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Analysis of Water Losses and the Management of Non-Revenue Water by Plateau State Water Board in Jos, Nigeria

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ABSTRACT: Water is essential for all human activities and for sustenance of human life. Adequate water supply to households remains a mirage due to poor water management leading to water wastages emanating from both the production and distribution process and the activities of water thieves and carelessness from inability of the SWAs to promptly resolve all reported cases of leaks and bursts in the distribution and production channels. This study has analyzed the ways through which water is lost from Water Distribution Production System and network and how it affects the revenue of PSWB. It utilized the authors' observations, key stakeholder interview and documented reports of leaks and bursts, illegal connections, administrative leakages and other non-revenue water obtained from Plateau State Water Board Jos. The study has established among other things that of all the leakages are as result of administrative and physical leakages, followed by vanadalisation and illegal connections which are more prevalent in Jos Central and Gada Biyu in Jos North and Bukuru/Rahol kanang area in Jos South Local Government Area, it also found that water losses impacts negatively on the revenue profile of the Board. The study concludes that water supply assets such as assessment pipelines networks to identify aged pipes where water leakages is common, prepaid water meters should be deployed to all areas to ascertain the actual volume of water delivered in the Water Distribution System (WDS) and water use for ease of determining the Non-Revenue Water (NRW)

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Protecting and maintaining water distribution systems is crucial to ensuring high quality drinking water. Distribution systems-consisting of pipes, pumps, valves, storage tanks, reservoirs, meters, fittings, and other hydraulic appurtenances -- carry drinking water from a centralized treatment plant or well supplies to consumers' taps (World Health Organization (2014). Spanning almost 1 million miles in the United States, distribution systems represent the vast majority of physical infrastructure for water supplies, and thus constitute the primary management challenge from both an operational and public health standpoint. Most of the State Water Agencies according to Ali, (2018) rarely operate to full capacity due to broken down equipment or lack of constant power, maintenance of equipment, pipes, plant and Machinery that are hardly carried out leading to constant leakage and wastage of high volume of water. These utilities also have problems of lack of metres, poor billing system, corruption on the part of the staff which equally leads to high-level unaccounted-for water, hence severe revenue loss. The flat rate of billing system aimed at accommodating the poor households mostly benefit the rich while illegal connections in low-income communities whose water consumers are unable or unwilling to pay the flat rate is common place. This results to a situation in which most State Water Agencies cannot recover their operating, maintenance, initial investment and other costs associated with their

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revenue collections and remain dependent on government for subsidy (Ali,n.d; Banerjee, *et al* 2010).

Water production and distribution dismally account for a very small proportion of Nigeria's gross domestic products and average less than half percent annually in spite of the contribution of water to nearly every facet of state economies as raw material in industries, source of water for irrigation, recreation and other money spinning uses. With a naira value of 2.37 billion Naira in 2008, water contributed 0.01% to GDP in 2009 (NBS, 2012). Lagos State Government which generated the total sum of 1.379 billion Naira contributed over 58% of the total output being the dominant player in the sector in revenue generation. This performance is followed by FCT with the percentage contribution of 15.1% (N358 billion), Rivers (9.25% or N219.5 million), Kano (1.74% or N41.2 million). Other states with over one percentage contribution are Delta, Oyo, Akwa-Ibom and Enugu States. The Plateau State is 28th on the ranking has contributed N6.34 million which represents 0.27% to total GDP as at 2008 (Economic Associates, 2010 and Ali, 2018). This age of widespread, long-term droughts, impacts from climate change, and rapidly increasing rates of urbanization as cities around the world explode in size and number, water loss is a critical issue. Some cities have experienced water losses as high as 70%. But even small losses that accumulate over time can have significant financial impacts on community water departments and economic impacts on water customers (Duffy, 2016 and Ali, 2018).

