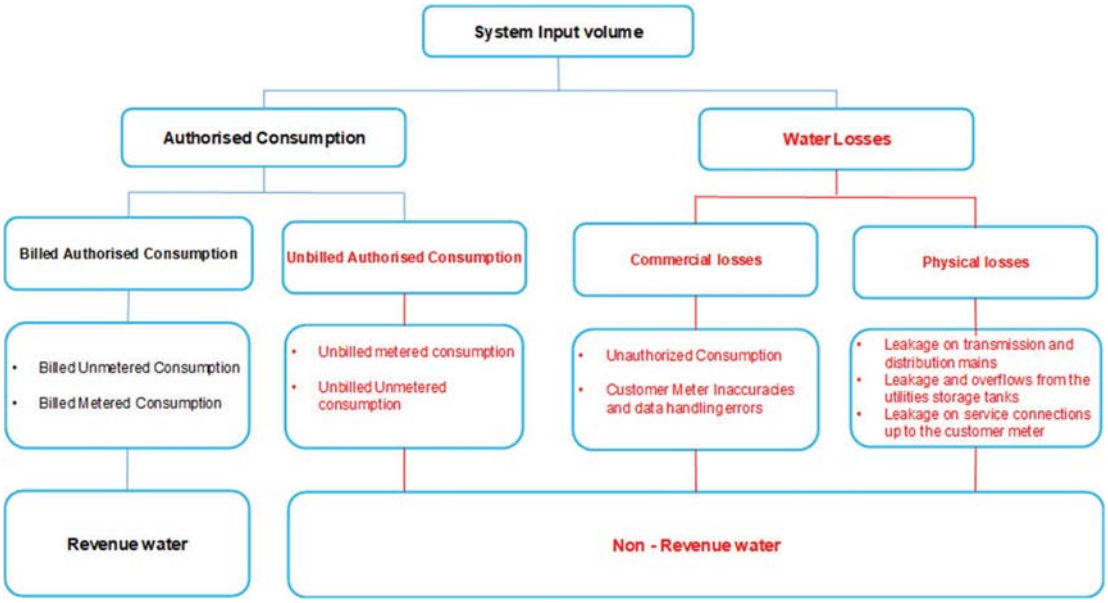

Fig. 2. The IWA best practice standard water balance

Source: adapted from USAID (2013).

Water Service Authority (WSA) or technical managers should use the above water balance format to calculate each component and to determine where water losses are occurring from (Ranhill & USAID, 2008). The task of managing NRW starts at the outlet meter at the water treatment works to a customer meter; it is therefore the task of everyone within the operations and maintenance team. They would be required to make necessary changes to the policies and implement those changes (Ranhill & USAID, 2008).

1.3. NRW assessment methods. It should be noted that the NRW assessment methods that are proposed in any given scenario are not always applicable, and in some cases, the accuracy of the apportionment of loss is very questionable (Vermersch & Rizzo, 2008).

1.3.1. Top-down approach. This method provides a good basis for analysis, but it requires that the data be refined regularly and water audits to be done continuously (Pickard et al., 2008). Below are the main steps that are taken when performing the top-down audit (Charalambous & Hamilton, 2011):

- Determining the volume of water put into the distribution network.
- Obtaining authorized consumption (billed + unbilled) from records.
- Calculating water loss (water loss=system input – authorised consumption).
- Estimating apparent losses (theft + meter error + billing errors and adjustments).
- Calculating real losses (real loss = water loss – apparent loss).

This audit relies more on the information that is readily available from the records of the municipality.

1.3.2. Bottom up approach. This procedure is used when the water authorities have confirmed that the data that were used in the top-down portion includes every aspect of the utility's operation: billing records, distribution system and accounting principles (Puust et al., 2010). The main purpose of this audit is to assess the efficiency of water distribution system and the interventions required to achieve the targeted results. The most accurate and up-to-date data are required in order to achieve reasonable results (Puust et al., 2010).

Puust et al. (2010), in their review paper, argue that the bottom-up real loss assessment can be done in two different ways: (a) 24 Hour Zone Measurement (HZM) or (b) Minimum Night Flow (MNF) analysis. HZM require District Metered Areas (DMA) to be zoned in a distribution system from one or two inflow points only, and then those areas with a 24-h inflow measurements should always be logged along with pressure measurements (Puust et al., 2010). The DMA needs to be properly done because this method also relies on it, mostly when calculating the minimum night flows (Charalambous & Hamilton, 2011).

