Service Level Indicators for Water Supply Systems: Appraisal and Implications for Sustainable Management

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Abstract

Access to adequate water supply is vital. The wellbeing of the human population and their environs is directly linked to the level of water service delivery. The service level of three main categories of water supply systems was assessed across 6 locations in Ogun State, Southwest Nigeria. The water supply systems categories included: self-supply systems (hand-dug wells and boreholes), communal water supply systems (boreholes only), and public water systems. Five service level indicators (access, quality, management, cost, and reliability) were assessed using structured questionnaires. Questionnaire administration targeted water supply system users and owners in two categories: owners/resident users and non-resident users. Results show that owners/resident users restricted the access of non-resident users to water assets, which expectedly dipped access to adequate service level for non-resident users. When post-abstraction treatment was practiced by water users, the use of sodium hypochlorite solutions (Water Guard®) was the most prominent option of treatment. Management and costs (cleaning, maintenance and repair) of water supply systems are borne by owners/resident users; costs borne by non-resident users is only from purchase of water. Reliability of water supply systems is hampered by geology and climatic seasonal variations as some water supply systems dried up during the off-rain season. Coverage area and number of public water supply systems needs to be improved to reduce reliance of water users on questionable alternative sources that can expose water users to water-related diseases and prevent restricted access to water supply sources.

1. Introduction

Ready access and availability of sufficient supplies of clean water are integral requirements for wellbeing, food adequacy and socio - economic development (Sanneh, 2018). Access to an adequate water supply, for instance, is one of the key strategies to alleviate poverty (Ibrahim, 2017). The quest for sufficient, reliable, sustainable water supply has led to the promotion of community-based water supplies to facilitate accessible, equitable and sustainable water supply delivery in Sub-Saharan Africa (JMP, 2014). It is well known that the level and consistency of water service delivery that a population is accessible to have direct impact on health, wellbeing and water security.

Monitoring of water service level using multiple indicators was proposed as a way to achieve water supply safety and sustainability (Kayser et al. (2013). Generally, indicators are defined as useful qualitative and quantitative parameters/tools, which provide a means of collecting information about a system, evaluating changes over time and communicating the information to relevant groups (Lundin, 2003; Guio-Torres, 2006; Shilling et al., 2013). Several water service level indicators (or measurable factors) have been developed to measure the service level of water supply systems and for determining the sustainability of those water supply sources. This study observed that there are, technically, no comprehensive service level factors for water supply systems. However, examples of different service level factors indicate that access (sometimes captured as coverage, or equity or availability), quantity, quality and reliability are commonly evaluated. Carter (2006a) in accessing water sources in Uganda, highlighted five sustainability factors (service level indicators) that can be used to assess the sustainability of a water supply system. The factors are access, quality, reliability, cost and management.

Access is defined relative to the volume of water consumed, classified as 'coverage' and linked directly to distance and maximum number of people that rely on a water supply system (Lloyd and Bartram, 1991; Kayser et al., 2013). In addition, Howard and Bartram (2003) associated the level of water access to health risk by highlighting that all hygiene needs can only be met when there is optimal access to water (100 litres per capita per day).

Quality is largely categorized based on compliance to WHO Drinking-water Quality Standard and or the National Drinking-water Quality Standards of the countries where the water supply systems are domiciled (WHO, 1997; Moriarty et al., 2011; Kayser et al., 2013). Understandably, quality is also captured in some studies and associated with sanitary risk (Lloyd and Bartram, 1991; WHO, 1997; Carter, 2006a; Adank et al., 2016). For instance, Carter (2006a) was specific in describing quality with contamination sources such as latrines and animal invasion of supplies.

Reliability, quantity, continuity and coverage are closely linked. Reliability, quantity, continuity and coverage are all influenced by the level of access to a water source, although, all four factors are slightly different depending on the definer. For instance, UNCESCR (2003) defines quantity in terms of availability, as the level of sufficiency and continuity. While Carter (2006a) considers quantity to be embedded in reliability; measuring reliability with respect to availability and the number of hours consumers could access water in adequate volumes. However, Lloyd and Bartram (1991) and WHO (1997) defines coverage, quantity and continuity separately. Coverage is defined relative to the total population served with the type of water supply system, continuity on the number of hours per day or per year that water is supplied, and quantity with respect to the volume per capita per day consumed.