One of the major challenges facing water utilities in the developing world is the high level of water losses from physical losses (leakage), water theft from the system, or because water users are not being properly billed. This has a serious effect on the financial viability of water utilities through lost revenue, lost water resources, and increased operational costs, reducing their capacity to fund necessary expansions of service, especially for the poor (Macheve, *et al* 2015). For too long NRW management has been given low priority by government officials, utility managers, donors and the water sector in general. However, over the last decade perceptions have changed rapidly, particularly in the developed world (World Bank, 2017; WSUP, 2017). The International Water Association (IWA) has acknowledged this trend by forming the Water Loss Task Force (WLTF), which over the last 8 years has played a major role in developing, standardizing and disseminating methodologies for addressing NRW. It is now widely acknowledged that NRW is a key indicator of a utility's operational and financial performance. A high level of NRW normally indicates a water utility that lacks good governance, autonomy, accountability, and the technical and managerial skills necessary to provide a reliable service. The global volume of non-revenue water (NRW) is staggering. It is estimated that each year more than 32 billion m^3 of treated water are lost through leakages from distribution networks (USAID/WBI, 2010). An additional 16 billion m^3 per year is estimated as delivered to customers but not invoiced because of theft, poor metering, or corruption. A conservative estimate of the total annual cost to water utilities worldwide is US$14 billion (USAID/WBI, 2010). In some developing countries, this loss represents 50-60% of water supplied, with a global average estimated at 35% (WSUP, 2017). Saving just half of this amount would supply water to an additional 100 million people without further investment (WSUP, 2017). A high level of water losses is one of the major challenges facing water utilities across the developing world. This includes physical losses due to leaks and theft of water from the system; and commercial losses resulting from unpaid bills, and water that is unbilled or incorrectly billed because of poor metering or poor customer records. The difference between the amount of water a utility puts into the distribution system and the amount of water billed to consumers is known as 'Non Revenue Water' (NRW). NRW has a serious effect on the financial viability of water utilities through lost revenue, lost water resources, and increased operational costs. High levels of NRW reduce a utility's capacity to fund necessary expansions or services, especially for low-income consumers. It is now widely acknowledged that NRW is a key indicator of a utility's operational and financial performance (EPA, 2010; Kingdom, *et al* 2006). A high level of NRW normally indicates a water utility that lacks good governance, autonomy, accountability, and the technical and managerial skills necessary to provide a reliable service (WSUP, 2017).It is particularly important to understand that NRW management requires the long-term commitment and involvement of all water utility agency staff. Many utility Managers do not have access to information on the entire network, which would enable them to fully understand the nature of NRW and its impact on utility operations, its financial health, and customer satisfaction (USAID/WBI, 2010). Most water utilities have historically focused on safe drinking water quality and continuously on demand and supply and the heavy regulatory activities of the national governments to ensure this high-quality service take their attention away from issues of water loss management. Unfortunately, a similar focus has not been given to system efficiency in the water supply process, and it is believed that many water utilities

suffer considerable losses from leakage and poor accounting (Duffy, 2016). Underestimating NRW's complexity and the potential benefits of reducing NRW often leads to the failure of reduction programmes.

Successful NRW reduction is not about solving an isolated technical problem, but is instead tied to overall asset management, operations, customer support, financial allocations, and other factors. It is not only the management's responsibility, but the responsibility of everyone in the utility. Particular attention is given to backflow events via cross connections, the potential for contamination of the distribution system during construction and repair activities, maintenance of storage facilities, and the role of premise plumbing in public health risk. The management of water loss should also identify advances in detection, monitoring and modeling, analytical methods, and research and development opportunities that will enable the water supply industry to further reduce the losses associated with drinking water distribution systems. It is against this background that this research seeks to analyze the various avenues of water losses within Water Supply Utility system in Jos metropolis.

MATERIALS AND METHODS

Jos metropolis is located between Latitudes 9^0 54' N and 10^0 10' N and Longitudes 8^0 48' E and 9^0 30' E. The study area comprises Jos South and Jos North Local Government Areas with their headquarters in Bukuru and Jos respectively. The area is situated within the northern senatorial zone of Plateau State, and is bounded by Barkin-Ladi and Jos East to the east, Riyom to the south and Bassa Local Government Areas to the west (see Figure 1). The areal extent of Jos metropolis from north to south is 104km while from east to west is about 80km on an elevation of 1,250m above sea level with Shere hills having the highest peak of 1,777m above sea level with an area of 1002.19 Km^2 (Mohammed, *et al* 2010).

