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# Components of Non-Revenue Water; Its Management as a Tool for Sustainable Water Resources: A Case Study of Doka District, Kaduna North LGA

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## Abstract

Non-revenue water (NRW) is the difference between net water inputs in the distribution system and billed authorized consumption. Water resources are under stress due to growing population and climate change making a shift towards the implementation of non-revenue water reduction strategies in most countries worldwide (Kanakoudis and Muhammetoglu, 2014). It is expected that by 2030, 47 % of the world population will live in regions with severe water stress (González-gómez, García-rubio and Guardiola, 2015). The increase in water demand coupled with Non-Revenue Water (NRW) is causing a challenge in meeting water demands for all competing uses of water; hence the need to assess the management of non-revenue water in Doka district of Kaduna North LGA. In assessing the existing situation and the management strategies to minimize non-revenue water in Doka district questionnaires and Key Informant Interviews (KII) were administered using purposive sampling. Results shows that plumbing materials to fix bursts and leakages which contributes highly to NRW is inadequate to the tune of about 70%. There should be a proactive programme of constantly reviewing the basis for estimation of bills for customers who are currently not metered to improve the accuracy of these estimates while efforts should be made to complete the metering of all customers;

**Keywords***: Assessment, Management Strategies, Non-Revenue Water, Kaduna State Water Corporation (KADSWAC) and water Demand*

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**Background to the Study**

Water loss which is a major component of non-revenue water and has been one of the major challenges in water utility management all over the world and it is even more challenging and serious in developing countries; Nigeria inclusive. (Adeosun, 2014). In most developing countries, first the needed resource for the development of infrastructure for the provision of adequate good quality water for continues supply to consumers are lacking. This is aggravated by the fact that there is lack of capacity and poor decaying infrastructure to deal with water loss in most water utilities which further reduces the availability of adequate good quality water to consumers (Thornton, 2002).

Non-revenue water is defined as the difference between net water inputs in the distribution system and billed authorized consumption. According to studies carried out by Al-omari (2013), NRW was estimated at 15 % of the system input volume in developed countries while for developing countries it was about 35 %. Globally, the total damage cost to water utilities caused by NRW was conservatively estimated at US$141 billion per year, with a third of it occurring in the developed world (Kingdom, Liemberger, and Marin, 2006). (Kanakoudis, Tsitsifli and Demetriou, 2015) stated that globally, one-third of the total water volume abstracted from the water resources and used as drinking water is lost in the distribution networks due to pipe leaks and bursts.

According to Kanakoudis *et al.* (2015), about 30 x 106$m^3$/day of water globally delivered to the customer is not invoiced due to water theft, corruption by the employees and lack of metering. Most developing countries face challenges in the management of the non-revenue water because of lack of good NRW management strategies (Mathur and Vijay, 2013). Water supply in most of the African cities is unsatisfactory due to high water losses and inefficiencies in the management system (Sharma and Vairavamoorthy, 2015). High NRW increases the operation and maintenance costs and low revenue collection affect the financial viability of water utilities in Africa (Dighade, Kadu, and Pande, 2015)

Historically, the attitude of man towards water is perceived as though it is a free natural resource and subsequently the way and manner water resources were managed did not make things better but rather contributed to the limitation of freshwater resource available to man. According to Thornton (2002), water was seen in the past as an infinite commodity and this led to the ignorance of issues like water loss in the management of water utilities in most countries. Whilst water, and for that matter freshwater resource is free natural resource to man, its availability to man at any particular point in time, place and space is limited hence, the necessity for what is called water resources management (Baumann, Boland and Hanemann, 1997). There is also the issue of natural disasters as flooding, droughts and climate change which again may have serious negative consequences on freshwater resources. These occurrences further reduce the availability of freshwater resource to man. Humans may have little or no control over some of these occurrences that affect freshwater resources, especially climatic change. (IPCC, 2014).