Cost and management are the least focused on factors, a phenomenon this study thinks could be associated, in part, to the fact that most studies on water supply are consumer-centered and based on access, quality and reliability. Not to imply that management issues, for instance, have been taken as trivial, or that the question of affordability (cost) has been treated with levity. However, access, quality and reliability have continually taken the center stage in assessment schemes for water service levels. Cost is classified by Lloyd and Bartram (1991) and WHO (1997) based on the tariff paid per month by consumers (which is restricted to piped, distributed water by public utilities). However, Carter (2006a) classified cost with respect to time and energy spent on water sourcing by consumers, and the capital costs on operation, maintenance and repair of a system. Except for Carter (2006a), studies have not been explicit in measuring management as an indicator. For instance, CWSA (2014) examined management based on the provision of technical assistance and systems inspections (applicable mostly to public utilities). Management has also been viewed based on water supply system performance in service delivery (Lockwood and Gouais, 2014).

In this study, the service level of water supply systems across 6 locations in Ogun State, Southwest Nigeria was evaluated. Ogun State, located within latitudes 2°45'E and 4°45'E and longitudes 6°15'N and 7°60'N, is bordered by Lagos State and the Atlantic Ocean to the south, Oyo State and Osun States to the North, Ondo State to the east, and the Republic of Benin to the west (Fig. 1). Ogun State covers a land area of 16,409.26 sq.km and had an estimated human population of 3,728,098 at the 2006 population census (National Population Commission, 2009). However, at a 2.6% annual growth rate (World Bank, 2017), the population is currently estimated as 5,340,113; 50.3% (2,686,077) of which are male and 49.7% (2,654,036) female. The population density is about 325 persons per square kilometer. The State is in the humid tropical climatic zone of south western Nigeria, with two distinct seasons: the rainy season, which

lasts from March/April to October/November, and the dry season from October/November till March/April. The mean annual temperatures range between 24ºC and 30ºC (Sadiq et al., 2015). Three types of water supply systems exist in Ogun State: public water supply (State-owned public utility), communal water supply and self-supply systems. Water is abstracted by the State-owned public utility from both surface and ground water sources. The surface water source is primarily the Ogun River (the largest body of water in the State). Public water supply systems across the State are, however, challenged by water shortages linked to break downs of infrastructure, power outages, poor coverage area, or complete absence of water supply in areas previously having water supply. Hence, consumers are compelled to alternate public water supply systems with communal and self-supply sources such as hand-dug wells and boreholes as a coping strategy against inconsistent service.

2. Methodology

Six study locations: Abeokuta, Abigi, Imeko, Ijebu-Igbo, Sagamu and Sango-Ota were selected in Ogun State, Nigeria by stratified random sampling method based on population density and geographical spread (Fig. 1). The study adopted Carter's sustainability factors: access, quality, reliability, cost and management as service level indicators for assessment (Carter, 2006b). Adoption of Carter's (2006) sustainability factors was based on the fact that the indicators are easy to measure, applicable to the study locations and have been previously tested in Sub−Saharan Africa, especially, on water supply systems that are similar to what is obtainable in the study area.

Three (3) categories of water supply systems were evaluated: self-supply systems (hand-dug wells and boreholes), communal water supply systems (boreholes only) and public water systems. Self-supply systems are privately owned water initiatives; excluded from government interventions or NGOs initiatives (Carter, 2006a; Oluwasanya et al., 2011a; 2011b), while Communal Water Supply System (CWSS) refers to heavily subsidized water supply services, which are implemented by governments and NGOs, but managed by communities (Danert and Sutton, 2010) to which no individual can lay claim. Public water supply system is a system that provides for the wider public; it is water treated for human consumption and distributed through pipes or other conveyances and have, at least, fifteen service connections or regularly serves at least 25 individuals (USEPA, 2015). The unusual characteristics of the outlined water supply systems are that poor coverage or limitation of public water supply systems, has led to increased adoption of self-supply systems and communal water supplies as coping strategies. (Sutton, 2004; Oluwasanya et al., 2011a). The use of alternative water supplies as coping strategy ensures water supply consistency.