Fig 1: Plateau State showing the LGAs

Most rivers in northern Nigeria owe their origins to the Jos Plateau due to its height above other regions in the northern Nigeria and is the source of Kaduna, Gongola, Korot, Shimanker, N'gell, Kassa, Delimi, Hadeija-Jama'are, Wase and Tenti rivers. The volume of these rivers are high during the rainy season and low during dry seasons due to the nature of rainfall and other climatic elements of the area (Bingel, 1978, Jiya and Musa, 2012). The presence of these rivers, streams, dams, hand dug wells, ponds and springs constitute very good water resource base for the area. Some of the rivers that the government has dammed and is harnessing for potable water supply to the metropolis are Nupis, Shen, Gwash, Rafin-Sanyi,

Agog rivers and Yelwa pond with Tolle Mache, Yakubu Gowon, Liberty (Laminga), Lamingo (Gwash), Kogingiri and Yelwa Dams built on them. The intensive rainfall in Jos metropolis presents great potential for rain harvesting to the quantities that will cater for households, industries and other water consuming units' need for water right to dry periods. But the technology and the awareness for the harvesting though cheap and simple is not being embraced by most water users due to long rainy season that guarantee abundant precipitation for nine months. Apart from this there are a lot of streams, ponds, mine pits, lakes and smaller rivers which compliment other major water sources in their raw forms which if developed along with dams will contribute potable water to the piped water system (Daloeng, 2019).

The Jos Plateau is composed of the crystalline basement complex of both igneous and metamorphic origins with younger granites and basalts as the other major rock types existing in the area. According to Schoeneich (1992), the Jos Plateau is denudational in nature and came into being at about the end of tertiary period when there was tectonic uplift of a small area of about 8, 000km^2 in the central crystalline shield. The raised Plateau which was followed by volcanism went through denudational activities during the late cretaceous age especially on the ages of the Plateau forming valleys which were filled with basaltic lavas. The Jos Plateau due to these geologic processes has risen to the heights of 1,600m, 1,777m and 1,300m at Ropp, Shere Hills and Dogon-Dutse respectively. The combination of favourable climate, relief, soils, vegetation and abundance of natural scenic vistas, the city presents very great opportunities and potentialities for agriculture, mining, trade, industrial production and recreation and tourism, some of these attractions are: Shere hills, Jos Museum and Zoological Gardens, Jos Wild Life Park, Riyom Rock, Solomon Lar Amusement Park. Also, the presence of higher institutions of learning, stadia, Tertiary health institutions of learning, tertiary educational institutions, good road network, water supply infrastructure, waterfalls, mining ponds, ongoing mining activities in Jos metropolis, though environmentally destructive presents very beautiful tourist attractive sites to every visitor to Jos City (Ali,n.d). Jos metropolis experiences AW climatic type and falls within the koppens AW climatic sub-region. Generally, weather conditions are warmer during the rainy season (April-October) and much colder during the hammattan period (December-February) (Ariyo, 2000). The mean annual temperature of the city ranges between 20^{0}c and 26^{0}c. These temperature ranges are due to influences of rainfall, relief and cloud cover at different periods and seasons of the year. Relative humidity is lower during the dry season between November to March and is very high during the wet season with the peak values of between 81% and 84% in July and August (Bingel, 1978, Ariyo, 2000, Nyong, *et al*, 2003, Nyong, *et al* 2008). Precipitation on the Jos Metropolis ranges from 70cm to 100cm during the peak period. The study area has wet and dry seasons. The wet season takes about 8 to 9 months between mid-March and end October, while the dry season takes about 3 to 4 months from mid-November to mid-March (Ariyo, 2000). The wet season is influenced by prevalence of the warm moist maritime south westerly monsoon winds which blow from the Atlantic Ocean south westward hinterland while the dry season is linked to the dry tropical continental north easterly winds (Hammattan) a cold dry and dusty mass blowing from the Sahara Desert (Ariyo, 2000). The population of Jos city is put at 1,387,795 based on the 2019 population projection (National Population Commission, 2006). It has a density of about 391 persons per square kilometer and is the most densely populated and urbanized place in Plateau State. Due to the presence of so many higher institutions, church institutions, commercial activities, administrative activities which have over the years mobilized and are continuously attracting labour, capital and entrepreneurship, all these have combined to make Jos to assume the status of a cosmopolitan city.

Data Analysis: Data used in this research are from primary and secondary sources. These Primary data are collected directly from firsthand experience through the authors' personal field observations, and interview of key stakeholders in the technical and engineering department of Plateau State Water Board, Jos. The data obtained from the field bother on locations of leaks and bursts, severity of leakages, estimated volume of water loss and the mitigation measures put in place by the authorities and timelines of resolution. Secondary type of data collected from the database of Plateau State Water Board are the number of leaks and bursts across locations, quantum of water loss and monetary losses incurred from the NRW.

RESULTS AND DISCUSSION

Water Supply Projects in Jos Metropolis: Plateau State Water Board is a government owned agency established by Plateau State Water Board Edict No. 4 of 1991 which was repealed by a law and upgraded from the Board to a Corporation. It is charged with the responsibility of providing potable water services to the over 3 million citizens of both Jos metropolis and other local government areas of Plateau State. Apart from other water supply projects in other parts of the

state, the board manages six major dams which provide water for households, commercial activities and industries within the Jos metropolis. These dams are Tolle Mache, Yakubu Gowon Dam, Yelwa Dam, Kogin-giri Dam, Laminga (Liberty) and Lamingo (Gwash) Dams. The water produced from these Dams is transported through pipes of different sizes to treatment plants after which it's distributed to consumers. The Board has six Directorates which include Administrative, Commercial, Accounts and Supply, Operations, Quality Assurance and Technical Services. It has four additional units namely: the project implementation units, Planning Research and Statistics, Public Relations, Legal. The Operations Directorate is charged with the functions of water production, treatment and distribution. The Commercial department on its part maintains customer data base of about 23,000 which are billed based on the flat rate tariff system, the Finance and Supply Directorate on the other hand has the mandate of managing the accounts of the Board. See details of the summary of the Board and other information in Table 1. The Board has 367 employees and serves only about 560,000 people representing only about 56% of the entire population within Jos metropolis.

Table 1: Basic Features of Plateau State Water Board

Characteristics/year	2019
Population served	3 million (Statewide)
Population served	560,000(Jos metropolis)
Number of dams and ponds/ Treatment Plant/Reservoirs	7/4/13
Total Number of connections	25,533
Number of employees	367 as at December 2020
Estimated Non-revenue water	48 %
Service coverage	20%
Average domestic tariff	N2500
Total daily water production	50400m^3
Total daily water distribution	50400m^3
Average Hours of service per day	7-8 hours
Length of piped water connections	450Km
Proportion of the connection that is metered	425 (1.8%)

Source: SUWASA, 2015 and Field Survey, 2020

Apart from the untapped potential of their inability to extend service coverage to serve over 740,000 number of people in Jos metropolis, they have very high non-revenue water rate of 58% and an uptime of 7 hours in a day which is slightly below the acceptable desired level of at least 8 hours prescribed by the African Development Bank (AfDB) as shown in Table 1 With over 500,000 households, the board is currently connected to only 23,453 leaving up to 476,547 households unconnected and relying on the water sources that are considered unreliable for drinking and other potable uses.

Indicators of Good Water Supply Agency and Projects: AfDB (2010) has spelt out that for a Water Supply Agency to offer good services to its customers and make profit, it must have met targets that bother on key performance indicators as shown in Table 2. Water loss control includes utility efforts to manage leakage to economically low levels, and reducing metering and billing errors such that reliable measures of customer consumption are attained and sufficient revenue is garnered by the water utility. Utilities should adopt policies for non-revenue water and water loss control just as they adopt policies for purchasing, procurement, personnel, and other utility program areas.