**Global perspective of Non-Revenue Water**

According to Adachi, Takahashi, Kurisu, and Tadokoro (2014), leakage from water distribution networks has been drawing the attention of water supply industries worldwide. This is mainly because leakage causes economical loss, contamination risk, and excessive environmental load in terms of water resources and operational energy consumption (Adachi, *et al*. 2014). Xu, Chen and Ma. (2014) stated that about 1.2 billion people, or almost one-fifth of the world's population, live in areas of physical water scarcity and at the same time, water use has been increasing at more than twice the rate of population growth in the last century. Based on the global water and sanitation assessment carried out by WHO and UNICEF in 2000, on average in the large cities in North America, the NRW was estimated at 15% while in Africa, Asia, Latin America and the Caribbean it was at 39%, 42%, 42% and 42% respectively as shown in Figure 1.1 (WHO, 2001). Additionally, estimates NRW in most of urban distribution systems in developing world range from 40% to 60% (Baietti, Kingdom, and Van Ginneken, 2006). Vander (2003) stated that the normal percentages for non-revenue water in the system are from 15% to 25%, including 5% 'losses' in the treatment plants. SIDA (2000) reported that non-revenue water in the range of 15% to 20% of the produced quantity is often a realistic and sustainable level for developing countries. The NRW for Southern Africa Development Community (SADC) ranges from 11% to 61% as reported by Mugabi and Castro (2009).Most utilities in Africa normally report a crude figure of NRW hence there is no proper reduction strategies planned for NRW (Kingdom *et al.* 2006). According to Ferley and Trow (2010) globally non-revenue water (NRW) is still a challenge but the problem is more severe in developing countries. This is because of lack of quantification and partitioning of non-revenue water into various components due to unavailability of data. It was observed by Sharma (2008) that the NRW level in developed countries is much lower than the developing and underdeveloped countries, such as, 7% in Germany and 90% in Nigeria.

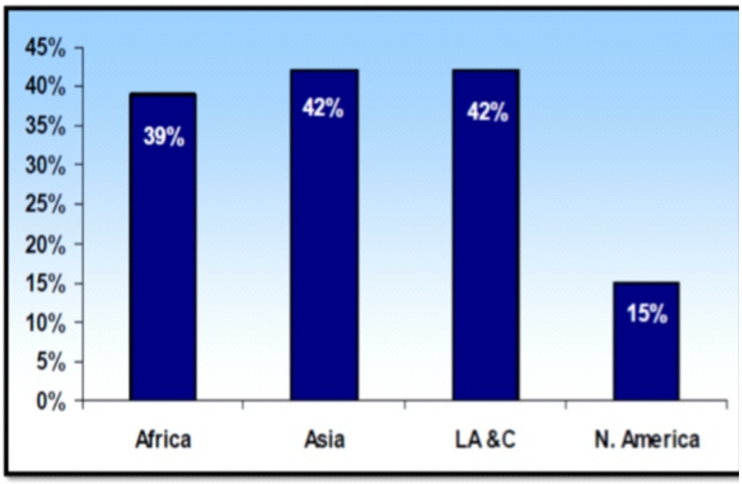


**Figure 1:** Estimation of Non-Revenue Water on a Global Scale
**Source:** Sharma, S, 2008

This could be attributed to the difference in the managerial and holistic approaches that have been used in ensuring that NRW is kept at minimum. Moreover, the use of technology and resources, coupled with strong political will and citizen participation in management, has led to lower NRW levels and better revenue accruals in developed countries (Figure 2).