Two types of structured survey forms (questionnaires) were used to assess the service level indicators of the water supply systems, namely, resident user/owners' and non-resident user questionnaires. Questions in both survey forms were adapted from Howard (2002a) and centered around the service level indicators. The goal of the study was to assess each service delivery indicator from two perspectives: owners/resident users' views and the non-resident user. Responders were selected from a larger population of water supply system users and owners based on the stratification method presented in Howard (2002a). Owners/resident users' questionnaires were administered to owners/residents of houses in which the water supply systems were domiciled. In the case of communal water supply systems, questionnaires were administered to residents living around the water supply system who also used such water supplies for their daily water needs. Non-resident user questionnaires were administered to persons making use of the water sources, but not residing close (that is persons residing farther than 500m from the water source) to the water supply systems. A total of 441 questionnaires were administered in all the six study locations (Table 1), 186 questionnaires for owner/resident users and 255 non-resident user questionnaires.

3. Results And Discussion

The data obtained from the owner/resident user and non-resident user survey forms is summarized in Tables 2 and 3 based on the relationship of each question with the service level indicators. In the following text, presented percentages represent the number of responders (in number unit of measurement) who commented on particular service level indicators. To the non-resident users, access to water sources is, generally, restricted. Restricted access refers to exercise of control by owners/resident users over self-supply systems to limit the access of non-resident users to water source.

Table 1
Questionnaire distribution across six locations in Ogun State, Nigeria

S/No	Study locations	Number of Resident user/Owner	Number of Non-Resident user	Sub − Total
1	Abeokuta SSS/CWSS	48	69	117
	PWS	23	29	52
2	Abigi	22	28	50
3	Ijebu − Igbo	12	21	33
4	Imeko	23	30	53
5	Sagamu	23	30	53
6	Sango − Ota	35	48	83
Total		186	255	441
SSS = Self-supply systems; CWSS = Communal Water Supply Systems; PWS = Public Water Systems				

In Abeokuta, 21% of the owners/resident users of self-supply systems/communal water supply systems and 80% of the owners/resident users of public water supply systems admitted to restricting access to their water supply systems. At Abigi, Ijebu-Igbo and Imeko, 15%, 19% and 21% of the owners/resident users of

water systems apply restriction on non-resident users. However, more owners/resident users restricted access to their water supply systems at Abeokuta than the rest of the study locations. This may be connected to the fact that Abeokuta is prone to water scarcity as reported in previous studies (Orebiyi et al., 2008; Orebiyi et al., 2010; Shittu et al., 2010; Taiwo et al., 2011; Ayedun et al., 2015). For non-resident users, the impact of owner/resident's restriction of access to water supply systems included walking longer distances to obtain water and reduction in the volume of water available for use per day.

The level of access that non-resident users have to water supply systems is contingent on proximity of the water systems to the residence of the non-resident user, with a minimum quantity threshold of 50 litres per capita per day. Based on the classification of the level of access into no access, basic access, intermediate access and optimal access by (Howard and Bartram, 2003), the observed level of access that non-resident users have in this study could best be classified as basic access. Howard and Bartram (2003) described basic access as accessibility to water within a 1000m distance and 30 minutes round trip. Except for Sango-Ota, non-resident users in all other locations trekked distances farther than 10 meters to access water. All non-resident users in Sango- Ota accessed water supply systems less than 10m walking distance. Seasonally water-stressed Abeokuta city recorded the highest (64%) percentage of non-resident users that had to walk more than 10m to access a water supply system.