To sum up, the NRW is a global challenge that prompted IWA to come up with technical

interventions in order to try and reduce NRW. The NRW water management methods are chosen based on the characteristics of the water scheme. The methods that were adopted by IWA, which are used to calculate and distinguish commercial losses from physical losses, have also played a major role in guiding the industry regarding measuring and monitoring water losses and authorized consumption as stipulated in the IWA best practice standard water balance. All these methods form part of the NRW management strategy that should be adopted by municipalities and water boards. The strategy also suggests that there should be leakage management policies in place to monitor and address water losses. Leakage management programs are implemented in the distribution network as part of the effort to reduce NRW. The following section discusses the methodology that was used to collect data for analysis.

2. Study area

The uMgungundlovu District Municipality (uMDM), one of the eleven municipalities in KwaZulu-Natal, as provided in Figure 3. According to the Note 21 of the audited financial statement, the municipality incurred water losses of up to 567 486 kilolitres of water valued at R1.8 Million during the 2008–2009 financial years (Auditor General, 2009). The Auditor General's (2009) report further states that the uMDM is consuming high volumes of unaccounted water, which also creates a negative impact on the municipality, in terms of obtaining a clean audit.

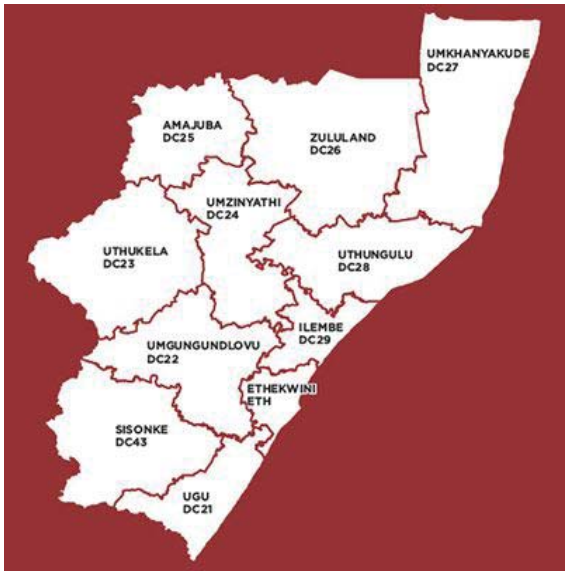

Fig. 3. KwaZulu-Natal map

Source: adapted from Google Maps (2015).

Furthermore, according to the Department of Water Affairs (DWA) design standards, some local townships such should be consuming 25 litres of water per person per day. However, the approximate current consumption rate is 46.32 litres of water per person per day. As such, the consumption rate is far higher than what the system was designed to produce (Department of Water Affairs, 2012; uMgungundlovu District Municipality, 2010). This provides evidence that the human factor plays a critical role in the reduction of water loss and NRW. The following section discusses the methodology that was used to collect data for analysis.

3. Data collection and methodology

The survey was conducted in one of the 11 district municipalities of KwaZulu-Natal, a province of South Africa. The municipality and township were randomly selected. However, the respondents were purposively selected. NRW can be regarded as a specialized field, therefore participants in the study were carefully selected to include employees who were familiar with the environment of water service provision. The participants were municipality employees who sometimes interact with customers in one way or another, and as such these are employees were fully informed about the customer relationship within the municipality.

Municipal employees engaged in water related activities were carefully selected from the five departments of the district municipal: technical finance, community, corporate and the office of the municipal manager. Managers and supervisors from the technical and finance department, as well as the civil engineer, plumbers and process controllers from water and sanitation division also took part in the study. The study was conducted in one of the UMDM townships, as well as at the head office that is from the water treatment works up to the consumer outlets with a total number of 133 employees.

A questionnaire comprising 53 questions was used as the research instrument. The scales were adopted from previous studies and modified to fit the context (AL-Washali et al., 2011; Klooster & Visser, 2008; Western Australian General Practice Network, 2008). A 5-point Likert scale was used. The questionnaire was divided into 4 sections which measured various themes. Section A was mainly on the demographics of the participants, section B was on water management, section C was on finance factors affecting NRW management, while section D was on social questions.

In order to do pretesting and validation of the questionnaire, the questionnaire was distributed to four budget officers from the finance department and senior technicians from the technical department. Concerns raised by these parties were considered prior to finalising the questionnaire for distribution to the participants. The Chronbach's alpha coefficient was found to be 0.892, which is greater than the recommended value of 0.700. This implies that the research instrument was reliable.

The population size was made up of 133 participants. Although, a census approach was adopted the researchers only managed to distribute 115 questionnaires to the participants at their work places. Collecting the data was not an easy process for several reasons including difficulties of locating the participants who do multitasks and long waiting periods due to data not readily available. The questionnaires were distributed in person. The distribution approach was preferred to other methods because clarification on some of the questions were done on the spot, before the questionnaire collection. Furthermore, some of the study respondents had limited access to computers and emails. Of the distributed questionnaires, 110 questionnaires were collected and usable, giving a response rate of 96%.

The data obtained from the respondents were analyzed using Excel Spreadsheet. The results were presented as descriptive statistics through the use of graphs, charts, histogram, pie charts and tables, which were used to present the data that were analyzed in different forms.

4. Results

4.1. Respondent characteristics. The demographics of the 110 participants took into consideration the race, age, gender and the level of qualification of the respondents. All the participants were employees of municipalities. The majority of the respondents were African (89.1%). The other slice of a pie chart was shared by Indians (5.5%), coloured (3.6%) and whites (1.8%). The information offered some insights into the composition of the participants relative to gender, age, level of qualification, as well as occupation of the respondents.

The composition of the participants in terms of gender and age is shown in the Table 1. The ratio of males to females is approximately 8:2 (80%:20%). Within the age category of 35 to 44 years, 75.0% were male. Within the category of males (only), 30.7% were between the ages of 35 to 44 years. This category of males between the ages of 35 to 44 years formed 24.5% of the total sample.

Table 1. Gender distribution by age

Age limits (years)		Gender		Total	Percentages
		Male	Female		
Age group	18 – 34	26	10	36	32.73%
	35 – 44	27	9	36	32.73%
	45 – 54	19	3	22	20.00%
	55 – 65	16	0	16	14.54%
	Above 65	0	0	0	0%
Total		88	22	110	100%

Within the age category of 18 to 34 years, 27.8% were females. Within the category of females (only), 45.5% were between the ages of 18 to 34 years. This category of females between the ages of 18 to 34 years formed 9.1% of the total sample.

Approximately 71% of the respondents had no more than a school qualification. Approximately 29.2 are in possession of a post matric qualification. Also, 11% of the respondents had a degree qualification. As the level of education increases, the number of qualified respondents decreases, from 37.3% to 5.5%.

4.2. NRW assessment methods and management policies. To identify the current NRW assessment methods and management policies adopted by uMgungundlovu District Municipality, respondents were asked to reflect on the current water management practices. As shown in Figure 2, 86.36% of the respondents reported that water loss can be calculated. There are lots of technical issues when dealing with NRW management, which involves mostly technical services employees. The trend in the results is that employees agreed that water balancing can be done. However, when it comes to the components building up to a proper water balancing system, they are rating every item below 50%. Even the most important items like "All consumers are metered", it was rated at 21.1%, and "There is technical capacity to monitor water usage" was rated at 36.7%.

The respondents (42.99%) reported that water meters were not working properly, while 47.6% disagreed that there was monitoring equipment used by the municipality to monitor water. What was even more alarming was that 50.46% of respondents did not think that the municipality takes NRW management seriously. Only 43.93% of respondents agreed that the infrastructure was in good working condition, meaning that the monitoring of water usage was not done properly.

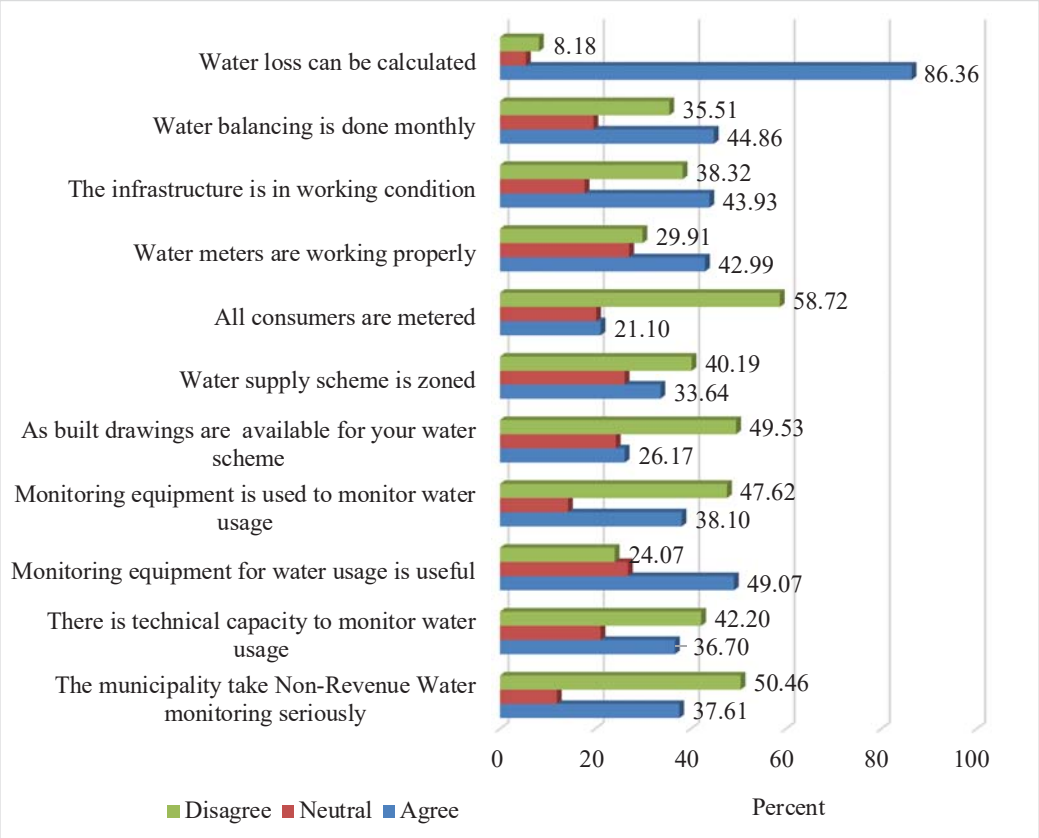

Fig. 4. Respondents views on NRW assessment methods and management policies

However, it is important to note that the municipality has policies in place, in pursuit of creating sound water management practices. Figure 5 illustrates the effectiveness of these policies and activities, which may be improved and adopted as municipal policies.

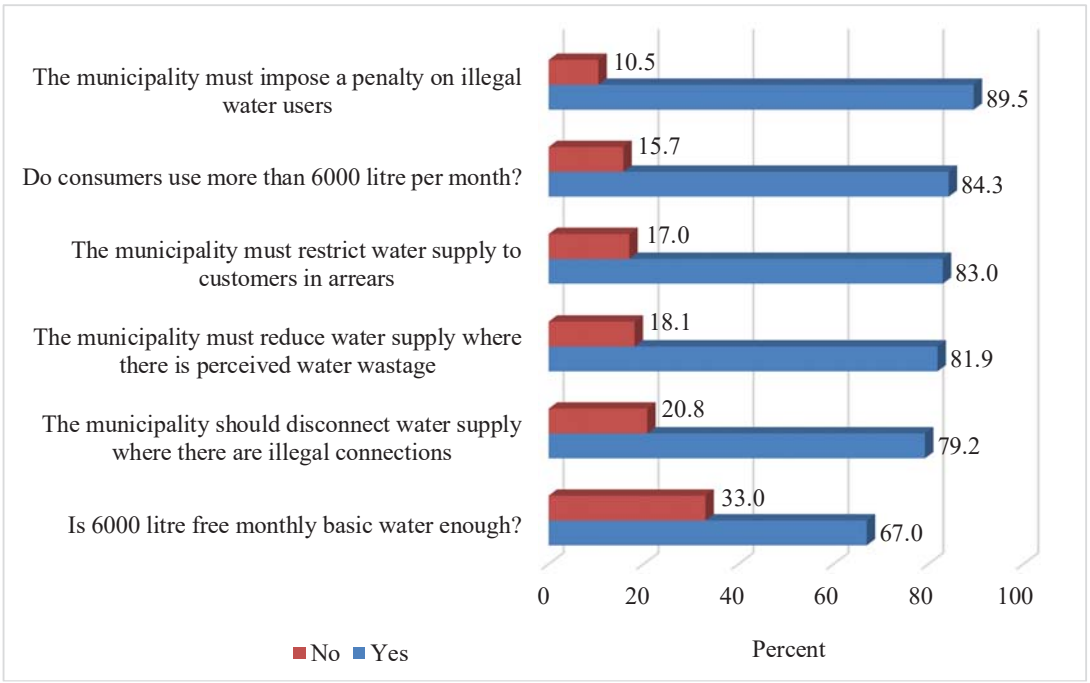

Fig. 5. Respondents' views on the effectiveness of the NRW municipal policies

The pattern observed in Figure 5 shows that the respondents generally agreed on the implementation of policies in an attempt to monitor the use of water and which endeavour to curb water losses. The result shows that 89.5% of the respondents agreed that the municipality must impose penalties on illegal water users. Also, 84.3% of the respondents agreed that consumers were using more than free basic 6000 litres of water and 67% of the respondents thought that the 6000 litres was not enough.

4.3. NRW is a major concern. For a system to be regarded as proactive, it should have all the requirements (i.e. relevant equipment, human resources and skills) in place. When asked to reflect on NRW management practices within the concerned township, about 64.2% of the respondents indicated that the Township water scheme was not generating sufficient revenue for the municipality. Presumably, reasons for the lack of revenue are reflected by the high number of respondents (68.5%) who reported that meter readings for the township were not reliable. Even though 50.9% reported that meter readings were done monthly, it is immaterial, since about 81.8% of the respondents do not know the number of consumers in the township. Generally, the respondents were not satisfied with water meter related issues.

These findings are surprising considering that water meter readings are a fundamental tool used to monitor and manage NRW. Having reliable data is one of the basics in monitoring NRW. There is little attention to monitoring NRW in the water service provision.

The respondents' level of awareness of municipal commitment to water conservation is illustrated in Table 2. However, the results of the analysis show that consumers did not seem to monitor their monthly water consumption, while on the other hand, the municipality does not seem to be effectively doing enough in informing the consumers on how to save water. Both these items were scored lower than the rest. Illegal water usage and connections is another area of concern in water provision.

Table 2. Water conservation

Item	Agree	Neutral	Disagree
Water is a scarce resource	79.82	8.26	11.93
Water usage is high amongst residents	77.57	10.28	12.15
Consumers monitor their monthly consumption	20.37	31.48	48.15
The municipality informs consumers on how to save water	30.91	19.09	50.00
If consumers are taught, they apply what they were taught by the municipality	37.61	26.61	35.78
Community awareness campaigns are effective	48.62	17.43	33.94

The respondents (50.46%) indicated that there is a high level of illegal use, as compared to those who felt it was low (49.54%). The majority of the respondents (66.3%) identified community members as being responsible for engaging in the illegal connections.

Figure 6 provides results on the main causes of illegal connections. The results show that there was water that was not accounted for, from the water distribution system that is affecting apparent losses. The three highly rated reasons for the misuse of water: "the belief that water should be free of charge" at 41.8%, "connection fee" at 39.1%, and "water charges" at 36.4%. The two lowest ranked items at 17.3% are "complicated application process for new house connections" and "consumers not being aware of the application process". This means that very few illegal connections are a result of the application processes.

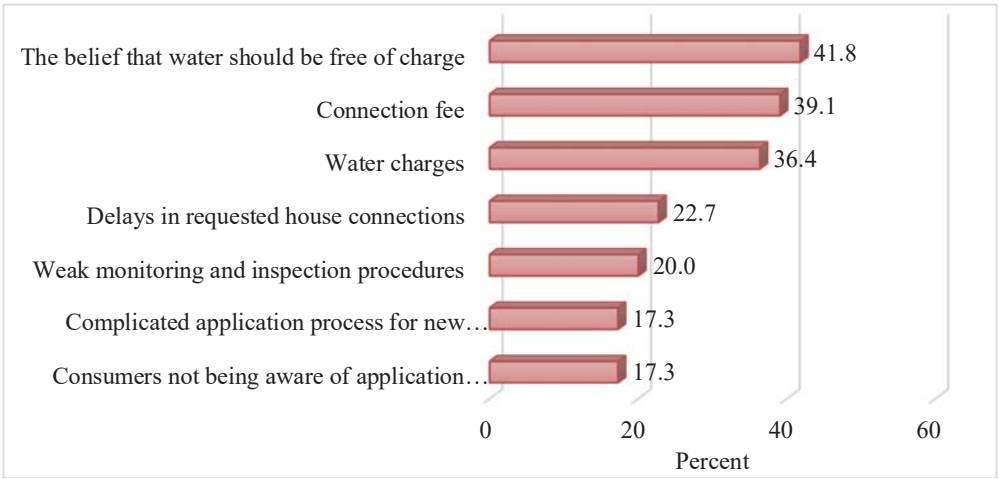

Fig. 6. Cause of illegal connections

About 20% of the respondents believed that illegal connections were a result of "weak monitoring and inspection procedures', while 22.7% believed that it was because of the "delays in requested house connections". The reasons why the first three items got high percentages might be that at the township, it is an existing supply with very few requests for new connections and these are more focused on the payment and charges of water services.

4.4. Water supply losses. The results presented in this section provide a picture of the current status of the apparent water losses in the township. The majority of the respondents (67.65%) indicated that the municipality must focus on real losses in order to reduce NRW. In addition, the results presented in Figure 7 show that 79. 82% of the respondents believed that "water is a scarce resource", while 77.57% of the respondents believed that "water usage is high amongst residents". The low rated percentage of consumer awareness campaigns (33.94%) and 35.78% on "if consumers are taught, they will apply what they were taught by the municipality" seem to be the causes for high water usage amongst residents. This also means that the municipality did not adequately inform consumers on how to save water, hence, the 50% on "the municipality informs consumers on how to save water", which results in the unbilled authorized consumption being high.

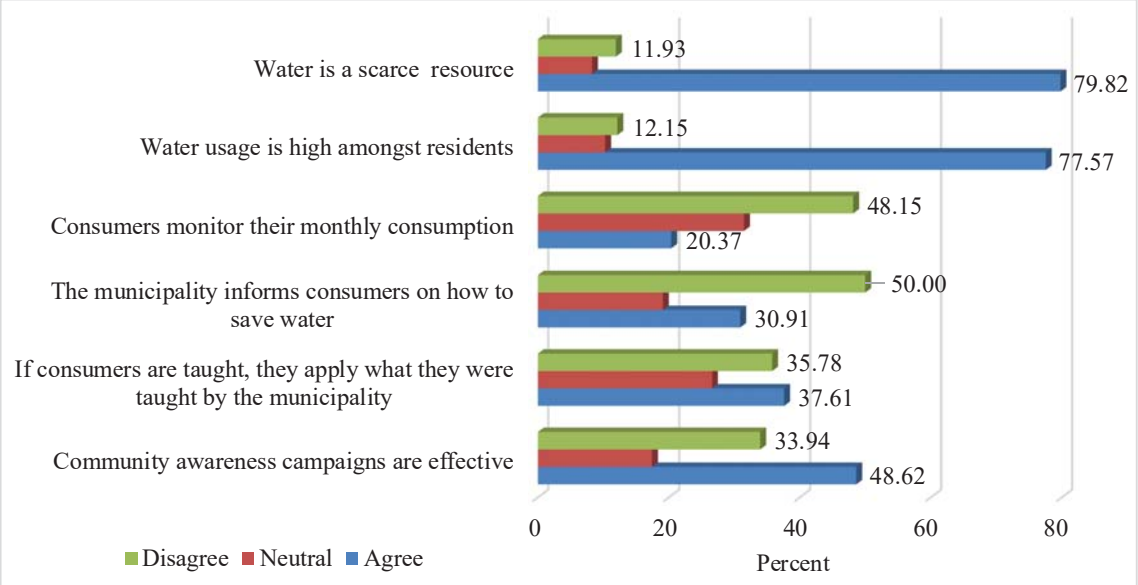

Fig. 7. Perception towards water usage

Discussion and conclusion

The results of the current article highlight some vital attributes relevant to managing water provision. First, the fact that the participants indicated that there were no assessment and consequently, in the water utility shows that the NRW management system is inefficient. This is precarious when it comes to specifically aligning the strategic goals and the implementation of the operational goals of water utility. Assessment methods and policies are vital in dealing with the elements of NRW.

Second, the results of the study indicated that employees of the various departments of the Municipality were aware of the NRW importance. However, they were not adequately aware of the existence of the current NRW assessment methods and performance indicators, a situation that might discredit the value of the NRW management system in place. Lack of awareness of the assessment methods and policies is therefore a hindrance to effective NRW management in the utility system. Zaier (2010, pp. 27-28) argued that human factor and organizations play a major role in the NRW reduction. Zaier (2010) further explains the consequences of these deficiencies; they translate externally into customers being unsatisfied by the quality of services, together with an absence of motivation and interest in the work for the internal customers. As a result, human resources have to work through various control levers to ensure that there is a strong will of membership of the staff actions of progress.

Third, among other things, the results also indicates that the main causes of illegal water use in the water distribution system lie within six main reasons. The reasons include the belief that water should be free of charge, water charges, connection fee, delays in

requested house connections, weak monitoring and inspection procedures, consumers not being aware of the application process, complicated application process for new house connections. The results are in line with Rabe et. al. (2012) who revealed that the City of Tshwane Metropolitan Municipality (CTMM) takes NRW management seriously, to the extent of metering all their own buildings and parks, as they believe that these areas might be a source of high water loss if they are not properly monitored.

Furthermore, the analysis also unveiled other noteworthy trends related to effective NRW monitoring. There is little attention to assessing water losses. The municipality was not proactive in managing NRW in the township; it is rather a more of a reaction organization that only acts on what has been reported by the community, community representative and municipal employees. Although the water utility has made many attempts to reduce real losses and pressure management, they were all encountered with many difficulties.

Implications

The results of the current article highlight some vital attributes that is essential for the municipality. The management should be aware of non-existence of data for calculating water loss; the unavailability of equipment to monitor and measure NRW; the level of service provided by municipal employees to the communities; the perceived quality of work done by municipal employees; the deteriorating conditions of water infrastructure, among other factors. Participants highlighted that the utility should focus on real losses. For example, households should be metered and meter readings should be done monthly and where there are discrepancies, to be verified and rectified timely. Bulk meters should be installed and read daily in all inlets and outlets of bulk pipeline. The abovementioned factors are essential in reducing NRW and in implementing a permanent system that is essential for water and sanitation provision. Based on the findings of the study, it is recommended that:

- The municipality should source the equipment for monitoring and measuring NRW. Policies should be promulgated, adopted and implemented fully and consistently, while all employees engaged with reducing NRW related tasks should be trained in NRW management, regardless of the department they come from and the position they occupy.
- The municipality should adopt and implement an active leak detection system. Therefore, the distribution system should be zoned properly, while pressure management equipment and methods should be used in the distribution system.
- It is also recommended that infrastructure be repaired regularly and managed properly and where operations and maintenance section has done repairs or replacement of fittings and parts within the system, they should keep records of all work done in the distribution system. GIS, operations and maintenance and asset register should also be updated regularly and be interlinked.

Limitations and areas for further studies

The present study focused on NRW management. The study also established that NRW management is not only about calculations that require technical knowledge, but it also requires the reliable infrastructure and participation of other stakeholders such as community members; community leaders; senior management of the municipality; political leadership of the municipality and citizens to be involved and trained on the impact of NRW management. In future studies, it could be necessary to determine the level of awareness of NRW among different stakeholders. In addition, future studies could investigate the conditions of the existing infrastructure for the water distribution system in the concerned municipality.

To sum up, the results showed that NRW management is an indispensable facet of water utility management, which also impacts positively on both the water service provision to the citizens and the organizations. Importantly, the findings of the study reinforce our perspectives regarding the essence of sustainability and efficient provision of scarce water resource. Essentially, the study has shown the significance of NRW assessment, monitoring and management to ensure efficient delivery of safe and clean water for all.

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