Performance Assessment of Water Infrastructure in Lagos State, Nigeria: Implications for Sustainable Development

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Abstract
At the root of water supply problems in sub-Saharan Africa is the state of infrastructure in the water sector. As the 2030 deadline for the Sustainable Development Goals approaches, this study assesses the condition of public water infrastructure in Lagos State, Nigeria, in order to evaluate progress made towards achieving the SDG-6 objectives. Using secondary data spanning 2017 to 2021, the study conducted an inventory and performance evaluation of waterworks in the state. The findings indicate significant disparities in pipe-borne water access, particularly in underserved urban fringes. Statistical analyses reveal that major water-producing facilities operate below their design capacity, with utilisation rates often under 40%. The result of ANOVA testing the effect of the levels of system design on the operational performance of major waterworks revealed significant differences in operational performance implying that performances were better with the levels of volumetric production of system design rather than with design capacity. Overall, seasonal changes have a significant impact on water production, underscoring the importance of diversifying water sources for domestic water supply. Also, the uneven distribution of water facilities necessitates the strategic positioning of new infrastructure that are guided by geospatial tools. From the findings on capacity underutilization, there is a need for technology modernisation and improved energy stability for all waterworks. The need for improvement in funding of water-producing facilities for infrastructure development was highlighted. This study recommends the urgent need for critical actions to enhance water production in Lagos State to achieve SDG-6 objectives.

Keywords: *Water infrastructure, SDG 6, Water production, Waterworks, Lagos, Performance evaluation*

Introduction
The lack of development in associated infrastructure for water production and distribution has been linked to the water crisis in developing countries worldwide. This, which is referred to as water infrastructure, is a broad term for systems of water supply, treatment, storage and distribution. It embraces a vast array of utilities that are put in place to ensure the provision of water, including dams, reservoirs, treatment plants, wastewater treatment facilities and pipeline networks. Humans have been involved in the development of water infrastructure in one form or another. Infrastructure is needed to supply citizens, communities, businesses and industries with potable water, as well as to collect, treat and discharge wastewater to manage storm water runoff and to prevent flooding.

Water infrastructure issues vary significantly across countries, with each facing unique challenges. Water infrastructure has been traced as a culprit in major water crises, particularly in the global south. In developed countries, substantial investments in water infrastructure have led to better provision of potable water, whereas in developing countries, the reverse is often the case due to the significant investments required. For instance, the poor state of water infrastructure in Haiti is highlighted by Chapman et al. (2020), who discuss the lived experiences of women in Gressier, emphasizing the critical need for improved water access and infrastructure development. Additionally, in Ghana, the lack of investment in water infrastructure has led to significant health issues, with many communities lacking access to clean and safe drinking water (Nyarko et al., 2020).

Chepyegon and Kamiya (2018) found that low water investments reduced water supply coverage. Many developing countries face significant challenges due to inadequate water infrastructure. This includes insufficient water distribution systems and a lack of proper sanitation facilities. Inadequate water supply affects not only the daily lives of residents but also their economic activities and health outcomes (Okafor & Adebisi, 2023). These deficiencies lead to public health issues and hinder economic development. Gallandat et al. (2024) explore the impact of improved water supply infrastructure on reducing diarrheal diseases in Uvira, demonstrating how targeted infrastructure investments can lead to significant public health improvements.

Moreover, the socio-economic impacts of water infrastructure deficiencies are profound. Dadson et al. (2017) consider investments in water infrastructure to be the most critical investments to promote socioeconomic development, particularly in developing countries that are characterized by high inter- and intra-annual surface water and precipitation variability. In such areas, water scarcity and inadequate infrastructure can severely impact agricultural yields, as noted by UN-Water (2023). Therefore, robust water infrastructure is essential for maintaining agricultural productivity and supporting rural economies. Additionally, inadequate water infrastructure has environmental implications, including unsustainable water management practices and degradation of water resources. In sub-Saharan Africa, poor water management and low investment in water infrastructure contribute to environmental challenges and hinder progress towards SDG 6 (Nkiaka et al., 2021).

However, Haruna et al. (2024) asserted that financial obstacles are a major barrier to improving water infrastructure in low-income and least developed countries. An earlier study by Meeks (2012) showed that improved water infrastructure in nine developing countries significantly boosted economic performance by enabling various economic activities to thrive. Also, the Environmental Protection Agency (2023) noted that secure, reliable water infrastructure systems are essential for sustaining economic growth and planning for future development. Therefore, progress made in infrastructure investment could be an essential vehicle for addressing the environmental and economic challenges imposed by water stress and water-related natural hazards (Ochoa-Tocachi et al., 2019).

Rapid urbanization further compounds the problem of water infrastructure deficits in developing countries. For instance, in many developing countries like Bangladesh, rapid urbanization and population growth have overwhelmed existing water infrastructures, leading to challenges in maintaining adequate water supply and sanitation systems (Ahmed et al., 2019). Similarly, in Kenya, water infrastructure struggles to keep pace with urban expansion, leading to inequalities in water access and frequent service disruptions. Millington and Scheba (2021) investigated Cape Town’s water crisis, examining the infrastructural and governance challenges that led to the crisis. Their study underscores the importance of resilient infrastructure and effective governance. In India, the challenges of urbanization and limited financial resources for infrastructure development are significant, as observed by Kookana et al. (2020).

Urbanization and industrialization require robust water infrastructure to support growing demands. Adequate water supply and sanitation systems are critical for urban center development and industrial zone establishment. Manase (2024) posited that investment in water infrastructure is crucial for supporting urban growth and industrial activities. Therefore, emphasis should be placed on the need for strategic planning and investment to manage water and food security in rapidly urbanizing areas.

In 2015, the United Nations set the 2030 Sustainable Development Goals (SDGs), of which water security and infrastructure investment are integral components. Sustainable Development Goal 6 (SDG 6) aims to ensure the availability and sustainable management of water and sanitation for all by 2030. Improvements in water and sanitation are crucial for achieving SDG 6 (Herrera, 2019). However, the lack of good water infrastructure in developing countries poses significant challenges to achieving this goal since a lot of the developing countries struggle with insufficient funding and infrastructure. In Nigeria, despite significant investments in water infrastructure, progress towards SDG 6 remains slow due to various systemic issues. Adeoti et al. (2023) highlighted that the sustainability of water infrastructure is a critical component of urban development, directly impacting the health, economic well-being, and quality of life of a city's residents.