Table 2: Service Level Indicators of Water supply Systems in Ogun State, Nigeria: Summary of Owner/Resident User Survey

Service Level Indicators	Characteristics	Abeokuta (Kayser et al.)		Abigi (Kayser et al.)	Ijebu – Igbo (Kayser et al.)	Imeko (Kayser et al.)	Sagamu (Kayser et al.)	Sango – Ota (Kayser et al.)
		(SSS/CWS) No. 48	(PWS) No. 23	SSS No. 22	SSS No. 21	SSS No. 23	SSS No. 23	SSS No. 35
Access	Water restriction (Yes)	21	80	15	19	21	4	4
Quality	Good/Fair	100 Good	85 Good	100 Good	100 Good	100 Good	100 Good	100 Good
Management	Age of WSS (Over 1 year)	91	N/A	65	90	60	86	100
	Construction (Private Owner or otherwise stated)	89	100 (OGSWC)	100	100	100	100	100
	Supervision (Owner or otherwise stated)	66	66 (Resident user)	80	85	70	100	96
	Repairs responsibility (Owner)	87	7 (OGSWC)	100	100	100	100	100
	Protection (Owner or otherwise stated)	85	69 (Resident User)	100	100	100	100	100
	Cleaning (Owner or otherwise stated)	79	85 (Resident User)	100	100	100	100	100
	Repair cost (Owner)	87	3 (OGSWC)	100	100	100	100	100
Cost	Water Sale (Alexander et al.)	90	31	95	90	90	45	61
	Maintenance cost (Owner)	83	76 (Resident User)	100	100	100	100	100
Reliability	WSS reliability (regular/irregular)	85 (regular)	41 (irregular)	100 (regular)	10 (irregular)	15 (irregular)	100 (regular)	100 (regular)
	Source dry up (seasonally)	57	14 (Occasionally)	-	52 (seasonally)	100 (Occasionally)	-	-

SSS - Self-supply System; CWSS - Communal Water Supply System; PWS - Public Water System; OGSWC - Ogun State Water Corporation

Service Level Indicators	Characteristics	Abeokuta (Kayser *et al.*)		Abigi (Kayser *et al.*)	Ijebu – Igbo (Kayser *et al.*)	Imeko (Kayser *et al.*)	Sagamu (Kayser *et al.*)	Sango – Ota (Kayser *et al.*)
		(SSS/CWS) No. 69	(PWS) No. 29	(SSS) No. 28	(SSS) No. 25	(SSS) No. 30	(SSS) No. 30	(SSS) No. 48
Access	Distance to Water source > 10m	64	10	36	8	7	18	-
Quality	Quality Perception (Lawrence *et al.*)	87	75	42	13	15	70	74
	Treatment before use (Yes/No)	7 (Yes)	100 (No)	7 (Yes)	7 (Yes)	11 (Yes)	14 (Yes)	36 (Yes)
	Mode of Treatment	93 (Water Guard)	-	2 (Alum)	7 (Boiling/ Filtration)	3 (Boiling/ Filtration)	20 (Water Guard)	54 (Water Guard)
Management	Contribution to source management	-	45	-	25	-	27	18
Cost	Water Purchase (Yes)	35	55	10	9	7	55	26
Reliability	WSS reliability (regular/irregular)	27 (irregular)	66 (irregular)	95 (regular)	9 (irregular)	100 (regular)	91 (regular)	95 (regular)
	Quantity (at least *50 l/p/c/d)	16	4	30	17	40	100	4

SSS - Self-supply System; CWSS - Communal Water Supply System; PWS - Public Water System; l/c/p/d - Litres per capital per day; * Gleick (1996)

Apart from 15% of owners/resident users of public water supply systems at Abeokuta, all other owners/resident users in the study locations attested to the fact that the quality of their water is perceived as good. Similarly, Abeokuta, Sagamu and Sango-Ota recorded high non-resident users' responses that the quality of water they obtained is good, while the least percentage of 13% for good water quality was recorded at Ijebu – Igbo. Oluwasanya (2009) reported that user perception of good water quality is premised, in part, on water clarity. That is, water clarity is an indication of good water – turbid water is poor water, clear water is good water. But clear (non-turbid) water may not be safe, even if it is perceived as such.

Abeokuta and Sango-Ota recorded high levels of post-abstraction water treatment practice amongst the non–resident users with the use of Water Guard® as the most common water treatment method. Water Guard® is a sodium hypochlorite solution used in household water treatment. The practice of post-abstraction water treatment amongst users is good practice in areas where water is hauled and stored, particularly, for the mitigation of water-related diseases due to water contamination during storage and transport activities. Still, more post-abstraction water treatment amongst non-resident water users should be encouraged. However, it should be noted that the practice may suggest that the quality of the available water may not be safe, and may limit water use activities to non-ingestion purposes.