Table 2: Indicators of Good Water Supply Agency

S/N	Indicator	Standard Desired (%) level	PSWB Actual (%)
1.	**Cost Recovery**	100	
	(a) Percentage of household paying bills		36
	(b) Cost of O and M 100 covered through household contribution	100	1
	(c) Percentage of Income of households spent on water	<3	4
2.	**Satisfactory service level**		
	(a) No of Hours supply per day	8hrs	7hrs
	(b) E-Coli contamination	<0	0
	(c) Water Pressure	High	Moderate
3.	**Gender & Equity Consideration**		
	(a) % of low income HHs within 500m connected from stand post	90%	10
	(b) % of high income HHs within 500m connected from stand post	90	30
4.	**Operations and maintenance capacity**		
	(a) Trained caretakers with tools	At least 2	24
	(b) Repair time following a break down	< 2 days	2weeks
	(c) Average time required for the purchase of spare parts	< 3 days	2 weeks

Source: AfDB, 2010, Field Survey, 2020

Reasons for Inaccessibility to domestic water Sources: Apart from inadequacies of water supply sources in the area, another reason for water unavailability and inefficiency in service delivery is water loss. The analyses were also supported statistically based on the sampled questionnaire as seen in Figure 2 which shows the result for the reasons of inaccessibility to the water sources by the water subscribers.

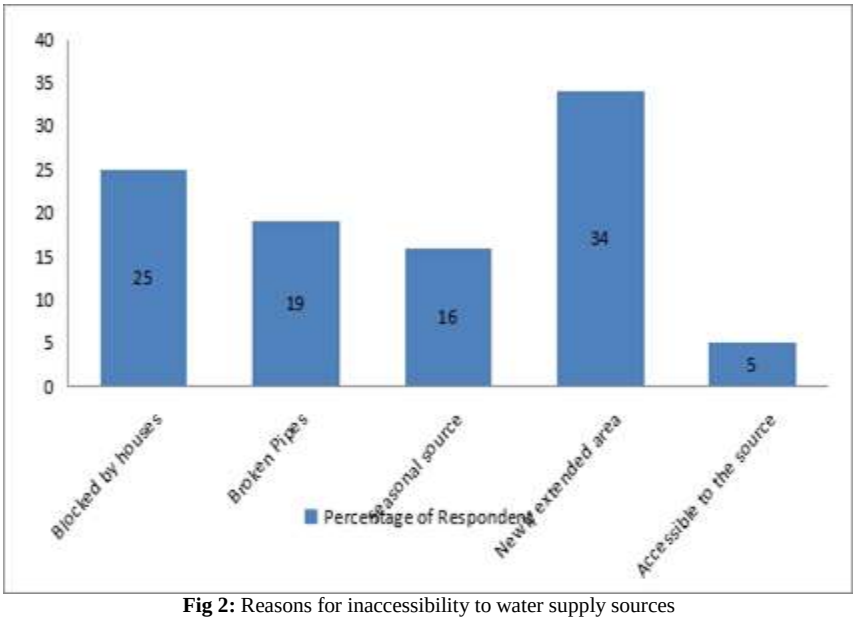

Fig 2: Reasons for inaccessibility to water supply sources
Source: Field Survey, 2020

Figure 2 shows the reasons of inaccessibility of the respondents to water supply projects in the area. These reasons include blockages of public water sources by houses as a result of unplanned cadastral layout, broken water supply pipes which were not noticed to be replaced by Plateau State Water Board management, seasonal effect on the water source most especially the wells, boreholes and streams during dry season and newly extended built-up areas with no or minimal connections. Furthermore, the figure 2 also shows that the domestic water users are clustered along the road with higher density around Bukuru Low-cost and Kufang areas, this finding is similar to that of MacDonald *et al*, (2009) which mapped water and sanitation projects in Ethiopia and found that water supply failures in this region were that of the reduced yield of the aquifer and deep-seated water level during the dry season. It is also in disagreement with the findings of George and Jacob (2010) on accessibility of water services in Kisumu municipality which revealed that the proportion of households with access to piped water supply within a distance of 200m is 77.1%, only 65.6% of the basic water requirements of the residents are met and that only 25% of the households access the minimum recommended 50 l/c/d.

Table 3: Location of Leaks and Burst in Jos Metropolis

Location	No of Leaks and Bursts	%	Remarks
Jos Central	915	18.0	Highest number due to aged infrastructure & high population
Bukuru B	125	2.0	Constant monitoring and community policing
Bukuru A	378	7.0	High population, vandalism & water theft
Rayfield	245	5.0	Moderate due to level of education of people, availability of alternate sources
Federal Lowcost	141	3.0	New connection due to new areas
Fudawa	200	4.1	Low connection area
Kabong Areas	701	14.0	High population, less educated people & construction activities
Lamingo Business office	160	3.1	Aged infrastructure
Zaramaganda	154	3.0	High population, vandalism & water theft
Ali kazaure	611	12.0	Pipes are aged and replacement going on
Angwan Rogo	530	10.4	Pipes are aged and water theft
Laranto	125	2.4	Low connection and coverage
Jos main	814	16.0	Aged pipes and water theft
Total	5,099.00	100	

Source: PSWB, 2020 and Authors' Field Work.

From Table 3, Jos central constitutes the largest location of Plateau State Water Board's areas of coverage and it is the area where the city initially started from. Apart from these, it is the most populous part of Jos metropolis with over 50-100 years of installation. The pipelines are buried underground and maintenance at times of leakage from bursts make it very difficult as much labour and financial resources are needed for excavation before repairs are carried out. The highest bursts and leakages (60%) occur

within Jos central area (18%), Kabong (14%), Ali Kazaure (12%) and Jos main areas (16%) of the Plateau State Water Board (PSWB) area of coverage due to a combination of aged infrastructure, high population and high rates of vandalism within and around the slums. Bukuru A area has the second highest rates of leaks and bursts as it also has high population and economic growth rates. High water demand in areas that are predominantly inhabited by the poor, with low capacity to either connect to the grid or even pay their monthly water tariffs. This disadvantaged majority resort to either illegal connection or vandalism of water supply infrastructure to pave way for theft of water. The Authors observation revealed that in most of these areas any noticeable leaks has people queue up to fetch water from broken unburied pipes. The level of education and income levels of inhabitants of an area are factors that could aid the connection to the grid and willingness to pay for monthly utility rates (Gunatilake *et al.,* 2012).

Most people living in Rayfield, State Lowcost and Lamingo areas are those who are highly and moderately empowered educationally and economically, these factors are responsible for the low and tolerable rates of water loss of 10%, 6% and 8% in the areas. Also, most of the areas are new with infrastructure that are still strong to withstand operational lapses like pressure and overflows. Gada Biyu is also an old area in Jos City from Table 3, it has 322 leaks/burst, the third highest after Jos Central and Bukuru. Apart from the high population of the area, it has a lot of pipes affected by acts of vandalism and construction activities.

The high rate of leaks in the area can be attributed also to the high crime rates and the low income rate of the people in the area. An interview with some stakeholders in the technical and engineering department in PSWB revealed that it takes the staff between 1-7 days to resolve all the reported issues of leaks and burst.

A Combination of causes in Table 4 as ranked by the intervention contribute to the over 40% non-revenue water of Plateau State Water Board. It is evident that most of the pipes conveying water from dams and reservoirs to households in Jos metropolis are aged rusted and highly vulnerable to bursts and leaks.

From the ranking on use of materials, the ranking of one shows that size and nature of pipelines used were not really the contributory factors to water losses in Jos metropolis. Pipe materials vary considerably and each has its own strength characteristics and potential for failure. Today, most new water pipelines and fittings are constructed with vinyl plastics (usually PVC), metal (from copper feeder lines servicing individual users to old-fashioned cast iron, more flexible ductile iron, and even stainless steel), asbestos cement, and reinforced concrete. Water pipe diameters vary considerably from 6 inches to 16 inches, with 8 inches being the most common (Duffy, 2016).

Table 4: Ranking of Causes of Water Losses (1-5)

S/No	Causes of water loss	Ranking
1.	Aged/aging infrastructure	5
2.	Use of wrong materials/ size of pipelines	1
3.	Poor operation (High pressure, over flows, etc)	2
4.	Poor maintenance	5
5.	Unmetred connections/ metre inaccuracies	5
6.	Billing adjustments	4
7.	Accidental bursts	4
8.	Illegal connections/outright water theft	5
9.	All of the above	4

Source: Field Survey, 2020

The pressure of water released to the system is also said to be moderate and does not constitute any threat to the water system that brings about losses. Table 2 and Ali (2018) also agreed that the water pressure is moderate and that the Board has optimum operations and maintenance capacity in areas of trained manpower (24 persons) and two weeks each for repair time following break down and average time required for the purchase of spare parts respectively. Poor maintenance, unmetred connection/inaccuracies, billing adjustment, accidental bursts and illegal connections were all ranked very high among the causes of water loses in Jos Metropolis.

Table 5: Ranking of Water Losses (1-5)

S/No	Effects of Water Losses	Ranking
1.	Loss of revenue	5
2.	Water pollution	5
3.	Customers use of alternate sources	3
4.	Customer dissatisfaction	5
5.	Bad publicity for SWA	4
6.	All of the above	5

Source: Field Survey, 2020

Table 5 lists the effects of water losses on the operational activities of Plateau State Water Board (PSWB). Loss of water entails serious loss of revenues to the State.

Apart from the leaks and bursts leading to water pollution, the customers can become dissatisfied with low pressure and quality of water received. This could easily lead to the switching to alternate water sources like wells, boreholes and water vendors from Table 5, the interviewees ranked all these effects very high as water loss can also bring bad publicity to the Board.

Table 6: Ranking of Water Loss Management Strategies (1-5)

S/No	Water Loss Management Strategy	Ranking
1	Water conservation programme	4
2	Energy conservation programme	3
3	Repairing reported leaks	3
4	Periodic metering test	1
5	System wide metre upgrade	1
6	Regular water supply auditing	2
7	Active leak detection and repairs	5
8	Accounting and billing test	4
9	Programmed for reduction of water theft	5
10	All of the above	5

Source: Field Survey, 2020

Table 6 revealed that a combination of nine strategies as ranked from 1-5 by those interviewed on the course of interaction revealed that all these could lead to water loss management issues in the area. The interaction with the technical staff also revealed that the water distribution network has at most non-existent metering, so the periodic metering test, system wide metre upgrade and regular water supply auditing are not carried out. This is the reason why the Board loses water up to 40% (SUWASA, 2015). The management staff interviewed claimed that they have perfect water and energy conservation programmes aimed at managing losses from the system. The repair of reported leaks is handled within two weeks, while repairs of active leaks detected are also promptly handled and is ranked the highest (5), they also agreed that they do a lot of accounting and billing tests and have also put in place programmes for reduction of water theft in the area. They all agreed that all the water loss management strategies contained in Table 6 can help in curbing the high-water loss rate in the area.

This corroborates the findings of (Duffy, 2016) which found that, the main threat to pipe integrity is physical deterioration from long-term effects such as rust, corrosion, electrochemical reactions, or biological fouling in adjacent soil and groundwater, the physical structure of the pipe walls can be weakened and thinned. Therefore, any bends, valves, tees, wyes, or flanges are possible points of failure since these connections are always not as strong as the pipe itself. Resultant dead loads include vibration from equipment and vehicles, thrust movement created by the force of water being carried by the pipe (hence the need for thrust blocks to brace the pipe), exterior pressure from soil both in the backfill adjacent to the pipe, and natural soil adjacent to the pipe's trench, simple settlement or shifting of soil, and the force of expansion of frozen water inside the pipe.

*Conclusion***:** Water loss not only impacts the revenue stream of any Utility, but regressively affects her operational activities. Employing improved methods of water auditing and loss control can reduce the large volumes of treated water that are lost to leakage, as well as to provide incentives to customers to optimize their water consumption. Based on the foregoing findings, the following solutions were proposed: aged pipes where water leakages are common should be replaced; prepaid meters should be deployed to all areas for ease of determining the Non-Revenue Water (NRW); trained personnel should be deployed quickly to respond to both emergency and periodic leakages.

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