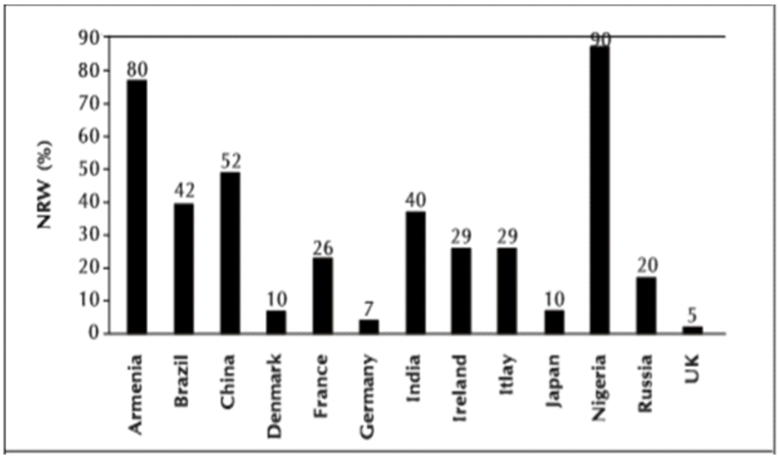


**Figure 2:** Average NRW Levels amongst Various Nations in the World
**Source:** Kingdom *et al,* 2006

Despite the Nigerian federal government's annual cash injection of US$ 550 million in the water sector, reliable access to water of acceptable quality remains scarce in Nigeria Federal Project Implementation Unit (FPIU), Nigeria, September (2014).. In 2004, half of Nigerians living in urban areas lacked piped water access, and for those who had it, water taps flowed only a few hours a day (World Bank 2014). Rapid annual urban population growth of 5.7% (Urban Water Reform, 2011) has made it more difficult for Nigeria's State Water Agencies (SWAs) frontline service providers in the water sector to meet the existing need for piped water and expand production capacity.

Nigeria's water sector has underperformed compared to smaller countries in West Africa. Niger and Burkina Faso, for example, have with fewer resources undergone major institutional reforms and made significant progress in the urban water sector (IBNET 2015). In both Niger and Burkina Faso, overall water coverage stands at 72%. Utilities are able to cover operating costs at a ratio of 1.22 in Niger and 2.07 in Burkina Faso, surpassing the ratio of 0.80 for Nigeria (Figures 3) which are indicators for operating cost coverage ratio.

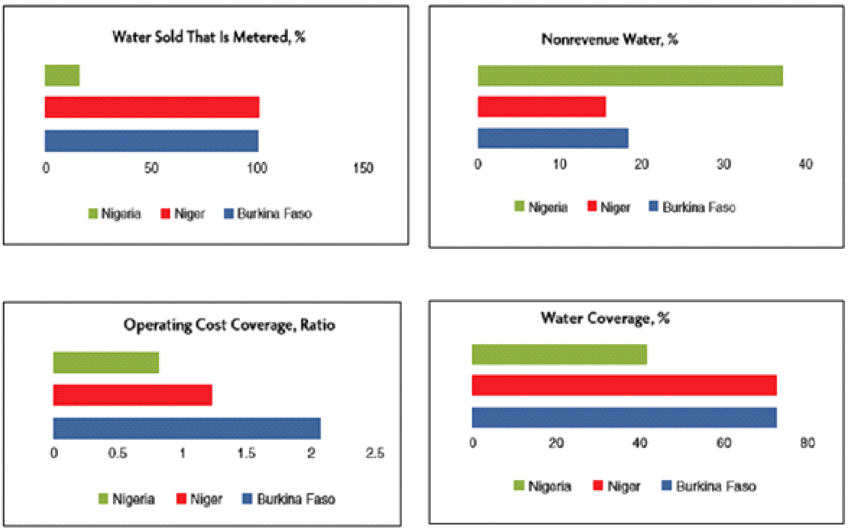


**Figure 3:** Water Sector Comparison in West Africa
**Source**: IBNET 2015.

In order to come to better understanding and set the framework for in-depth research into the current topic, it is necessary to find out the various components of NRW and their definitions as they relate to the topic. Various literatures were consulted however, the one which seemed to have dealt with the issue of non-revenue water to a greater extent in recent times and to which most writers and researchers kept referring to was the document which has been developed by the International Water Association (IWA) Water Loss Task Forces for concepts and methodologies for quantifying and definitions of the components of non-revenue water.

According to the International Water Association (IWA) Task Force on Water Loss, (IWA, 2003), Non-Revenue Water (NRW), is "the difference between System Input Volume and Billed Authorised Consumption". According to the task force, system input is "the annual input to a defined part of the water supply system" while billed authorised consumption, is "billed metered consumption including water exported and billed unmetered consumption". These definitions and others are shown in Figure 4.