On management, 85% of self-supply/communal water supply systems and 7% of public water supply systems in Abeokuta are privately maintained by the owners/resident users, while 100% of self-supply systems in all other study locations are privately maintained by owners/resident users. The remaining 15% and 93% respectively are maintained by non-resident users. Maintenance in this context was defined to responders as supervision, repair responsibilities, protection and cleaning. Supervision involves overseeing the operation/use of the water source by users and protection involves upkeep of the water source by looking out for broken parts, highlighting where the system required fixing and ensuring that the structure of the water source remains intact. Repair responsibilities refers to bearing repair costs. Cleaning is ensuring the water source is well kept, especially, ensuring it is free from potential sources of contamination. Cleaning of the water supply systems is 100% done by owners/resident users in all study locations except for Abeokuta, where cleaning is carried out by only 79% (self-supply supply/communal water supply systems) and 85% (public water supply systems) by owners/resident users. The remaining 21% and 15% are carried out by non-resident users.

For cost, the maintenance/repair costs for most (94%) water supply systems in the study locations is borne by owners/resident users. However, non-resident users are sometimes charged for repairs, especially, in the case of communal water supply systems. Across the six study locations, owners/resident users are involved in selling of water from their water supply systems. Non-resident users' financial contributions (cost) resulted from fees paid for water where owners/resident users were selling water. Beyond this, non-resident users' financial contributions to water supply systems is minimal, or sometimes non-existent, across the study locations. Public water supply systems in Abeokuta, and self-supply supply systems in Ijebu-Igbo, Sagamu and Sango-Ota recorded minimal (45%, 25%, 27% and 18% respectively) contributions of non-resident users to water supply systems management. However, non-resident users' contributions are non-existent in self-supply supply/communal water supply systems at Abeokuta, Abigi and Imeko. Public water supply systems in Abeokuta and self-supply supply systems in Sagamu recorded the highest percentage of water supply systems support for maintenance and repair with the associated high prevalence of water purchasing.

Only Abigi, Sagamu and Sango-Ota recorded 100% reliability of the water supply systems. Self-supply systems in Ijebu-Igbo and Imeko, and public water supply in Abeokuta are described as irregular by owners/resident users. Responders stated that the water supply systems dry up occasionally/seasonally. Public water systems are known to be irregular during the dry season, as surface water, which is a major source of raw water for public utilities, experiences considerable reduction in water volume resulting in the provision of intermittent supply (Orebiyi et al., 2008; Ufoegbune et al., 2010; Adekunle et al., 2013; Ayoade et al., 2015). Owners/resident users attested to irregular self-supply/communal water supply systems in Abeokuta, Ijebu-Igbo and Imeko, which may be attributed to the geology of the three locations, which is classified as having a basement complex. Generally, basement complex rocks are characterized by low groundwater yield (Ifabiyi, 2000; Akinwumiju and Olorunfemi, 2016). Hand-dug wells and boreholes located in basement complex terrain are known to experience low yields, especially, during the dry season when supply cannot recharge the minimal porosity in the aquifer (Bayewu et al., 2017).

Non-resident users attributed reliability of a water supply source to the level of access to adequate water from the systems. Non-resident users lamented limited access to water supply systems, which is mainly due to restrictions placed on the sources by owners/resident users such as locking of the water systems. The reliability of water systems as it relates to non–resident users was evaluated based on the quantity of water accessible for use. The quantity of water available was determined based on the basic daily water minimal requirement of 50 litres per capita per day (l/p/c/d) suggested by Howard and Bartram (2003). Sagamu recorded the highest percentage (100%) of non – resident users that had access to the basic 50 l/p/c/d, while the least percentage of 4% each was recorded for public water supply systems in Abeokuta and self-supply supply systems in Sango-Ota.