Furthermore, according to Jideonwo (2014), Sojobi (2016), and Balogun et al. (2017), the challenges facing public water utilities and public water supply systems have technical, social, economic, legal, institutional, and environmental dimensions. Such challenges have been found to be responsible for the aging and lack of maintenance of most public water supply assets with enormous impact on daily life and many long-term economic activities (Sakai et al. 2020). To meet up with the SDG 6 standard, therefore, attention needs to be placed on the adequacy of infrastructure, which necessitates the need for an inventory assessment.

An inventory assessment of water infrastructure examines criteria such as adequacy of supply and/or distribution facilities, repair rate of water leaks, the age of the pipeline, proportion of deterioration in the pipeline, length of pipe deterioration, change in technology, storage tanks, leakages in the distribution pipe network, rate of change in the numbers of technical staff per unit length of pipeline, and in the unit, ineffective water coverage areas.

Some of the reasons for inventory, apart from the needs to sustain water supply, include to evaluate the level of soundness, determine the condition of deterioration, installed capacity, current operational capacity and for efficient maintenance management. Though many studies have highlighted the need to address the problem of public water infrastructure decay and management challenges facing most of the cities, research searchlight has not been focused in these areas in both the urban and rural areas.

An inventory analysis would normally inform water supply authorities where and what actions are needed. For example, Sakai et al. (2020) developed indices by which they evaluated the extent of deterioration of water pipelines and the effectiveness of maintenance management systems in Japan. They obtained a score of caution and received a downward grade in terms of maintenance management.

This study, therefore, aims to assess the current state of water infrastructure in Lagos State in light of SDG 6. The study is designed to examine the production capacity of existing facilities and to establish the level of progress, if any, in water supply to the inhabitants of the Lagos area. The primary goal was to determine the system's operational status; second, to further examine the system's water production activities, culminating in the objective, which is to assess the system's performance over time.

Study Area

Lagos State is situated in the southwestern part of Nigeria, along the Atlantic Ocean coast. It is located between latitudes 6°23'N and 6°41'N, as well as longitudes 2°42'E and 3°42'E. The state is bounded by Ogun State to the north and east, the Republic of Benin to the west, and the Atlantic Ocean to the south. Lagos has a total land area of 3,577 square kilometers and an entire metropolitan area of 738 square kilometers. With an estimated population growth of 13% per annum, one of the most significant challenges faced in Lagos is overpopulation, which is a significant parameter in the depletion of natural resources brought on by the environments carrying capacity.

The topography of Lagos is relatively flat, with elevations ranging from sea level to about 50 meters above sea level. The state is characterized by coastal plains, mangroves, and sandy beaches, contributing to its low-lying nature. The flat terrain makes Lagos prone to flooding, especially during heavy rains. Lagos experiences a tropical wet and dry climate, with two distinct seasons: the wet season (April to October) and the dry season (November to March). The city receives heavy rainfall during the wet season, with an annual average of about 1,800 mm. The seasonality of rainfall is known to affect the existence of surface waters, especially during the dry season when many small streams and rivers dry up, thus leading to low levels of water in major streams and rivers. Temperatures are generally high throughout the year, ranging between 25°C and 32°C. Lagos' natural vegetation consists primarily of mangrove swamps and coastal vegetation. The state also has patches of tropical rainforest, especially in the northern and eastern parts. Urbanization has significantly altered the natural vegetation, leading to the expansion of built-up areas and the reduction of green spaces.

Lagos is endowed with numerous surface water bodies, including lagoons, rivers, and creeks. The Lagos Lagoon is the largest and most significant, covering about 6,354 hectares and playing a crucial role in the state's drainage system. Due to its proximity to the Atlantic Ocean, Lagos is characterized by notable brackish water bodies, including the Ologe Lagoon, Lekki lagoon and numerous creeks, such as the Badagry Creek. In addition to these brackish waters, Lagos is endowed with freshwater rivers such as the Ogun, Yewa, Aye, Owo, Oworu and Osun. Despite the huge presence of these water sources in Lagos, access to potable water for consumption is very poor. The Lagos Water Supply Master Plan (Lagos Water Corporation, 2010) estimated the amount of water consumed by one person in one day (per capita water demand) at 30 gallons/capita/day (gcd). The water supply capacity of the existing waterworks at full utilisation was put at 210 mgd. Based on the 18 million population estimate, a supply deficit of 330 mgd was observed. The water agency identified an inadequate water supply and developed a master plan to grow the supply to a surplus of 12 mgd by 2020.

Materials and Methods

To achieve the objectives of this study, this paper relied on secondary data obtained from the Lagos State Water Corporation, the agency responsible for water supply in the state. The collected data spans five years, from 2017 to 2021. Key data characteristics of concern to this paper are threefold, which include the systems data comprising of the working state of the system's infrastructures, installed capacity design and utilisation measured in the units of million liters (cubic meters, gallons), types/categories of producing units, and sources of raw water input. Secondly, the production data of the minimum, maximum, average daily/monthly totals, quarterly and annuals; and thirdly, distribution network data detailing the supply of water to various user communities, which were grouped according to areas and zones.

The core of the methodological procedures in the study is the taking of the inventory of the potable water-producing systems (waterworks), which are in three categories, notably: major waterworks, mini waterworks, and micro-producing units. This classification was based on infrastructural dimensions, capacity design, input water sources, and distribution networks. Further analysis examined the functionality of these facilities so as to determine the working state of the operational facilities. Taking the seasonality of rainfall and subsequent changes in the level of surface waters in the study area into consideration, analysis was done on a quarterly basis. The first and last quarters correspond with the period of little or no rainfall, which may lead to a reduction in surface water levels. The second and third quarters of the year are the rainy season months when river channels are filled to capacity. Following from this analysis, an assessment was made of volumetric water production and distribution of the producing units.

In a bid to further understand the factors accounting for the systems' operational performance, inferential analysis was conducted using single-factor ANOVA based on activities in each quarter of the operation periods. The results were promptly accompanied with their discussions and presented in tables.

Results and Findings

Count, Location and Start dates of Water Facilities in Lagos State

An inventory was carried out on the public water production system, including the infrastructure on the ground. Lagos State has a total number of 52 water-producing facilities. These facilities can be categorized into three depending on their size and capacity. In the first level of potable water producers are the major waterworks, which are the primary suppliers to the residents. These producers rely on surface water intake. There are four of them namely the Iju, Adiyan, Isashi, and Ikosi-Ketu waterworks. Additionally, there are 31 mini waterworks, and these mini suppliers rely on groundwater sources. The third category are the micro waterworks, which are 17 in number, and these also rely on groundwater sources but operate at smaller capacities than the mini waterworks.

Figure 1 illustrates the location and distribution of the water-producing facilities and pipeline networks. From the figure, the facilities are spread unevenly across the state. The major waterworks are located along the Lagos-Ogun border, while the mini and micro stations are concentrated within the metropolis. Namely, areas along the western and eastern flanks of the state in the Alimosho and Epe axes, respectively, are not covered in terms of water infrastructure. The implication is that the emerging urban areas, which are recent extensions of the metropolis, do not have access to public water supply. It is important to note that rapid population growth and urban sprawl are outpacing infrastructural development in the water sector in Lagos. The peri-urban areas in particular, are underserved and the need for new water facilities to service such areas is urgent. Strategic placement of new facilities can ensure equitable access and alleviate pressure on existing systems.

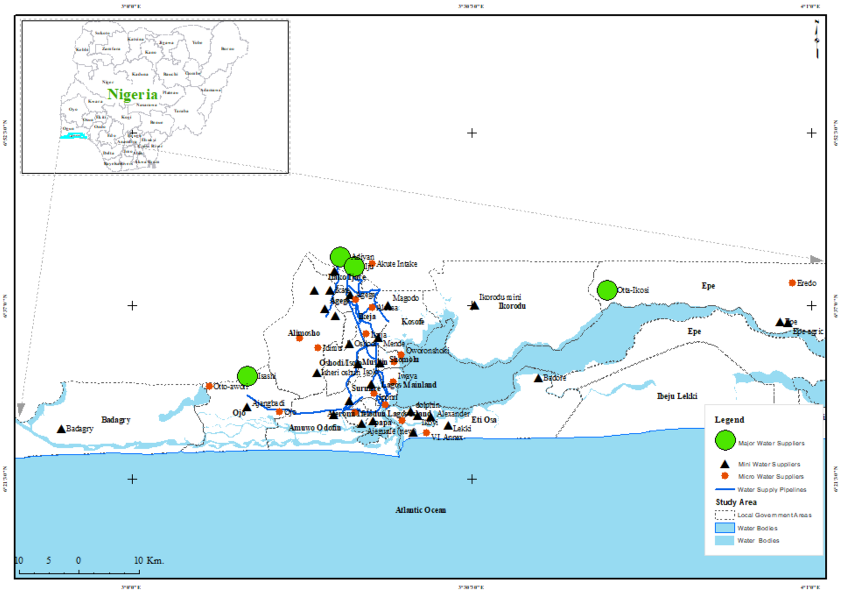

Figure 1: Map of study area showing the distribution of water infrastructures in Lagos State

The earliest established of the major waterworks is the Iju, located on the Ogun River in Ogun State, and has been in operation since the colonial days in 1915. The waterworks was constructed to service the colonial residences in Ikoyi but was located at its current site because the quality of available surface water of the Ogun River was better than what was available in the nearby areas of the island. The second waterworks is the Isashi waterworks, which was constructed in 1976 in preparation for the arts festival of 1977 in Lagos. Subsequent expansion schemes led to the construction of Adiyan Waterworks in 1991. Located on the Adiyan River, which is a tributary of the Ogun River, the Adiyan Waterworks is also located in Ogun State. The most recent is the Ota-Ikosi waterworks, which was commissioned in 2016 to serve areas between Itoikin and Agbowa. Aside from the major waterworks, other mini and micro facilities were constructed and commissioned across the state, as summarized in Figures 2 and 3, respectively.

From available data, the established water facilities in Lagos are all dated before 2015, which is the start year of the SDGs. The Otta-Ikosi water scheme, though commissioned in 2016, was a project dated as far back as 2005. In essence, it has been observed in the study that new water projects are yet to be put in place since the inception of the SDGs in Lagos.

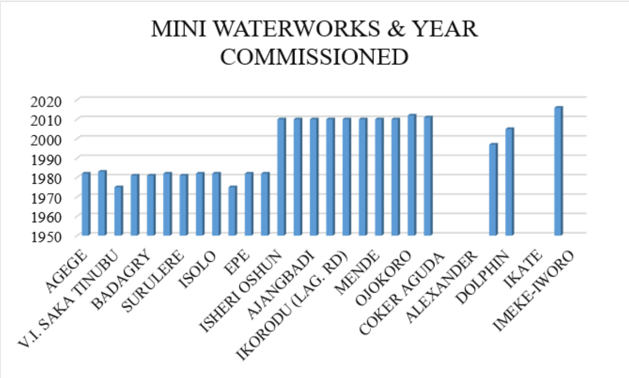

Figure 2: Mini Water Suppliers and Year of Commission

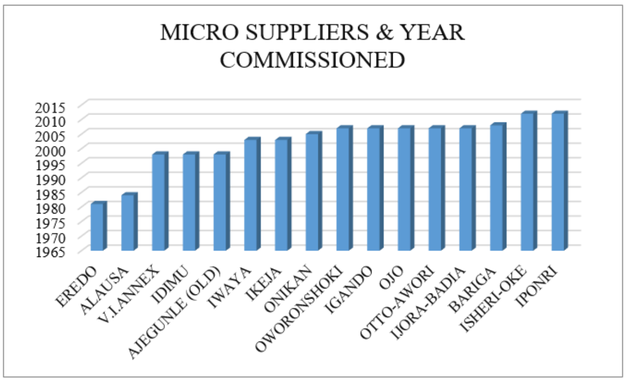

Figure 3: Micro Water Suppliers and Year of Commission

Design Capacity of the Major Waterworks in Lagos State:

The design capacity of any system describes the levels at which a system is designed to operate based on inputs into the system and the outputs expected from the system. When the appropriate inflow and other available operational variables are fed into the system, it performs at optimal capacity. Where the expected operational facilities are not being effectively fed into the system, the system cannot perform at the expected optimal level, and this manifests in the outputs from the system.

The capacity design of Iju was a little above 2.4 million gallons per day when the population was less than 100,000. At its inception, Iju Waterworks was comprised of three massive engine pumps, two settling tanks, a service reservoir of 6 million gallons, 200 fountains and 250 fire hydrants. The processed water was distributed through a cast iron trunk mains pipeline. Adiyan Waterworks, which was commissioned much later in 1991 as an upgrade of the existing one, was an improvement on Iju with 318 million liters (0.318 million cubic meters) per day. Figures 4 and 5 summarize the design capacities of the major and mini waterworks, respectively.

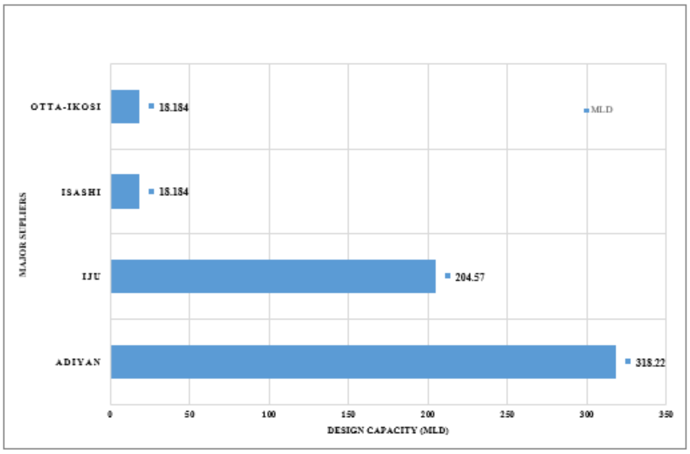

Figure 4: Design capacity of major waterworks in Lagos state (ML/D)

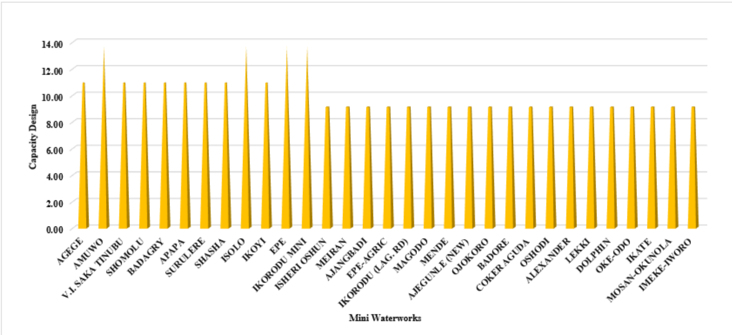

Figure 5: Mini Waterworks' Design Capacity (Million Litres/Day)

A decagram in Figure 6 shows the micro-waterworks and designed capacities in the study area. As the figure revealed, with an installed capacity of 5.91 m/liters/d, only the Alausa facility approached 6 million liters per day; other facilities were below 5 million liters/d.

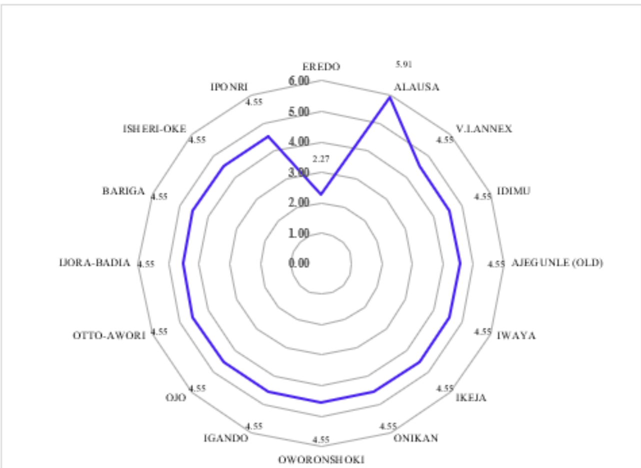

Figure 6: A decagram showing the design capacity of micro waterworks (million liters/day)

Capacity Utilisation:
The capacity utilisation for all the major potable water producers between 2017 and 2021 is shown in Table 1, and from here, the level of utilisation of the waterworks is a far cry from the installed capacity in every year under study. It is obvious that waterworks were not operating at the optimum level of the installed capacity.

Table 1: Total Capacity Utilisation of Major Suppliers in Lagos State between 2017-2021

Year	Designed Capacity (ml/d)	Mean (%) Annual Capacity Utilisation
2017	**559.15**	**18.63**
2018	**559.15**	**27.91**
2019	**559.15**	**17.15**
2020	**559.15**	**18.25**
2021	**559.15**	**12.92**

Source: Lagos State Water Corporation

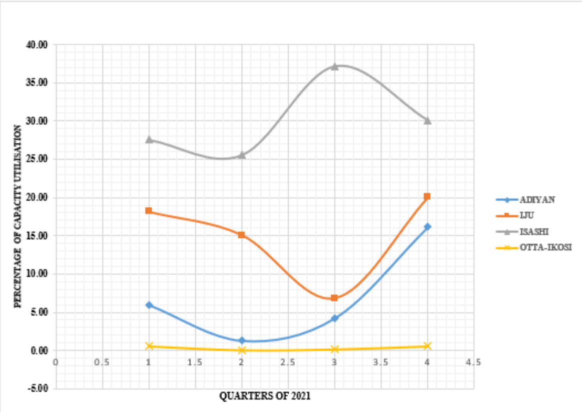

Figure 7: Capacity Utilisation of

Major Waterworks in All Four Quarters of 2021
Table 1 and Figure 7 reveal that major waterworks in Lagos State operate significantly below their design capacity. According to Figure 7, in all four quarters of 2021, Isashi had a higher capacity utilisation of about 40%. Iju and Adiyan facilities, which are the largest water-producing facilities in Lagos State, show utilisation rates much below 20%. However, according to the available data for the year 2018, Iju and Adiyan waterworks performed better, with capacity utilisation ranging from 50% to 55% (for Adiyan), from 35% to 52% (for Iju). The Otta-Ikosi facility remains nearly non-functional. The underperformance relative to design capacity highlights systemic inefficiencies, such as outdated equipment, inadequate maintenance, and frequent disruptions in power supply.

Seasonal variation in capacity utilisation.
Breaking it down to periods of the year, which is tied to the seasonality of rainfall, the pattern of the capacity utilisation is highly varied and generally below 40% with a few exemptions. In the first and fourth quarters, the dry months of the year, capacity utilisation was generally between 20 and 35%. Likewise for the second (April–June) and third quarters (July–

September) of the year, which are the peak rainy season months (Figure 9) and the August break periods of the rainy season (Figure 10) respectively, the production capacity was not improved on as waterworks still produced below 20% in the second quarter and between 20% and 40% in the third. This indicates that other than surface water intake, there are other extraneous factors influencing the capacity utilisation of these facilities.

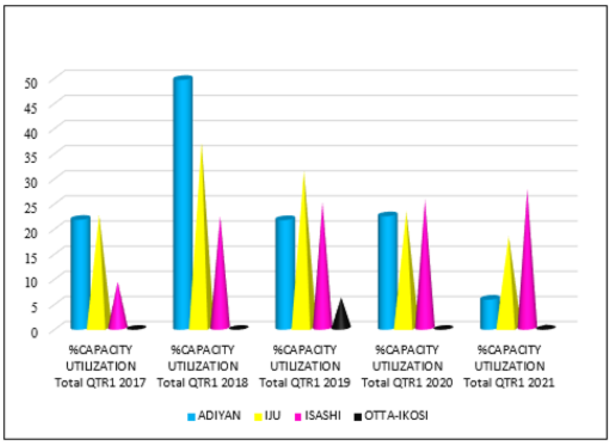

Figure 8: Capacity Utilisation in First Quarter 2017-2021

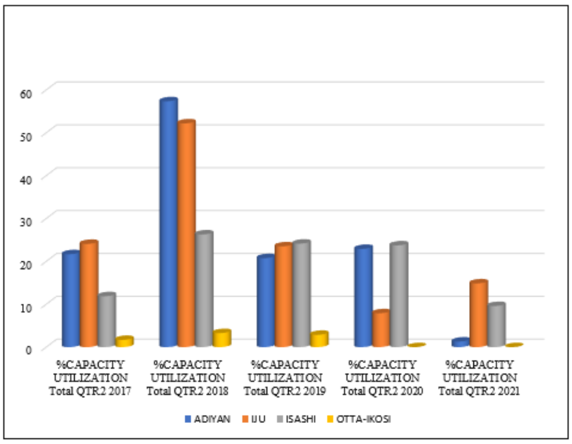

Figure 9: Capacity Utilisation in Second Quarter 2017-2021

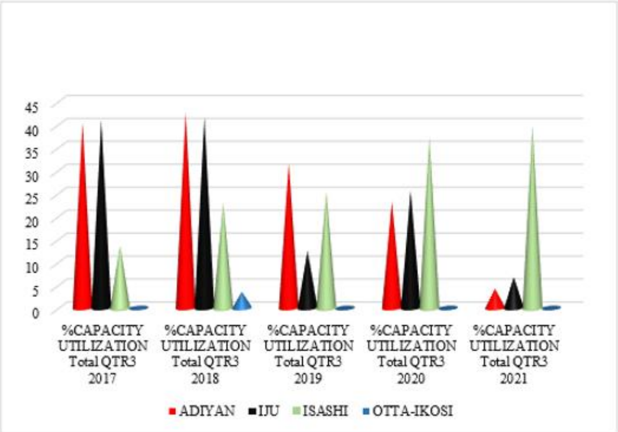

Figure10: Capacity Utilisation in Third Quarter 2017-2021

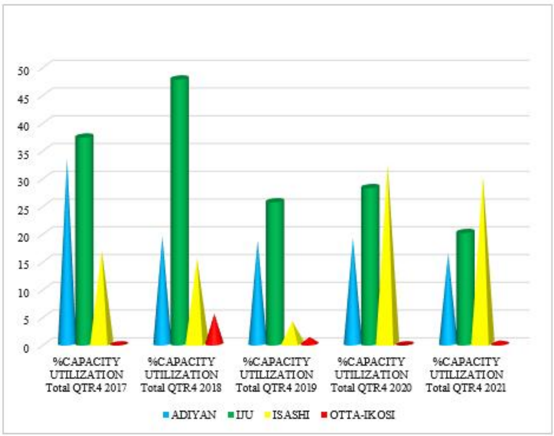

Figure11: Capacity Utilisation in Fourth Quarter 2017-2021

Only four mini waterworks, Amuwo, Isolo, Epe, and Ikorodu, have a capacity of 13.6 million liters. With this group of mini suppliers, the spatial distribution appears to show that Ikorodu, Amuwo and Isolo waterworks were designed with a target of supplying water to the core, high-density metropolitan areas, while the eastern and western flanks of the study area were to be taken care of by Badagry and Epe facilities. These four were followed by Agege, Saka Tinubu (V.I.), Somolu, Badagry, Apapa, Surulere, Shasha, and Ikoyi facilities in the second layer. Furthermore, of the 31 mini facilities in the state, only 8 were functional. These are the Isolo, Ikoyi, Magodo, Mende, Ojokoro, Alexander, Lekki and Dolphin facilities, respectively. Similarly, of the 17 micro-water facilities, only three, namely Alausa, Victoria Island annex and Akute Intake, are functional. However, it is thus important to highlight the state of abandonment of Ijora Badia and Oworonsoki facilities. Of these, only Ikoyi and Lekki mini facilities showed appreciable performance, while Amuwo, Dolphin, Oshodi, Surulere, and Apapa water facilities struggled for improvement in the last quarter of the same year 2021.

Assessment of functionality of the water production facilities:
The state of the infrastructure shows that the waterworks are essentially bedeviled with underlying challenges. For instance, while only three of the four major facilities are functioning, salient challenges include power issues with the Ota-Ikosi facility because it requires connectivity with the national grid and leakage of distribution pipe. Challenges with the other three (Iju, Isashi, and Adiyan) facilities were merely with the raw water inlet chamber and raw water suction at the intake.
The annual productions commencing from 2017 to 2021 were depicted in the graphic presentations in Figures 12 to 16. As depicted in the base year 2017, production witnessed an upward trend. That upward trend continued into the following year (2018), as Figure 13 indicated, but it was not sustained as the trend nose-dived into a downward trend.

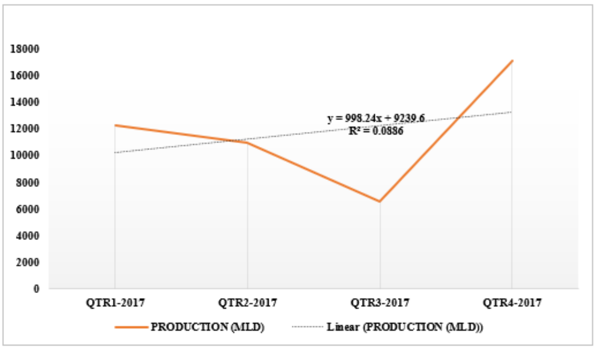

Figure 12: Annual Production (Million liters/day), 2017

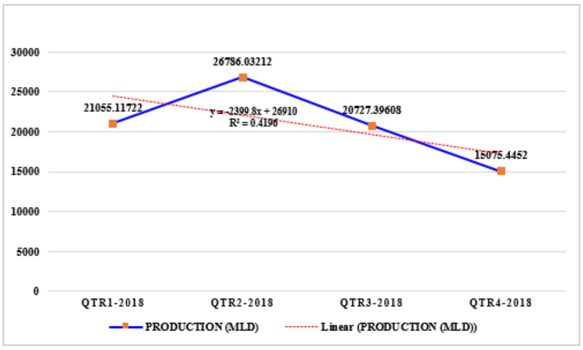

Figure 13: Annual Production (Million liters/day), 2018

As depicted in Figures 14 and 15, slight improvements were recorded in the third quarters of 2019 and 2020, but those slight improvements appeared to be masked by the downward movements.

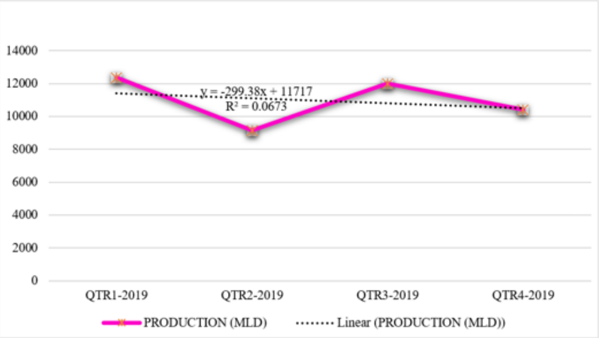

Figure 14: Annual Production (Million liters/day), 2019

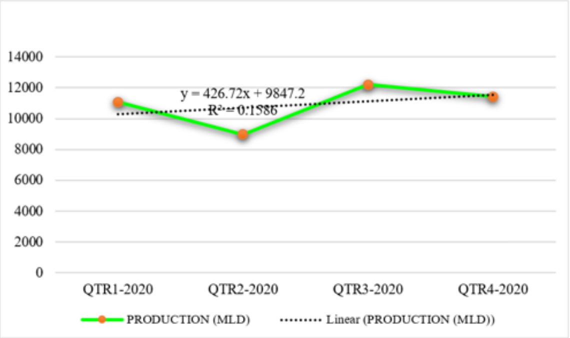

Figure 15: Annual Production (Million liters/day), 2020

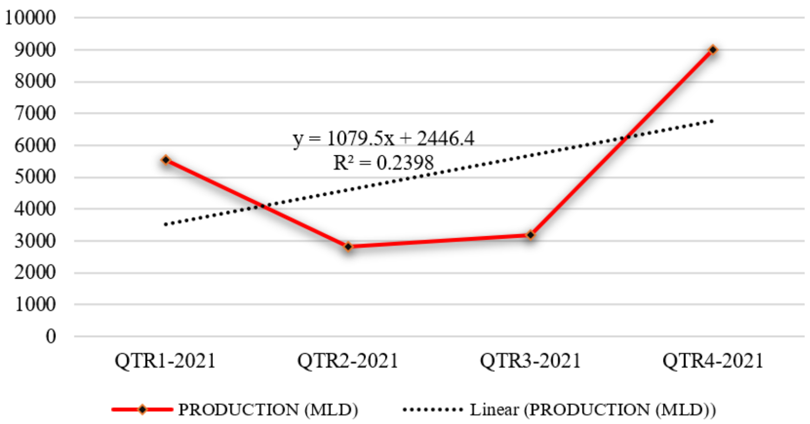

Figure 16: Annual Production (Million liters/day)

In Figure 17, the general picture portrayed confirmed the earlier observation made about the year 2018 as the time period when the system made considerable improvement, although it was not sustained.

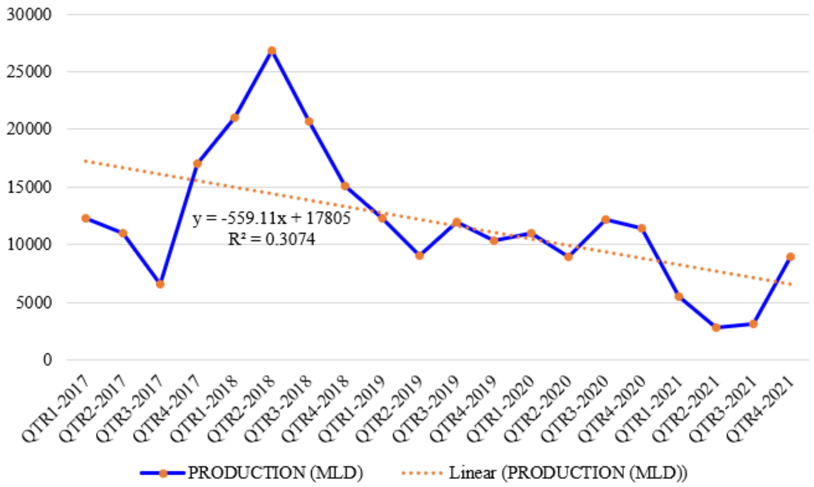

Figure17: Trend Pattern of the Annual Volumetric Production of Major Waterworks in All the Four Quarters of 2017-2021

The quarterly production figures for the three active major suppliers, Iju, Adiyan and Isashi, were selected to highlight further the volume of production in different time periods of the year, as shown in Figures 18 to 21. In a five-year period, the water production figures for Adiyan and Iju were on a downward trend from 2017 to 2021, respectively (*cf.* Figure 18).

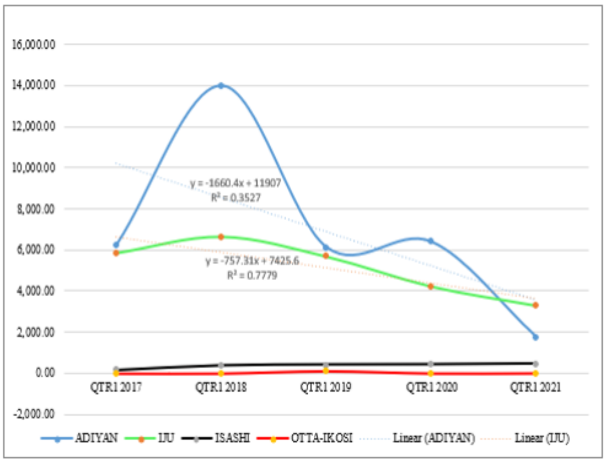

Figure 18: Water Production of Major Waterworks Per Month in the First Quarter (Million liters/day), 2017 -2021

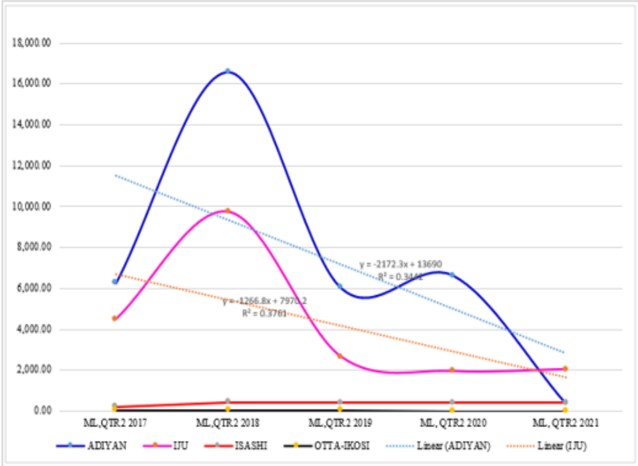

Figure 19: Water Production of Major Waterworks Per month in the Second Quarter (Million liters/day), 2017-2021

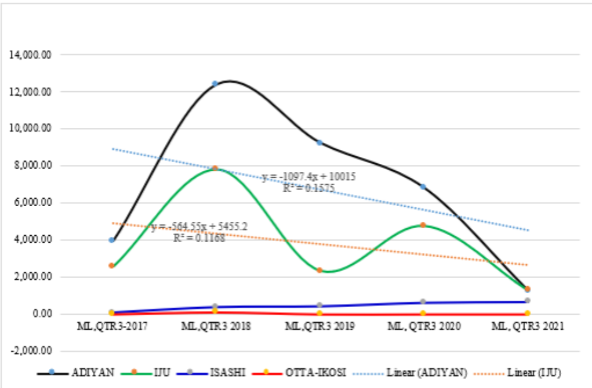

Figure 20: Water Production of Major Waterworks Per Month in the Third Quarter (Million liters/day), 2017-2021

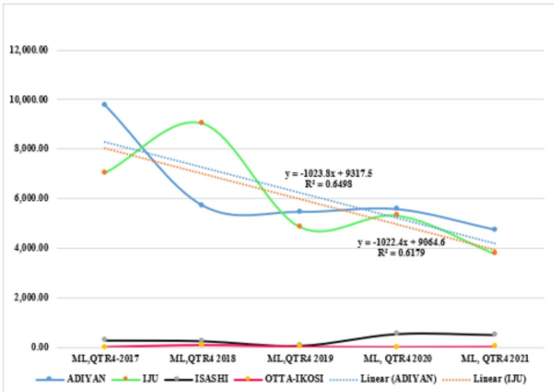

Figure 21: Water Production of Major Waterworks Per Month in the Fourth Quarter (Million liters/day), 2017-2021

In order to obtain a key indicator for describing progress in the supplying system, major water suppliers were selected for a test that investigated the effect of system design on the operational performance. A single ANOVA procedure was employed in testing the effects of levels of system design on operational performance of the major water suppliers in the study area. In the analysis, the dependent variable investigated was the operational performance of the suppliers based on the aggregation of all the quarters for instance, volumetric production of all the first quarters combined from 2017 to 2021, all second quarters combined, and all third to fourth in that order. The results are presented in Tables 2 to 5.

Table 2: The result of single factor ANOVA testing the effect of the levels of system design on the operational performance of major waterworks in the first quarters of 2017-2021

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Design Capa	20	2795.79	139.7895	17265.72415
Prod.	20	62310.1127	3115.505634	13933723.05

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	88548865.1	1	88548865.1	12.69427802	0.001007939	4.098171731
Within Groups	265068786.8	38	6975494.388			
Total	353617651.9	39				

In the first quarter of the period 2017-2021, the outcomes of hypothesis tested showed that operational performance of the waterworks is dependent on or is a function of the levels of system design which comprised of design capacity (mean= 139.7895, sd. =131.399) and volumetric production (mean= 3115.506, sd. 3,732.79) both in units of million litres. A one-way analysis of variance revealed the overall $F(1,38)= 12.694278$, $p= 0.001$, $\eta^2= 0.2504$, $r= 0.50$, $\omega^2= 0.2262$, $\eta^2_p= 0.2504$ was significant. Since $t_{calc.} =3.5629 > t\text{-test } t_{.05}(1,38) = 2.0244$, statistical evidence from the post hoc indicated that performance was better achieved with production level than it was with the designed capacity. The standardised difference d= 1.1266888 represents an effect size amounting to one and one-eight of the standard deviation cf. Table 2, or a difference of more than 113percent in all the first quarters of 2017-2021.

Table 3: The result of single factor ANOVA testing the effect of the levels of system design on the operational performance of major waterworks in all the second quarters of 2017-2021

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Design Capa	20	2795.79	139.7895	17265.72415
Prod.	20	58691.02858	2934.551429	18552319.84

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	78106942.4	1	78106942.4	8.412351706	0.006164554	4.098171731
Within Groups	352822125.7	38	9284792.782			
Total	430929068.1	39				

In a test that investigated the effect of levels of system design: design capacity (mean= 139.7895, sd.= 131.399) and volumetric (liters) production (mean= 2934.55, sd.= 4,307.24) on the operational performance of the major suppliers during the second quarter of the study period, the omnibus was significant $F_{.05}(1,38) = 8.41235$, p-value= 0.00616, $\eta^2 = 0.18125$, r= 0.42574, $\omega^2 = 0.1352$, $\eta^2_p = 0.18125$, leading to the rejection of the hypothesis of no difference in the operational performance. Post hoc assessment which was based on t-test revealed the production level was found to be significantly greater than capacity design $t_{.05}(1,38) = 2.0244$, translating to an effect size d= 0.91719 which is more than 9/10 of standard deviation. This implies that the waterworks system performance was more pronounced with volumetric production than with design capacity.

Table 4: The result of single factor ANOVA testing the effect of the levels of system design on the operational performance of major waterworks in all the third quarters of 2017-2021

Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Design Capacity	20	2795.79	139.7895	17265.72415		
Prod.	20	60425.9775	3021.298876	14257986.85		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	83030962.84	1	83030962.84	11.63285377	0.00155	4.09817
Within Groups	271229798.8	38	7137626.285			
Total	354260761.7	39				

The overall third quarter performance was subjected to test with single factor ANOVA, hypothesising that operational performance of major water suppliers in all third quarters of the study period is dependent on the effects of the levels of system design which comprises of design capacity (mean = 139.7895, sd= 131.399) and volumetric litres production (mean= 3021.299, sd.=3775.97). The analysis revealed overall main effect was significant $F_{.05}(1, 38) = 11.633$, p-value= .00155, $\eta^2 = 0.2344$, r= 0.484, $\omega^2 = 0.209999$, $\eta_p^2 = 0.2344$ thus leading to the stepping down of the null proposal of no difference and upholding the alternative.

A post hoc test using Fishers' method pointed out that with t-statistic = 3.4107 $> t_{.05}(1, 38) = 2.02$ implying that volumetric production level is significantly higher than the design capacity. Therefore, the performance in the third quarter was reflected with volumetric production than it is with design capacity. The effect that occurred indicates a standardised mean difference d = 1.07856 a magnitude that is one/one-tenth of the standard deviation.

Table 5: The result of single factor ANOVA testing the effect of the levels of system design on the operational performance of major waterworks in all the fourth quarters of 2017-2021

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Design Capa	20	2795.79	139.7895	17265.72415
Prod.	20	62990.8762	3149.543809	11066785.32

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	90586210.01	1	90586210.01	16.34532531	0.00024856	4.098171731
Within Groups	210596969.8	38	5542025.52			
Total	301183179.8	39				

For the test in all the fourth quarters, the main effect was significant $F_{.05}(1,38)= 16.345$, p-value $=0.000249$, $r^2_{pb}(\eta^2) =0.30077$ implying volumetric production accounts for 30% of variation in operational performance, $r_{pb} =0.5484$, $\omega^2 = 0.277265$, $\eta_p^2 = 0.300768$. Post hoc test on the difference of means between the design level and volumetric production indicated that test statistic $t_{stat.} =4.0429$ was greater than the t from the table $t_{.05}(1,38) = 2.024$ in favour of volumetric production level of system design cf. Table5. This implies that operational performance in all the fourth quarters was better obtained at the level of volumetric production than it does with design capacity.

Summary and Recommendations for Sustainable Development

The central objective in this study was the assessment of the status of the existing water infrastructure in Lagos State. This was primarily focused on the identification and inventorying existing state water facilities. Subsequently, due to the relationship and the significance of the facilities to the production of water for consumers, the study examined the state of the functionality of the existing and available water facilities in the state as a precursor for the assessment of water production. That functionality assessment was promptly followed with (seasonal) time-dependent volumetric water production (million liters) of the three tiers of suppliers in the state, namely, major, mini and micro waterworks, as exemplified in the graphic and statistical descriptions. A capstone of this assessment was the performance assessment of major suppliers based on inferential statistics for the period of 5 years for which data was available.

From the results, it was observed that all the metrics of assessment showed that the state of functionality of the entire system’s facilities is distressed. Descriptive statistics from graphical assessments of quarterly water production of the system showed declining trends throughout the five years of data coverage. Although one or two occasions were observed when the system performed creditably, especially in the quarters, those performances were not sustained for a good length of time as volumetric production remained nearly stagnant.

In each assessment of every quarter using single factor analysis of variance to investigate the effect of levels of system design on operational performance, consistently signified is that operational performance was much achieved at the volumetric production level of system design than it was with capacity design.
In order to achieve the SDG 6 objectives and promote sustainable development, there is a need for a re-visit of the state's public water infrastructure. The expansion and renovation of old waterworks, as well as the construction of new ones, are essential in order to improve the production capacity and consequent volume of potable water supply to residents. The study thus recommends a thorough system re-engineering, including the deployment of system tools that should include geospatial technology with a view to providing a wholesome assessment of the entire water supply system.
The findings of this study on water infrastructure in Lagos State reveal critical gaps that hinder reliable supply of potable water, impacting public health, economic growth, and progress towards Sustainable Development Goal 6 (SDG 6). To address these challenges, stakeholders must implement targeted policy actions. The recommendations provide actionable steps focusing on funding mechanisms, regulatory changes, and technological adoption.

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