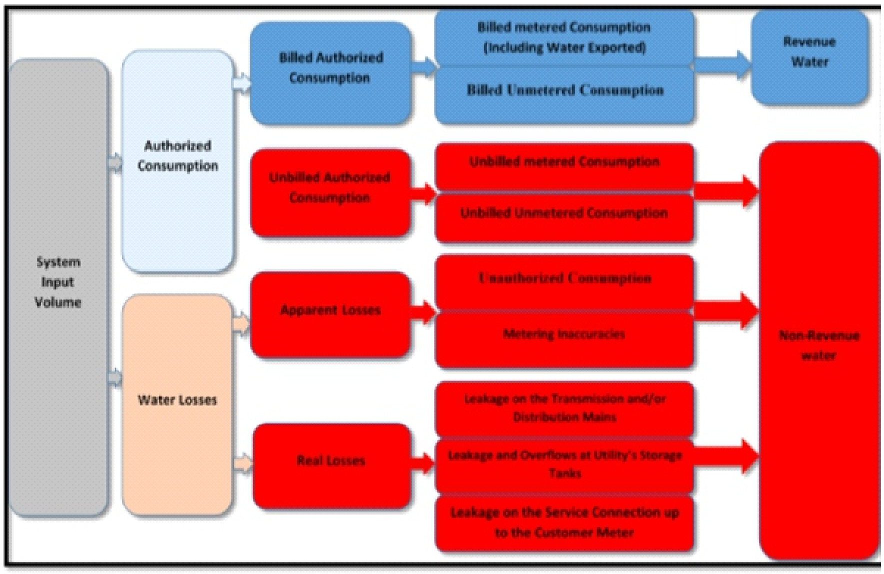


**Figure 4:** Computation of non-revenue water
**Source:** Adopted from Liemberger, 2010

Until the early 1990s, there were no reliable and standardized methods for accounting for water losses. Leakage management performance was measured in terms of "unaccounted-for water." Since this term had no generally accepted definition, there was wide room for interpretation. Unaccounted-for water was typically expressed as a percentage of system input, which is already problematic. Given this situation, utility performance could not be measured or compared, realistic targets could not be defined, and performance against targets could not be tracked reliably. While this situation still exists in many countries, significant progress has been made to address these past shortcomings. Over the last 20 years, a number of organizations from around the world have developed a suite of tools and methodologies to help utilities, evaluate and manage water losses in an effective manner.

One recommendation of the WLTF (Water Loss Task Force) was to use the term "non-revenue water" instead of "unaccounted-for water." NRW (non-revenue water) has a precise and simple definition. It is the difference between the volume of water put into a water distribution system and the volume that is billed to customers.

NRW can be defined as the water supplied by the water utility to the consumers but not billed which can be estimated by subtracting the volume of the billed authorized consumption from the system input volume ((Ferley, Wyeth, Ghazali, Istandar and Singh, 2008). According to Xin,Tao,Lu and Xiong. (2014), NRW includes physical and commercial losses.

**Physical Losses**

Physical losses (Real losses) are losses which occur as a result of storage overflow, pipe bursts and leaks (Ferley *et al.,* 2008). According to Kingdom *et al*. (2006), around 90 % of water that is physically lost from leaks cannot be seen on the surface but in the long run the leaks might eventually become visible after many years, but until then, large volumes of water could have been lost each and every day. Sometimes, undetected leaks can be quite large, such as those that run directly into a sewer or a drain channel (Ferley*et al.,* 2008). Kanakoudis and Muhammetoglu (2014) stated that a water utility that does not practice a policy of efficient and intensive active leakage control will always have a high level of leakages, except if the infrastructure is new or is in excellent condition.

According to Kingdom *et al.* (2006), the three main components of physical losses include;

i. Leakage from transmission and distribution mains,
ii. leakage and overflows from the utility's reservoirs and storage tanks as well as,
iii. Leakage on service connections up to the customer's meter.

Kingdom *et al.* (2006) stated that leakages from transmission and distribution mains are the major physical losses which normally occurs in most of distribution networks. Leakages and overflows from reservoirs and storage tanks are easily quantified but most of the overflow normally occur at night hence the monitoring system should be put in place to avoid such occurrences. In addition to the above, age and pipe material are parameters that influence leakage magnitudes in most of the cases (Motiee, McBean and Motiei, 2007). This comes as a result of a combination of corrosion of pipes and high water pressures which increase breakages, and result in more leakage.

**Apparent Losses**

Apparent losses, also known as commercial losses are losses which occur due to metering errors, water theft and billing anomalies (Kingdom *et al.* 2006). Souza and Costa (2014) indicated that apparent losses include losses which are as a result of measurement errors (flow meters), illegal connections and unaccounted for uses like irrigation, street washing, and firefighting. According to Dighade*et al.* (2015), apparent losses are caused by under-registration of customer meters, inaccurate meters, meter not working, vandalized meters, bypassed meters, bribery and corruption of meter readers. Ferley and Liemberger (2004) started that apparent losses are due to lack of proper customer metering policy and education, and regulatory and legislative policies.

**Metering Errors**

Metering errors are apparent losses which can easily be introduced through negligence, aging meters, or even corruption during the process of reading the meters and billing customers (Ferley et al., 2008). According to Ferley *et al*. (2008), incompetent or inexperienced meter readers may read the meter incorrectly or make simple errors, such as placing a decimal in the wrong place if the meter reading is done manually without the use of a data logger.

**Unauthorized Consumption**: According to Liemberger (2010), illegal connections, meter tampering, meter bypasses, meter reader corruption and illegal hydrant use are some of the major unauthorized consumption which contributes to high NRW. According to Thornton (2002) unauthorized consumption is a label for water that is taken against the policies of the water utility.

**Unbilled Authorized Consumption:** includes water used by the utility for operational purposes, water used for firefighting, and water provided for free to certain consumer groups. The determination of various components which make up the total NRW is a critical aspect in the management of the NRW.

Although it is widely acknowledged that NRW levels in developing countries are often high, actual figures are elusive. Most water utilities do not have adequate monitoring systems for assessing water losses, and many countries lack national reporting systems that collect and consolidate information on water utility performance. The result is that data on NRW is usually not readily available. Even when data is available, it is not always reliable, as some poorly performing utilities are known to practice "window dressing" in an attempt to conceal the extent of their own inefficiency.

**Assessment of the Management Strategies to Minimize Non-Revenue Water in Doka District**

The management strategies to reduce non-revenue water in Doka district of Kaduna North LGA as obtained from the questionnaire and responses from Key Informant Interviews (KII) took into consideration the following parameters (Table 1.1):

1. How often the KADSWAC staff are sponsored to attain workshops to improve their skills in their areas of specializations and learn new techniques.
2. The availability of plumbing materials to fix leakages;
3. The frequency of reports on bursts / leakages;
4. The various causes of leakages/ bursts and actions taken on reported bursts (how soon)?
5. The consumers with meters, Consumers with error free meters; and the payment of water bills.

**Table 1:** Assessing the Management Strategies to Deal with Non-Revenue Water

| Sponsorship of staff for workshop/retraining | Frequency | Percentage |
|---|---|---|
| Quarterly | 3 | 6 |
| Twice | 5 | 10 |
| Once | 22 | 44 |
| Never | 20 | 40 |
| **Total** | **50** | **100** |
| **Timely provision of plumbing materials** | | |
| Inadequate | 38 | 76 |
| Adequate | 9 | 18 |
| Surplus | 3 | 6 |
| **Total** | **50** | **100** |
| **Timely collection of reports On bursts/leakages** | | |
| Daily | 21 | 42 |
| Weekly | 18 | 36 |
| Fortnightly | 7 | 14 |
| Monthly | 4 | 8 |
| **Total** | **50** | **100** |
| **Timely repair of bursts/leakages** | | |
| 1-2days | 11 | 22 |
| 3-5days | 29 | 58 |
| 6-8days | 8 | 16 |
| Above 8days | 2 | 4 |
| **Total** | **50** | **100** |
| **Timely identification of causes of bursts** | | |
| High pressure | 5 | 10 |
| Vandalism | 14 | 28 |
| Aging infrastructure | 25 | 50 |
| Poor workmanship | 6 | 12 |
| **Total** | **50** | **100** |
| **Adequate metering of customers** | | |
| 0-25% | 9 | 18 |
| 26-50% | 18 | 46 |
| 51-75% | 23 | 36 |
| 76-100% | - | - |
| **Total** | **50** | **100** |
| **Error free meters** | | |
| 0-25% | 15 | 30 |
| 26-50% | 31 | 62 |
| 51-75% | 4 | 8 |
| 76-100% | - | - |
| **Total** | **50** | **100** |
| **Payment of water bills** | | |
| 0-25% | 6 | 12 |
| 26-50% | 34 | 68 |
| 51-75% | 10 | 20 |
| 76-100% | - | - |
| **Total** | **50** | **100** |

**Source**: Author's Fieldwork (2018)

According to KADSWAC on how often the staff attend workshops, trainings, seminars and conferences in their areas of specialization, as it relates to NRW which is a priority theme and performance area to the water utility showed that 44% of the respondents attended workshops once in a year while 40% of them never attended workshops in a year (Table 1.1). This is not unconnected to underfunding and logistics involved to facilitate such trainings as obtained from the responses of the KII conducted alongside the bureaucracy in causing delay in fund approval. However, its implication would be that capacity building for the staff would be lacking as technology is advancing in NRW management.

The surveys conducted on the availability of plumbing materials to fix bursts/ leakages which is a major contributor to the real losses component of NRW revealed that the materials were inadequate to the tune of 76%, while its adequacy amounted to 18% and a mere surplus by 6% (Table 1.1). The inadequacy of plumbing materials will go a long way in mitigating against reduction of NRW. This is in conformity with the observation made by Kingdom, *et al* (2006) where it was established that poor operations and maintenance and lack of active leakage control contributes immensely to real losses.

As can be seen in Table 1.1, the frequency of reports on bursts/ leakages has it as 42% daily on reported cases, 36% on a weekly basis, and 8% monthly. This high percentage for daily reports may not be unconnected to inadequacy of plumbing materials to carry out a thorough maintenance, as obtained from the KII conducted, hence increase in NRW. This is in conformity with the findings of Kuan (2010), where he established that Every Drop Counts Learning from Good Practices in Eight Asian Cities.

The responses obtained on how long bursts/leakages are fixed out shows that within 3 - 5 days is 58%, within 1 - 2days is 22%, for 6 - 8days is 16% while above 8days is 4%. The variations in the durations were associated with the time the emergency and distribution team of KADSWAC got the notification alongside with availability of plumbing materials for maintenance. This is in conformity with the observation of Balkaran and Wyke (2003), who stated that managing water loss: fixing of leakages is strategic in Reduction and Control of Non-Revenue Water.

Subsequently, the data attributed to the causes of the bursts/leakages as 10% was due to high pressure, 28% to vandalism, 50% to aging infrastructure and 12% to poor workmanship. Most of the pipes within the study area are asbestos and were laid decades ago (1939), hence the aging infrastructure having the highest percentage. This is in conformity with the opinion of Baird, (2013) where he opined that a game plan for aging water infrastructure is key to optimizing revenue. It was revealed that all burst asbestos pipes were being replaced with ductile iron pipes within the study area as a means to reduce NRW by KADSWAC.

On the other hand, assessment of KADSWAC customers with water meter revealed that 26 - 50% of their customers has the highest portion being 46% which is less than half the total customers, while no one was recorded for 76 - 100%. This is far below the standard. This will also add up to the NRW of KADSWAC, which is in conformity with Mutikanga, Natongo, Wozei, Saroj, Sharma and Vairavamoorthy (2013) where it was evaluated that generation of revenue for any water utility is a function of proper metering to consumer lines.

On the accuracy or error free meters 26 - 50% of their meters were error free to the tune of 62% while 0 - 25% were error free in the tune of 30%. This indicates that even having the meter does not guarantee a genuine revenue generation as its error will affect the readings on consumption and consequently the billing there on. This is in conformity with the result of Arregui, Cabrera, Cobacho and Garcia. (2006) where it was established that meter inaccuracies adds up to the apparent loss component of NRW.

Finally, the percentages of consumers who pay up their water bills as at when due indicated that 26 - 50% of KADSWAC' customers had the highest percentage compliance of 68% Table 1. This is to show that if the number of customers with meters is stepped up, more revenue would be generated, this is in conformity with the observation of Criminisi, Fontanazza, Freni and Loggia (2009) where it was stated that water meter under registration is a contributor to apparent loss in water supply. The KII interview conducted revealed that most new buildings that need to be connected to KADSWAC must install a water meter.

**Conclusion**

The outcome indicates that the present situation in Doka District cannot be rated good. It was confirmed that the present strategies being implemented by the management to reduce NRW levels in the system are one- sided in that most activities are majorly to check commercial losses, in particular bursts/leakages with less emphasis on other equally important activities that need to be adopted in any water utility for a better performance of the system. Projects such as distribution system expansion, improved water quality and upgraded level of service are all important for optimum service delivery. As an analogy, if most customers of KADSWAC in Doka District are experiencing better servicesat affordable prices, more revenue would have been generated. It should be remembered that water is life, and people will ordinarily do everything to get water for their survival whether it provided to them or not.

**Recommendations**

I. A comprehensive launch to the management of NRW, in conformity with the findings of Liemberger (2010) should be chosen, with all assumptions to be based on careful scientific analysis of the situation and not mere estimations.

ii. The present situation where it is only assumed that the major contributor of NRW is from physical losses can be deceitful. The outcomes of such assessment and measurement will allow for the sources and quantity of water losses within the utility system. These assessment and measurements can be carried out using bulk meters at the treatment plant and booster stations, pressures valves and gate valves. According to Thornton (2002), it is advisable to start with those components that will produce the fastest and great proceeds so as to make the scheme viable.

iii. Emoluments for productive work done as well as disciplinary actions for wrong doings should be stated out for all staff members and this should be well known to staff members especially the meter readers and other field staff,

iv. There should be a practical programme of regularly evaluating the bases for estimation of bills for customers who are presently not metered to optimize the accuracy of these estimates while efforts should be stepped up to connect all customers to meters.

v. Management should take up on educational programmes to create awareness to the populace about the NRW situation in the water system and the modalities being adopted to reduce it. This should be done with the view to solicit the support and cooperation of the general public by educating them of the consequences of high NRW levels to the supply of water to the inhabitants rather than only spelling out punishments that would be meted out to those who engage in activities that lead to NRW increase in the system.

**References**


Adachi, S., Takahashi, S., Kurisu, H. & Tadokoro, H. (2014). Estimating area leakage in water networks based on hydraulic model and asset information, *Procedia Engineering*, 89 (1) 278-285

Adeosun, O. O. (2014). *Water distribution system challenges and solutions in Nigeria*, https://www.wateronline.com/doc/water-distribution-system challenges-and-solutions-0001, Accessed 16th April, 2018

Al-omari, A. (2013). A methodology for the breakdown of NRW into real and administrative losses, *Water Resources Management*, 27 (1) 1913-1930

Arregui, F., Cabrera, E., Cobacho, R. & Garcia, J. (2006). Reducing apparent losses caused by meters inaccuracies, Water practical technology, 1 (4) doi: 10.2166/wpt.2006093

Baietti, A., Kingdom, W. & Van Ginneken, M. (2006). Characteristics of well performing public water utilities, World Bank Water Supply & Sanitation Working, (Note 9). worldbank.org/INTWSS/Resources/Workingnote9.pdf (Accessed 04/04/2018)

Baird, G. M. (2013). A game plan for aging water infrastructure, *American Water Works Association Journal,* 102 (4) 74-82

Balkaran, C. & Wyke, G. (2003). *Managing water loss: Strategies for the assessment, reduction and control of non-revenue water in Trinidad and Tobago*, proceeding on the 8th Annual Water Distribution System Analysis Symposium, Chicago, USA, 1-8

Baumann, D. D., Boland, W. J. & Hanemann, M. (1997). *Urban water demand management and planning,* McGraw-Hill Professional, New York, USA

Criminisi, A., Fontanazza, C. M., Freni, G. & La Loggia, G. (2009). Evaluation of the apparent losses caused by water meter under-registration in intermittent water supply, *Water Science Technology, 60* (9) 2373-2382

Dighade, R. R., Kadu, M. & Pande, A. M., (2015). Non-Revenue water reduction Strategy in urban water supply system in India, *International Journal of Research in Engineering and Applied Science,* 3 (1) 186-199

Ferley, M. & Trow, S. (2010). *Non-revenue water: International best practice for assessment, monitoring and control*, IDS Water, March

Ferley, M., & Liemberger, R. (2004). *Developing a non-revenue water reduction strategy: Planning and implementing the strategy* 41-50. ws.iwaponline.com/content/ppiwawstws/5/1/41.full.pdf (Accessed 01/02/2015)

Ferley, M., Wyeth, G., Ghazali, Z., Istandar, A. & Singh, S. (2008). The manager's non-revenue water handbook, A guide to understanding water losses, Ranhill Utilities Berhad and the United States Agency for International Development(USAID), Malaysia,p110.https://warrington.ufl.edu/centers/purc/docs/resources_NRWManagersHandbook. Pdf (Accessed 17/05/2018)

González-gómez, F., García-rubio, M. A. & Guardiola, J. (2015). Why is non-revenue water so high in so many cities? *International Journal of Water Resources Development*, 27 (02) 345- 360

Intergovernmental Panel on Climate Change (IPCC) (2014). Fresh water resources in climate change; Impacts adaptation and vulnerability

International Benchmarking Network for Water and Sanitation Utilities (IBNET). (2015). *Standard Country Report*, February

International Water Association (IWA), (2003). *Assessing non-revenue water and its components; a practical approach,* http://www.iwapublishing.com/pdf/WaterLoss-Aug.pdf Accessed 3rd Apri1 2008

Kanakoudis, V. & Muhammetoglu, H. (2014). Urban water pipe networks management towards non-revenue water reduction: Two case studies from Greece and Turkey, *Clean Soil and Air Water Journal*, *47*(7) 880-892

Kanakoudis, V., Tsitsifli, S., & Demetriou, G. (2015). Applying an integrated methodology towards non- revenue water reduction: The case of Nicosia, Cyprus, *Desalination and Water Treatment, 57*(25) 114-129

Kingdom, B., Liemberger, R. & Marin, P. (2006). *The challenge of reducing non-revenue water (NRW) in developing countries, discussion paper series*, No. 8, World Bank

Kuan, L. (2010). *Every drop counts learning from good practices in Eight Asian cities*, Yew School of Public Policy, Asian Development Bank and Institute of Water Policy

Liemberger. R. (2010). Recommendations for initial non-revenue water assessment, International Water Association 1-13, www.miya-water.com (Accessed 21/05/2018)

Mathur, Y. P. & Vijay, A. (2013). Non-revenue water reduction- A tool for achieving 24x7 water supply, *IOSR Journal of Mechanical and Civil Engineering, 7*(3) 25-38

Motiee, H., McBean, E., & Motiei, A. (2007). Estimating physical unaccounted for water (UFW) in distribution networks using simulation models and GIS, *Urban Water Journal*, *4*(1) 43-52

Mugabi, J. & Castro, V. (2009). *Water operation partnership- Africa utility performance assessment report, the World Bank, Nairobi, Kenya*, www.wsp.org/UserFiles/file/WOP_Report.pdf (Accessed 23/04/2018)

Mutikanga, H., Natongo, O., Wozei, E., Saroj, K., Sharma, S. K. & Vairavamoorthy, K. (2013). *Investigating the impact of utility sub-metering on revenue water in Kampala city*, Institute of water Engineering Netherlands

Sharma, S. (2008). *Performance indicators of water losses in distribution system*, Delft, The Nether lands UNESCO-IHC, www.switchurbanwater.eu/.../pdfs/GEN_PRS_PI_of_Water_Losses_AC_Apr08.pdf. (Accessd 23/04/2011)

Sharma, S. & Vairavamoorthy, K. (2015). Water loss management in developing countries: Challenges and prospects, *Journal American Water Works Association*, 101 (12): 57-68

SIDA (2000). Water and wastewater management in large to medium-sized urban centres - experiences from the developing world, Colling Water Management AB, IUCN Water Demand Management Guideline Training Module, Unpublished

Thornton, J. (2002). *Water loss control manual,* McGraw-Hill Companies, New York, USA

UNICEF/WHO (2000). Meeting the MDG drinking water and sanitation target, The urban and rural challenge of the decade WHO and UNICEF, World Health Organisation, www.who.int/water_sanitation_health/monitoring/jmpfinal.pdf (Accessed 26/04/2018)

Vander, Z. (2003). Water losses and the political constraint to demand management, *Physics and Chemistry of the Earth, 27*(11) 805-813

World Bank (2014). *Proposed additional financing for the national urban water sector reform project,* Report No. 48580NG, Water and Urban, Country Department, Africa Region

World Health Organization, WHO (2001). *Implementation completion and results report for national water rehabilitation fund project*,

WWAP/ UN (2003). *Water for People, Water for life,* UNESCO and Bergham Books

Xin, K., Tao, T., Lu, Y. & Xiong, X. (2014). Apparent losses analysis in district metered areas of water distribution systems, *Water Resources Management 28* (1) 683-696

Xu, Q., Chen, Q. & Ma, J. (2014). Water saving and energy reduction through pressure management in urban water distribution networks, *Water Resources Management, 28,* 3715-3726