3.1 Assessment of Service Level Indicators: Implications for Sustainable Water Management

The results presented in this paper highlighted few concerns on the evaluated indicators. For instance, the claim by most of the responders that the quality of their water was perceived as good may not be a guarantee of high-quality or safe water. Similarly, the practice of post-abstraction water treatment method by some users suggested that water from the available water supply systems in the study area may not always be perceived as safe. Oluwasanya (2009) highlighted the need to understand why water users may not see anything that is wrong with their water quality. It was reported that there are certain user-prescribed criteria for good water and preconceived water safety conditions (Oluwasanya, 2009). Preset criteria for good water include 1) water clarity - turbid water is poor quality, Clear (un-turbid) water is of good quality, 2) number of users of particular system (if the number of users of a particular system is large then the water must be good), and 3) the length of time the water source had been in use without users being infected with water-related illness (Oluwasanya, 2009). That is, once the preset criteria are in place, then the water must be good. However, clear water though appearing good does not mean safe water. Long term usage without infection with water disease may mean localized community immunity. Immunity to water disease due to long term usage does not imply the water is safe for use for new users and would be risky to non-residents who are tapping this supply infrequently. Usage of source water by many people also does not imply the water is safe for use and is related to acquired immunity. Thus, as suggested by Oluwasanya (2009), preset water user criteria for good water, in part, must be aligned with established water safety guidelines. Water users who do not see anything wrong with their water may find it difficult to see the need to take informed water safety measures or adopt appropriate management procedures. There is therefore, the need to always identify correctly through research (e.g. service level indicator assessment) the attitude of water users to water safety and development indicators, and the factors, which inform the attitude, so as to target guidance, enlightenment and training appropriately.

Also, the limited coverage area and unreliability of Public Water Systems is noted in this paper. The resulting reliance on alternative water sources further exposes consumers to the risks of water-related ailments – which could sometimes be fatal. In addition, buying water from sources other than PWS can strain the financial budgets of water users. The need for the provision of adequate, safe and affordable drinking–water through functioning public utilities and to drive Sustainable Development Goal (SDG) 6, cannot be overemphasized. SDG 6 is….please insert. However, provision of PWS is capital intensive and rests on the government. The rate of increase in population and city expansion in the study areas had far exceeded the coverage area of existing facilities of the public water supply systems. While fixing the highlighted problem is long term, the short term goals to protect public health may be to 1) create ongoing awareness on the importance of consuming safe drinking-water, 2) emphasize and encourage affordable post-abstraction water treatment methods and 3) appropriate system management. A good strategy to achieve the first and second short-term goals could be to educate consumers on the cost benefit analyses of living a water-related disease free, especially, when considering the fatality of such diseases, which can involve considerable costs in labor and health care. But adherence to the stated practices maybe a different ball game, as water scarcity, costs of post-abstraction treatment, cleanliness of water hauling and storage vessels and a lack of control over water quality when forced to buy water from owner/residential self-supply systems can expose non-residents to enhanced disease risks. Nonetheless, appropriate system management may be driven through continued advocacy to domesticate Water Safety Planning for the identified three main water supply sources in Nigeria towards the provision of safe and affordable water for all, without leaving anyone behind.

4. Conclusion

This paper evaluated five service level indicators of water supply systems in selected locations in Ogun State, Southwest Nigeria. All self-supply supply/communal water supply systems in the study area are privately owned or constructed by Non-governmental Organizations. As such, the government is not involved in the construction, operation, maintenance and management of the water sources. Poor access to water supply systems by non-resident users is evident and quite prevalent. Non-resident users walk more than 10m to access water. Poor access is further compounded by limited coverage of public water supply systems and seasonality for other sources, such as self-supply or communal hand-dug wells. Water users rely on self-supply and communal systems as alternative sources during dry seasons and other times when the public water system is not available. As such, self-supply and communal sources should be included in evaluation and assessment of sustainable water supplies. Restriction of access to water supply systems by owners/resident users affects the volume of water that non-residents users can get, resulting in walking long distances to obtain water and restriction of hygiene practices known to reduce water-related disease burdens.

While some water users do not subject their water to post-abstraction treatment, large numbers of non-resident users practice post-abstraction water treatment in Abeokuta and Sango-Ota. Abeokuta and Sango-Ota are urban cities and are, generally, expected to have residents with higher levels of literacy compared to other study locations. However, post-abstraction water treatment practices should be encouraged for all users who haul and store water. Costs to cover water supply systems maintenance/repair on the part of owners/resident users, and for the purchase of water on the part of non-resident users, are factors that can impact the accessibility of water supplies and public health. Coverage area and the volume of public water supply systems needs to be increased to reduce reliance of water users on questionable alternative sources that can expose water users to water-related diseases or limit water usage. It is important to always identify the water user perceptions of their water supplies correctly through research or assessment of development indicators. Such evaluation would target guidance and identify appropriate training and investments that need to be made to assure the provision of adequate amounts of safe drinking water to supply more than basic needs and support appropriate hygiene uses. Water supply is a complex topic, and as always, people will seek to find the optimum solutions for their circumstances and needs.

5. Declarations

Conflict of Interest

The authors declare that there is no conflict of interest.

Availability of data and material

The data used is this study are available. Assessed water supply systems in this study were majorly privately owned and are used with the support of the respective owners.

Code Availability: Not Applicable

Authors' contributions:

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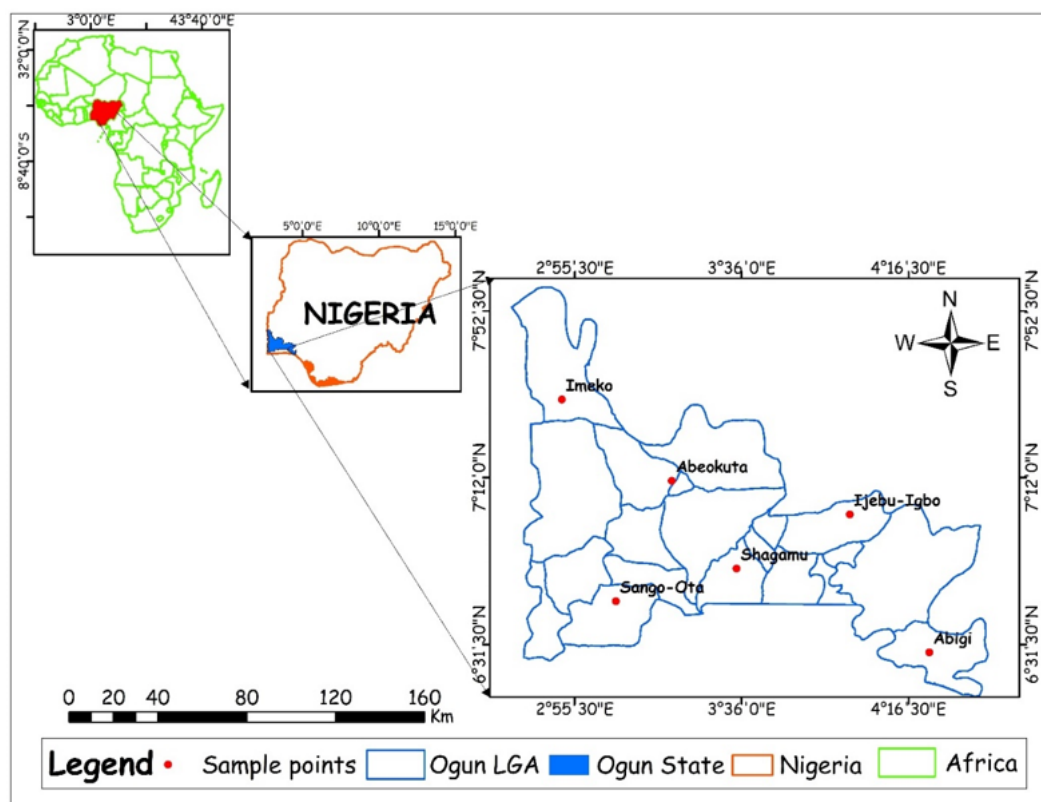
Figures

Figure 1

Map of Ogun State in Nigeria showing the study locations (Reproduced using Arc Map 10.1) Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors