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Research

Sustainable development goal 6 and the challenge of pipe-borne water connectivity in a growing tropical city: a case study

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Abstract
Water dams have been constructed in various regions across the globe to enhance access to potable water. Among these, the Aiba water reservoir, commissioned in 1957, was envisioned as a pivotal source of treated water for Iwo and its environs. Unfortunately, despite its inauguration, the primary objective of ensuring a sustainable and reliable water supply to the community remains unrealized to date. This research seeks to evaluate the accessibility of the study area to pipe-borne water (PBW) and discern the driving forces through the administration of structured questionnaire across 480 respondents out of which 458 were retrieved for analysis. The study utilized both descriptive and inferential statistics, employing Statistical Product for Service Solutions (SPSS) version 23. The respondent demographic revealed that 83.6% were female, and 18.4% claimed paying water tariffs while 76.2% relied on groundwater as their principal source of water. The data showed revealed diverse factors hindering PBW connectivity namely: Administrative bottlenecks (12%), while 57% cited the availability of alternative water sources as a reason for not connecting to PBW; 9% reported poor infrastructure for PBW, and 18% highlighted the unreliability of water supply from Aiba Water Works (AWW). Further analysis through Factor Analysis (FA) pinpointed three salient variables significantly influencing PBW accessibility. These are proximity to the main network (42.557%); cost of connectivity (22.275%); and availability of other sources (14.480%). These findings underscored the critical importance of expanding the PBW network, given the prevalent non-proximity of most residences to the main water pipes. Moreover, the research suggests that capacity building initiatives should be implemented to enhance the economic well-being of citizens, thereby fostering an improved quality of life for the inhabitants of the studied area. In conclusion, this study provides valuable insights into the complexities surrounding water accessibility and offers practical recommendations to realise SDG 6 by 2030.

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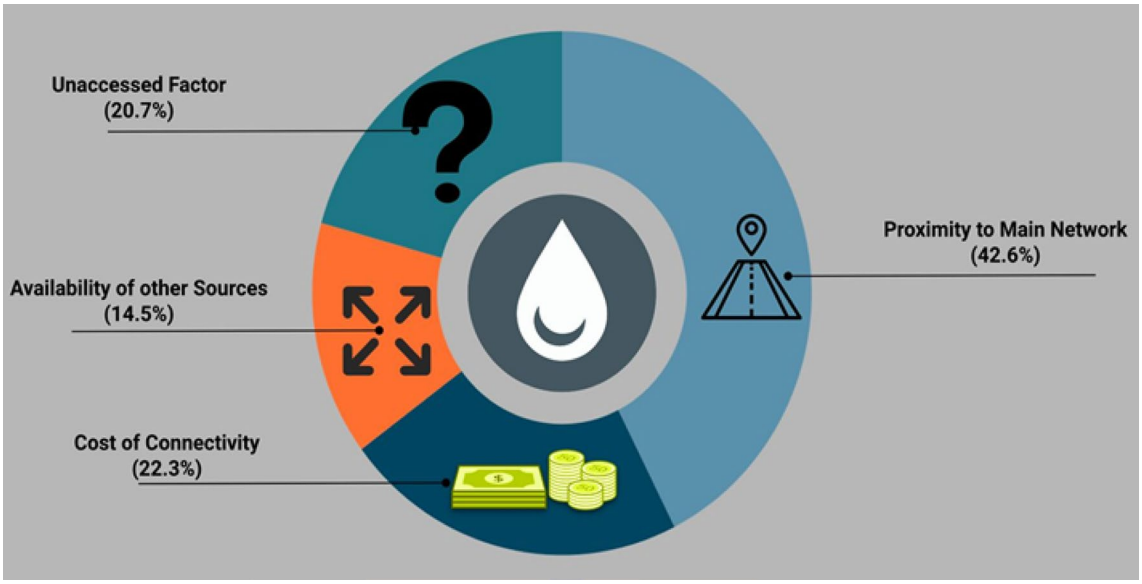
Graphical Abstract



Keywords Pipe-borne water · Water accessibility · Expanding community · Climate change era · Water infrastructure · Nigeria

1 Introduction

In view of the appreciable success recorded globally at the end of Millennium Development Goals (MDGs) in 2015, especially in water accessibility, it was resolved that further steps needed to be taken to further the sustainability of the hitherto accomplished [1]. Water is considered accessible when an individual has access to a minimum volume of 50 L per day, conveniently located within a distance of at least 200 m if the water source is not within their residence [2]. Likewise, the [3] report defines access to safe water as the availability of potable water at a rate of at least 30 L per person per day, situated within or at 250 to 500 m from every household or reachable within the maximum of 30 min. There was, therefore, the birth of another fifteen-year (2016–2030) programme that aimed at further development and sustaining the various achievements made so far tagged Sustainable Development Goals (SDGs). It comprises seventeen (17) goals with diverse targets under each goal. One of the major targets of the United Nations as stated in Goal 6, target 1 of Sustainable Development Goals is the accessibility of the global citizens to potable water without stress [2]. SDG 6 is centred on ensuring access to clean water and sanitation for everyone, recognizing these as fundamental human rights and vital components for sustainable development. Globally, billions of people still lack access to safe drinking water, and inadequate sanitation poses serious health risks. This goal seeks to address these challenges by promoting water conservation, sustainable management of water resources, and the development of efficient sanitation infrastructure. By 2030, the objective is to achieve universal access to affordable and safe drinking water, as well as adequate sanitation and hygiene services, with a particular focus on marginalized and vulnerable communities. In pursuit of SDG 6, efforts are directed towards improving water quality, reducing water scarcity, and enhancing water-use efficiency in various sectors, including agriculture and industry. The goal recognizes the interconnectedness of water issues with health, poverty, and environmental sustainability. Emphasis is placed on community participation, integrated water resources management, and the promotion of hygiene education. Achieving SDG 6 contributes not only to improved health outcomes but also to enhanced agricultural productivity, ecosystem protection, and overall societal well-being.

In the same vein, SDG 13 addresses the urgent need for immediate and comprehensive action to combat climate change and its impacts, recognizing it as one of the most significant threats to sustainable development. Climate change poses risks to ecosystems, biodiversity, and human societies, affecting vulnerable communities

disproportionately. This goal seeks to mobilize global efforts to mitigate greenhouse gas emissions, adapt to the changing climate, and build resilience to climate-related disasters. By 2030, the objective is to integrate climate change measures into national policies, improve education and awareness, and enhance capacity-building to address the challenges posed by climate change. In the pursuit of SDG 13, there is a focus on promoting sustainable practices, transitioning to low-carbon economies, and investing in renewable energy sources. The goal emphasizes the need for international cooperation to implement effective climate policies and support developing countries in their climate adaptation and mitigation efforts. Climate action is not only crucial for environmental sustainability but also for achieving broader development goals, including poverty reduction, health improvements, and economic resilience. SDG 13 underscores the interconnectedness of climate, social, and economic systems, highlighting the necessity of addressing climate change as an integral part of the global development agenda.

However, the success achieved in water accessibility at regional scale is an issue to be considered. For instance, it was noted that in most developing countries, water access is still poor despite the global intervention. It has been revealed that most countries in Africa such as Togo, Benin Republic, Namibia, Ethiopia, Sudan, among others, still have to travel kilometres in search of water for their various domestic uses [3–5]. Though Nigeria has made frantic efforts to improve on access to potable water by constructing water points, yet the effort is yet to be impactful as [6] had to describe the water access situation as demanding emergency attention. In Nigeria, records showed that accessibility to potable water had improved to some extent as about 75% of urban population and 44% of rural population were found to have access to potable water as especially, through the exploitation of groundwater resources [7]. Apart from this, the tropical south in Nigeria is endowed with about eight months of rainfall (from March to October) and vast surface water resources [7]. It was, however, noted that still about 62% do not have access to reliable source of water [4, 8]. The contributory factors to this situation include unhygienic groundwater and surface sources. Groundwater sources reached through hand-dug facility, are often reportedly too shallow and susceptible to effluent discharges among other challenges. The pipe-borne water (PBW) source which could have been a good succour as a reliable source for home use has become inaccessible to potential consumers due to the problems categorised by [9] as institutional and physical challenges. The reasons for this situation include poor management of most water works, poor funding, fund misappropriation, poor maintenance culture, governments' seemingly preference for ground water exploitation in lieu of pipe borne network, urban sprawl, among others [9, 10]. Pipe borne water network connection was observed to be restricted to urban centres while rural communities are less considered for this safest facility [11].

Moreover, urban centres in developing countries have been characterised with increasing expansion and population surge, thus, over-stressing and subjecting the available PBW network to undue pressure. In some other localities, governments at different levels (probably considering the cost implication) have shirked this responsibility in developing PBW network further in favour of subsurface water exploitation [11, 12]. PBW was adjudged to be the cleanest and safest water source for human home use. Though the region is reach in rainwater, the challenge of poverty-ridden economy hinder possession of big storage facilities, like underground types, to harvest the rainwater for future use. Surface streams and rivers are open to contaminations from refuse dumps, industrial and home effluents, and so on [13]. However, all these resources are accessible by homes. No wonder! Various records of deaths and illnesses in Africa have been traced to consumption of unsafe water sources for their diverse domestic uses [14–18].

All these, notwithstanding, Aiba water reservoir was built and commissioned in 1958 to provide water for Iwo and its environs such as Agberire, Bode-Osi, among others. Fortunately, the network facility has not gone beyond Iwo, and only a part. Most inhabitants obtain water from their home use from subsurface facility [19].

The challenge of climate change scenario is also exacerbating its impact on various water resources mostly explained by its extremes which made rainfall unreliable and high recurrence of heat wave [13, 20].. The challenge of climate change, the impact of which has been observed touching every facets of life, including water resources, has also been observed and incorporated into SDG 13. SDG 13 addresses the urgent need for immediate and comprehensive action to combat climate change and its impacts, recognizing it as one of the most significant threats to sustainable development. Climate change poses risks to ecosystems, biodiversity, and human societies, affecting vulnerable communities disproportionately. This goal seeks to mobilize global efforts to mitigate greenhouse gas emissions, adapt to the changing climate, and build resilience to climate-related disasters. By 2030, the objective is to integrate climate change measures into national policies, improve education and awareness, and enhance capacity-building to address the challenges posed by climate change. In the pursuit of SDG 13, there is a focus on promoting sustainable practices, transitioning to low-carbon economies, and investing in renewable energy sources. The goal emphasizes the need for international cooperation to implement effective climate policies and support developing countries in their climate adaptation and

mitigation efforts. Climate action is not only crucial for environmental sustainability but also for achieving broader development goals, including poverty reduction, health improvements, and economic resilience. SDG 13 underscores the interconnectedness of climate, social, and economic systems, highlighting the necessity of addressing climate change as an integral part of the global development agenda.

The only available facility is the PBW facility, which, if annexed and developed, will save homes from various water-associated illnesses and deaths and also prevent enormous economic hours often spent searching for potable water in the community. On this note, this work was designed to assess the challenges facing accessibility of Iwo community to PBW facility for home use. Specific objectives are to: (i) describe and evaluate the accessibility to PBW services in Iwo community; and (ii) identify, extract, and rank the significant determinants for the access or otherwise, to PBW in the study area. It is expected that understanding this will enhance institution of appropriate and implementable policies and programmes that will stimulate water access for home use.

2 Method of study

2.1 Study area

Iwo is the headquarter of Iwo Local government Area (LGA) in Osun State, Nigeria (Fig. 1). It is one of the LGAs endowed with vast water resources, both surface and subsurface. Aiba Water Works (AWW) was established in 1957 to manage the Aiba Reservoir (AR) which was commissioned in 1957. AR was constructed on Aiba River with the intention to provide potable water for Iwo residents and its suburbs. The reservoir, however, is currently unable to supply water to the town, not to mention supplying water to the rural communities around it. An unconfirmed source revealed that the AWW weekly water supply is about 500,000 L, the quantity that is far below the demand of the expanding community. In view of this challenge, majority of the inhabitants in the main town now rely heavily on ground water exploitation through

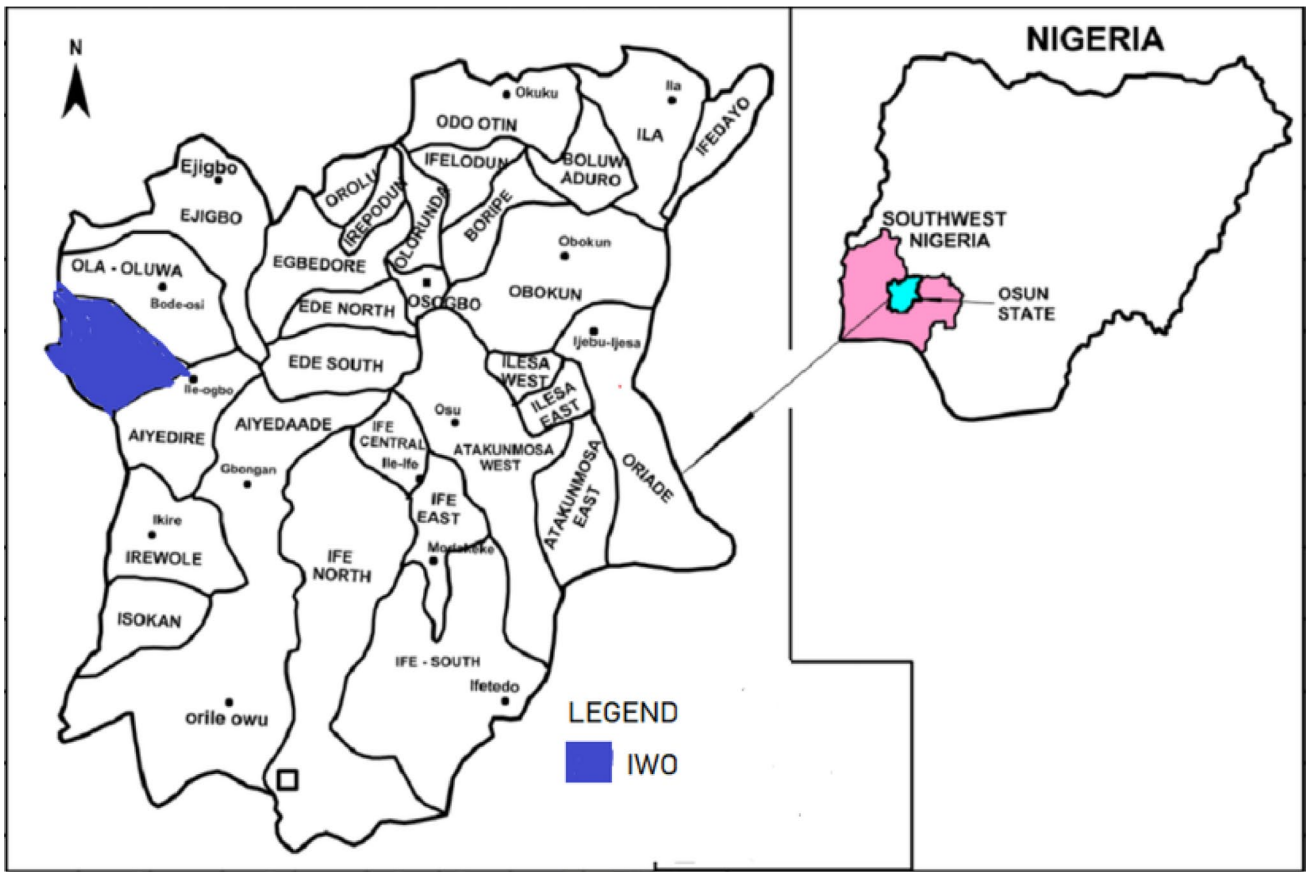


Fig. 1 Map of Osun State showing the location of Iwo (Inset: Map of Nigeria showing the location of Osun State)

borehole drilling and hand-dug wells. Only a fractional part of the town, mostly around the dam periphery, receive water from the dam. Most of the challenges that contribute to the inability of the AWW to reach most of the inhabitants include neglect of the PBW network in favour of the ground sources by the appropriate authorities. Ground water exploitation is being promoted by both the local and state governments in different ways. Boreholes and hand-dug wells are often provided by the government and offer supports for it in different locations. Though Iwo enjoys maritime wind which brings its moisture in form of rainfall to the town in about eight months yearly, this resource has not been utilized effectively, while surface sources are unattractive for home consumption because of high level of contamination. Thus, the only source that is safer for human consumption is ground source.

3 Material and methods

3.1 Study design

This study employed a cross-sectional research design to gather data on various factors affecting households within a specific town. The primary dataset was derived from a structured questionnaire administered to a sample of households. Eighty households were surveyed monthly. These houses were marked in secure places of the each house for proper identification during the subsequent months to avoid second time survey and to avoid being tampered with.

3.2 Data collection

The data collection process took place between February and July of 2023. The town under investigation was geographically divided into four major sections, utilizing the two primary roads that nearly bisected the town into halves. These divisions formed the basis for the survey, allowing for comprehensive coverage of the town's residential areas. The exercise was carried out in the morning time before potential respondents leave for their various farms and market places and also in the evening time, when those that were not available in the morning could have come back from their various places of work. Female heads in each of the households were involved following the view of [7] that water-related information is gotten domicile with women of the house better than their male counterparts. This is because the responsibility of water availability is heavily rested on them by African culture. However, where the female head was not available, male head or any other adult in the house was taken as replacement.

3.3 Sampling procedure

A multistage sampling method was employed to select households for participation in the survey. In each of the six town divisions, a total of eighty households were then randomly chosen. To ensure continuous participation and accurate identification, these selected households were marked for subsequent monthly surveys. Consequently, a total of 480 households were included in the study. The procedure adopted in the study is shown in the flow chart (Fig. 2).

3.4 Data analysis

Both descriptive and inferential statistical analysis were carried out. The summary of the data in terms of respondents' characteristics, distance to water source, preferred water source, payment of water tariff, views on AWW performance, reasons for the observed decay or underutilization of a particular water resource, among others, were the information obtained in the questionnaire. On the other hand, inferential statistics such as factor analysis was used to determine the factors contributing to the underutilization of a water resource. Factor Analysis (FA) was used to determine and rank the significant variables contributing to a water resource underutilization and/or decay. The data set was tested for its factorability with Kaiser–Meyer–Olkin (KMO) and Barttlett's Tests. The results of which indicated that the data was factorable with KMO of 62.3, significant at $p \leq 0.005$. In the use of FA, the ranking factor, Eigen value was set at 1.000 which implied that any variable which failed to attain the standard set will be discarded as insignificant to the explanation of reasons for the decay and/or underutilization of PBW.

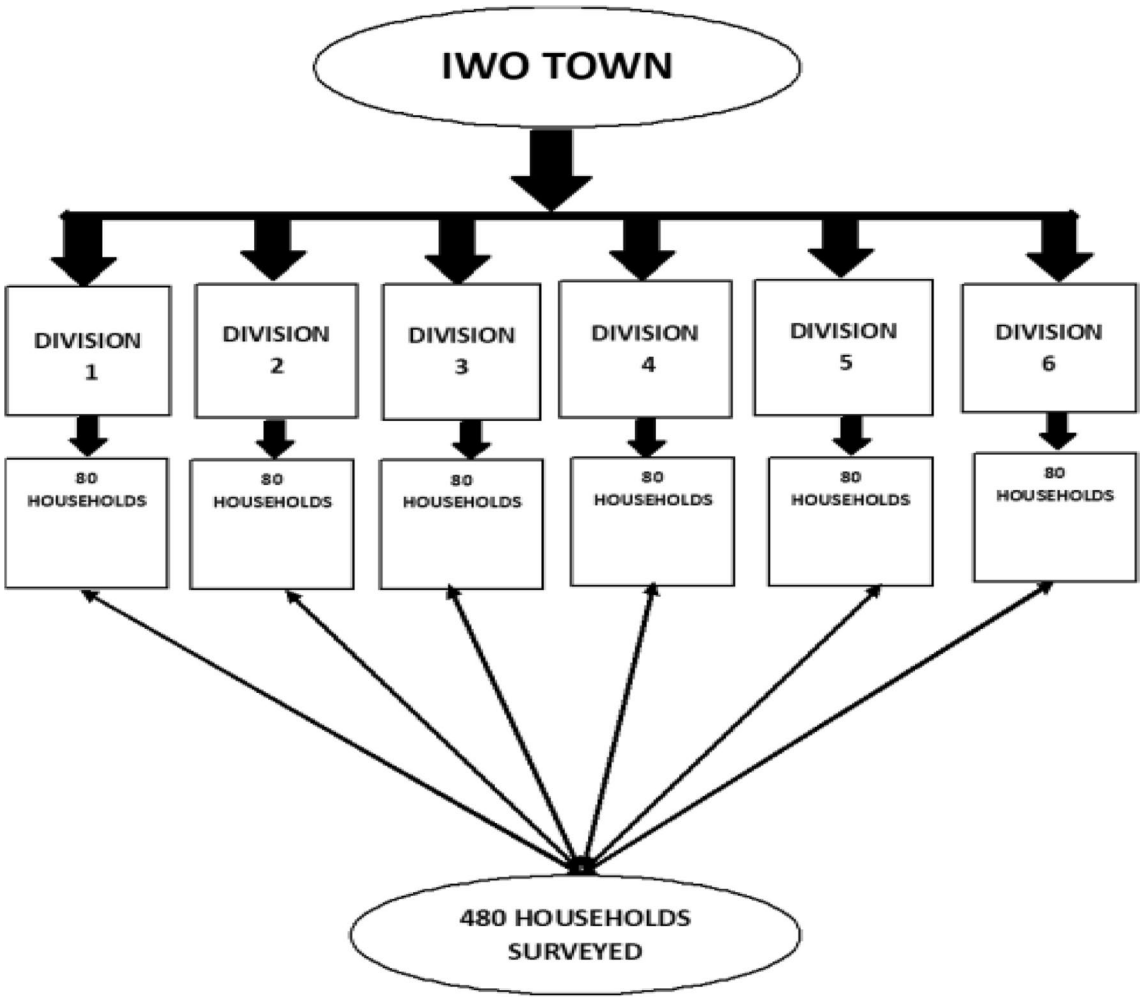


Fig. 2 Sampling Procedure Flow Chart

3.5 Survey administration

Four hundred and eighty copies structured questionnaire was administered by the authors along with the assistance of four trained personnel. The use of multiple survey administrators aimed to enhance the efficiency and thoroughness of data collection. The questionnaire covered a range of topics relevant to the study objectives, and respondents were encouraged to provide detailed and accurate information.

3.6 Data retrieval and completeness

Out of the 480 questionnaires administered, a high response rate of 95.42% was achieved, with 458 questionnaires completed and successfully retrieved. This noteworthy level of completeness is indicative of the effectiveness of the survey administration process and the commitment of both the authors and their assistants to obtaining comprehensive data. The described materials and methods employed in this study ensured a systematic and thorough approach to collecting data, contributing to the reliability and validity of the findings.

3.7 Theoretical background

The research on the challenges of pipe-borne water connectivity in the tropical region is situated within a broader theoretical framework that encompasses various dimensions such as geography, infrastructure development, socio-economic

factors, and environmental considerations. This theoretical background provides a foundation for understanding the complexities and intricacies associated with pipe-borne water connectivity challenges in tropical regions. The first theoretical background in this work is the entitlement theory. The entitlement approach to water access revolves around the idea that individuals have a right or entitlement to a certain quantity and quality of water for their basic needs [21, 22]. This approach places a strong emphasis on recognizing water as a fundamental human right, essential for life, health, and well-being. Key details of the entitlement approach to water access include human right to water. This perspective views water not merely as a commodity but as a fundamental right that everyone is entitled to. This right, in the view of [22, 23], is often linked to broader human rights frameworks and international agreements that highlight the importance of access to clean and safe water for all individuals. Secondly, entitlement approach considers both quantitative and qualitative aspects of water access. quantitatively, it stipulates a minimum quantity of water that individuals are entitled to for their basic needs, often measured in litres per person per day. According to [24], qualitatively attributes emphasize the right to access water that meets certain quality standards, ensuring that it is safe for consumption and does not pose health risks. Also, entitlement approach views water access not just as a technical or infrastructural matter but to fulfil basic human needs and uphold human dignity [21, 25]. It recognizes that access to water is vital for drinking, sanitation, hygiene, and sustaining life in a dignified manner. Equity and non-discrimination are fundamental principles of the entitlement approach [26]. It asserts that all individuals, regardless of their socio-economic status, should have equal and non-discriminatory access to sufficient and safe water. This perspective challenges disparities in water access based on factors such as income, gender, or geographical location. The theory also calls for the development and implementation of legal and policy frameworks that explicitly recognize and protect the right to water. According to [27], this may include incorporating water rights into national constitutions, enacting water-related laws, and establishing mechanisms to ensure accountability in providing equitable access. Community involvement is a key aspect of the entitlement approach [21, 22]. It emphasizes the importance of involving local communities in decision-making processes related to water management, ensuring that their perspectives, needs, and priorities are considered. The entitlement approach aligns with various international agreements that emphasize the right to water, including the United Nations General Assembly resolution recognizing water and sanitation as essential human rights [27]. Lastly, ensuring accountability in the provision of water entitlements requires effective monitoring mechanisms. This involves tracking progress in water access, evaluating the quality and quantity of water provided, and holding relevant stakeholders accountable for fulfilling their obligations in providing equitable and safe water access. In essence, the entitlement approach to water access reflects a commitment to securing the basic human right to water for everyone, emphasizing equality, dignity, and sustainability in water provision [21, 24], This perspective serves as a guiding principle in shaping policies, practices, and interventions to address water challenges on a local, national, and global scale. Access to pipe-borne water in Iwo has become a mirage because the intended areas of coverage at the planning stage could not enjoy the access [28–31]. Areas around the water works in Iwo was observed to be the areas that enjoy access to pipe-borne water. Thus, most of the inhabitants had to secure water from alternative sources of which groundwater formed the major one. Rainwater is also harvested during raining period for home use to certain extent. The contributory factor to water access, according to [8] and [30], includes increasing urban expansion and population, establishment of various secondary and tertiary institutions, both private- and publicly owned, and also increase patronage of the main market in the town [19].

4 Results and discussion

4.1 On the basic attributes of the respondents

The information provided was analysed for the basic characteristics of the respondents. The findings are as follows:

In term of the gender distribution, Table 1 shows that female respondents formed 83.6% (383) in the survey while male gender was 16.4% (75). The dominance of the female gender was intentional in line with Ogunbode et al. [8]'s report that female gender is responsible for the provision of water for various home uses in African homes. Thus, the gender is better consulted for water-related information in the region. Where female head was not available, the male head was involved. Also, the result, as presented in Table 1 shows that 73% claimed obtaining water for their home uses in less than 30 min while 25% spent more than 30 min to get water for their domestic activities. The remaining 2% (08) of the respondents abstained. It was observed during the survey that most homes have either dug-out well or deep borehole within their house premises, thus, making the resource close to the users. The findings of [31] and [32] also corroborated this

Table 1 Basic attributes of the respondents

Categorization		Distribution	
Category no.	Attributes	Sample size	% of total in the category
A	Gender Distribution		
	Male	75	16.4
	Female	383	83.6
B	Time spent to fetch water		
	< 30 min	335	73
	> 30 min	115	25
	No data	08	2
C	Payment of water tariff		
	Yes	84	18.4
	No	374	81.4
D	Available Water sources		
	Groundwater	350	76.2
	Groundwater and PBW	83	18.6
	No Data	25	5.2
E	Reason for poor connectivity to PBW network		
	Administrative bottleneck	55	12.0
	Availability of other sources	261	57.0
	Poor network of the pipeline	41	9.0
	Unreliable supply	83	18
	No knowledge of PBW existence in Iwo	18	4

observation. However, connections to other sources may be challenging in view of their respective distances to homes for immediate use. For stance, [10] observed the associated challenges in connecting homes to public water services.

In furtherance, the Table revealed that the respondents' responses to the question on the payment for water used in their homes. While 18.4% (84) claimed that they pay water tariff to the government, the remaining 81.4% (373) did not. The payment of water tariff is significant to augment government's expenditure on water provision services [33]. Poor performance of AWW could have been attributed to the poor tariff payment in the study area, thus, denying timely maintenance of various components of the facility like broken pipes, mend leakages, minor inputs in water treatment, among others. [33] lamented on the level of high cost of accessing potable water in the Greater Accra region of Ghana which was found to be equivalent of $14.70 dollars per month (13.25% of their respondents' monthly income. However, [34] and [35] reported thee high level of corruption and its grievous impact on infrastructural decay, including water supply subsector in Nigeria. As a result of this, Ohwo had to suggest legislation to tackle the problem of corruption and that the State Water Services (SWS) be granted some autonomy to set tariffs. In addition, groundwater formed the dominant source of potable water for 76.2% (349) (71.2% obtain groundwater from hand-dug wells and 12.5% obtain water from deep borehole for their respective home uses) while 18.6% (85) obtain water for their respective household uses from both groundwater and PBW network. The remaining 5.2% refrained from responding to the question. From the analysis, no respondent claimed sourcing water from pipe borne water network or rainwater alone. Hence, both sources only serve as supplement to the groundwater and so not dependable for home uses. The dominance of groundwater as the main source of water for home use was also reported by [36, 37] for Oyo State, Nigeria. Apart from this, [6] and [33] corroborated the observation in their findings on poor management of PBW network. [38] reported that pipe-borne network was only accessible to only 18.2% of the Nigerian population as at the end of MDG pursuit in 2015.

4.2 Analysis of pipe borne water connectivity/utilization in the study area

FA results showed that 3 variables significantly explained 39.311% of what determines access to pipe borne water services in Iwo. The 3 variables are: (i) the proximity of homes to the PBW network; (ii) affordability to pay for the cost of connection and the tariff charged; (iii) Availability of other water sources.

The proximity of households to pipe-borne water (PBW) network emerged as the predominant factor influencing water accessibility, attaining the highest rank in the analysis. This was substantiated by an Eigen value of 5.107, signifying a substantial contribution to the overall variance. Specifically, it accounted for 42.557% of the variance within the dataset, constituting 53.7% of the absolute value and thereby serving as the primary explanatory factor among the extracted determinants. In the Rotated Component Matrix (RCM), the variable associated with the proximity of households to the PBW network secured the top position with a loading factor of 0.868 within the array of the first-order variables analysed. This underscores its significance in influencing the overall water supply dynamics in the study area. A noteworthy observation is the prevalence of non-connected homes and their considerable distance from the main pipe network. Despite the absence of hindrances related to willingness and affordability within the community, the obstacle remains the substantial distance of most residences from the pipe network. This geographical barrier poses a significant threat to the realization of the community's intention to access safe water. The findings align with the concerns raised by [39] and [40] regarding poor access to safe water in Akure, Nigeria. These researchers attributed the issue to deficiencies in the urban PBW network, highlighting the relevance of infrastructure in determining water accessibility. Similarly, [41] reported analogous results in Ghana, where inadequate access to safe water was linked to reliance on groundwater, some of which exhibited undesirable quality. Thus, the study underscores the critical role of proximity to the PBW network in shaping water accessibility, emphasizing the need for targeted interventions to address the geographical challenges faced by households in accessing safe water in Iwo.

The cost associated with connecting to and sustaining the PBW network in households emerged as a noteworthy variable in the factor analysis (FA). This variable, reflecting the cost implications of accessing and maintaining water services, exhibited a significant role in the overall dynamics of water supply. Within the RCM, it attained the highest value of 0.827 in the second order of the variables analysed, highlighting its substantial influence. In terms of the Eigen value, the cost-related variable ranked second, with a value of 2.673. While trailing behind the first extracted variable, this cost-related factor still contributed significantly, explaining 22.275% of the total variance accounted for by the three extracted variables. This underscores its importance in shaping the patterns and challenges associated with water connectivity. The non-proximity of most homes to the main PBW network has created a scenario where households are compelled to bear the financial burden of connecting their homes to the central network. This cost factor, coupled with the recurring monthly tariff required for sustaining the pipe-borne water services, acts as a deterrent for many households. The financial implications involved often hinder the annexation of pipe-borne water services, contributing to the persistence of reliance on alternative water sources. [42] highlighted the role of the poor urban economy in contributing to the challenges of connecting to the PBW network. The study indicated that a substantial portion of the urban population lacks the affordability necessary to enjoy the benefits of connecting to the PBW network. This economic constraint further exacerbates the disparities in access to safe water. Furthermore, poor attitudes toward the payment of water tariffs were identified as additional factors impeding the timely maintenance of PBW network facilities, most especially, where government shirked its responsibility of water provision for her citizens. [43] and [44] underscored the negative impact of these attitudes, emphasizing the need for improved payment compliance to ensure the sustained functionality and effectiveness of the water supply infrastructure. Eliminating unnecessary bureaucratic hurdles in the study area is essential, particularly streamlining the convoluted steps involved in obtaining home connections [45]. The aim, according to [45] and [[46] is to simplify the process by minimizing the need to navigate through multiple stages for approval, fostering a more efficient and user-friendly experience for residents seeking connections.

The third significant variable contributing to the underutilization of PBW services in Iwo is the inhabitants' preference for other water sources since there is apparently no law that prohibits resource exploitation within the system**.** This variable claimed the top rank among the third order of variables analysed, evidenced by a high RCM value of 0.956. With an Eigen value of 1.738, it explains 14.480% of the total variance within the dataset. The diverse availability of multiple water resources in the study area plays a pivotal role in shaping the decisions of inhabitants regarding which water source to exploit for their domestic needs. This preference becomes particularly pronounced due to the perceived lackadaisical attitude of the government toward the development and expansion of PBW infrastructure. Consequently, households often opt for alternative sources, such as groundwater from hand-dug wells and borehole drilling, for meeting their domestic water requirements. The variable gains significance in the context of the government's apparent prioritization of groundwater exploitation over the development of PBW infrastructure. This prioritization is often driven by cost considerations. As a result, the government's focus on groundwater further influences and reinforces the inhabitants' inclination to rely on these alternative sources. Based on the theoretical basis of this work, temporal and spatial accessibility to potable water is a right of the citizenry and so, must be prioritised by the relevant stakeholders, especially, Osun state administration. [44] and [47] have previously highlighted the

prevalent dependence of both rural and urban communities on groundwater sources in the absence or near absence of a comprehensive PBW network. This underscores the broader trend of communities resorting to alternative water sources due to limited access to PBW services (Jepson et al., 2023). In summary, the inhabitants' preference for water sources emerges as a key determinant influencing the underutilization of PBW services in Iwo. This preference is shaped by the availability of multiple water resources and is further exacerbated by the perceived neglect of PBW infrastructure by the government. Understanding and addressing these preferences are crucial for devising effective strategies to promote the utilization of PBW services and enhance water accessibility in the region.

Total variance explained

Component	Extraction sums of squared loadings			Rotation sums of squared loadings		
	total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.111	59.261	59.261	5.107	42.557	42.557
2	1.370	11.420	70.681	2.673	22.275	64.832
3	1.036	8.630	79.311	1.738	14.480	**79.311**

Extraction method: principal component analysis

5 Conclusion and recommendation

The investigation into Pipe-Borne Water (PBW) connectivity aimed to assess the accessibility of the study area to piped water and identify the determinants through the distribution of structured questionnaires to 480 respondents, with 458 successfully retrieved for analysis. Utilizing both descriptive and inferential statistics, the study employed Statistical Product for Service Solutions (SPSS) version 23. Demographic analysis revealed that 83.6% of respondents were female, with 18.4% acknowledging payment of water tariffs, while 76.2% primarily relied on groundwater as their water source. The data uncovered various impediments to PBW connectivity, including administrative bottlenecks (12%), the availability of alternative water sources (57%), poor PBW infrastructure (9%), and the unreliability of water supply from Aiba Water Works (AWW) (18%). Further analysis through Factor Analysis (FA) identified three significant variables influencing PBW accessibility: proximity to the main network (42.557%), cost of connectivity (22.275%), and the availability of alternative sources (14.480%). These findings underscore the need to expand the PBW network, considering the non-proximity of most residences to the main water pipes. The study also recommends the implementation of capacity-building initiatives to enhance the economic well-being of citizens, contributing to an improved quality of life in the studied area. In conclusion, this research provides valuable insights into the complexities surrounding water accessibility and offers practical recommendations to contribute to the realization of Sustainable Development Goal 6 by 2030.

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Author contributions TOO: Conceptualization, supervision. Data curation, Investigation, resources, Formal analysis, Writing: Review and Editing; VIE: Project administration, Investigation and editing. VOO: Project administration, Data curation, Formal analysis, Review and editing. JAA: Project administration, Review and editing.

Data availability Data used in the study is available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate All experiments were performed in accordance with relevant guidelines and regulations. All experimental protocols were approved by Bowen University Research Ethical Committee with the approval number BUREC/COAES/AGR/003. Informed consent was obtained from all subjects that participated in the survey.

Consent for publication Not applicable.

Competing interests The authors declare that they have no competing interests.

References

1. WHO, UNICEF Progress on drinking water, sanitation and hygiene: 2017 Update and sustainable development goal baseline. New York, WHO/UNICEF joint monitoring programme for water supply and sanitation, 2017.
2. Moyer JD, Hedden S. Are we on the right path to achieve the sustainable development goals? World Dev. 2020;127:104749. https://doi.org/10.1016/j.worlddev.2019.104749.
3. United Nations, The Human Right to Water and Sanitation: Media Brief. UN-Water Decade Programme on Advocacy and Communication and Water Supply and Sanitation Collaborative Council. 2011.
4. Bayu T, Kim H, Oki T. Water governance contribution to water and sanitation access equality in developing countries. Water Res Res. 2020;56:e2019WR025330. https://doi.org/10.1029/2019WR025330.
5. Iduseri EO, Abbas II, Izunobi JU, Ogedegbe SO, Ogbonna DO. Access to safe drinking water in developing countries: a comparative analysis of the Urban and rural areas of Zaria, Kaduna state, Nigeria. J Appl Sci Environ Manage. 2021;25(11):1869–78. https://doi.org/10.4314/jasem.v25i11.4.
6. World Bank Nigeria: Ensuring water, sanitation and Hygiene for all. 2018.https://www.worldbank.org/en/news/feature/2021/05/26/nigeria-ensuring-water-sanitation-and-hygiene-for-all Accessed on 21/8/2023
7. Egbinola CN. Trend in access to safe water supply in Nigeria. J Environ Earth Sci. 2017;7(8):89–96.
8. Ogunbode TO, Owoeye MO, Afolabi CO, Oyebamiji VO. Impact of domestic water provision on women in their educational attainment: a case of Iwo, Nigeria, Bahria University. J Hum Soc Sci. 2022;5(1):14–30.
9. Okon I, Njoku C. Evaluation of domestic access to PBW in Calabar Metropolis, Southern Nigeria. Open Access Library J. 2017;4:1–21. https://doi.org/10.4236/oalib.1103924.
10. Ibrahim RB, Toyobo EA, Adedotun SB, Yunus S. Evaluation of the public PBW supply in Ilorin West Local Government area of Kwara state Nigeria. Econ Environ Stud. 2018;18(3):1105–18. https://doi.org/10.25167/ees.2018.47.4.
11. Ogunbode TO, Akande JA, Ogungbile PO, Odekunle O. Sustainability and resilience of Aiba Dam in Iwo. Nigeria J Appl Sci Environ Manage. 2019;23(10):1937–42. https://doi.org/10.4314/jasem.v23i11.5[12].
12. Burzawa J. Sip Every Drop: Inaccessible and Jeopardized Water Resources in Nigeria and Ukraine Global Majority E-Journal, 2020, 11,2, 64–76.
13. Gabr ME. Impact of climatic changes on future irrigation water requirement in the Middle East and North Africa's region: a case study of upper Egypt. Appl Water Sci. 2023;13:158. https://doi.org/10.1007/s13201-023-01961-y.
14. Sommer JM, Shandra JM, Restivo M, Coburn C. Water, sanitation, and health in Sub-Saharan Africa. Hum Ecol Rev. 2015;22(1):129–52.
15. Prüss-Ustün A, Wolf J, Bartram J, Clasen T, Cumming O, Freeman MC, Gordon B, Hunter PR, Medlicott K, Johnston R. Burden of disease from inadequate water, sanitation and hygiene for selected adverse health outcomes: an updated analysis with a focus on low- and middle-income countries. Int J Hyg Environ Health. 2019;222(5):765–77. https://doi.org/10.1016/j.ijheh.2019.05.004.
16. Hannah R, Max R (2021) Clean water and sanitation clean water and sanitation, https://ourworldindata.org/clean-water-sanitation
17. Gabr ME, Soussa H. Assessing surface water uses by water quality index: application of Qalyubia Governorate, Southeast Nile Delta. Egypt Appl Water Sci. 2023;13:181. https://doi.org/10.1007/s13201-023-01994-3.
18. Gaffan N, Kpozehouen A, Degbey C, Ahanhanzo YG, Paraïso MN. Effects of household access to water, sanitation, and hygiene services on under-five mortality in Sub-Saharan Africa. Front Public Health. 2023;2023(11):1136299. https://doi.org/10.3389/fpubh.2023.1136299.
19. Ogunbode TO, Oyebamiji VO, Oluwole OA, Akande JA. Analysis of household daily water consumption dynamics in the tropical environment. Scientifica. 2023. https://doi.org/10.1155/2023/9956847.
20. El-Rawy M, Batelaan O, Al-Arifi N, Alotaibi A, Abdalla F, Gabr ME. Climate change impacts on water resources in arid and semi-arid regions: a case study in Saudi Arabia. Water. 2023;15:606. https://doi.org/10.3390/w15030606.
21. Dapaah EK, Harris LM. Framing community entitlements to water in Accra, Ghana: a complex reality. Geoforum. 2017;82:26–39. https://doi.org/10.1016/j.geoforum.2017.03.011.
22. Dickin S, Bisung E, Nansi J, Charles K. Empowerment in water, sanitation and hygiene index. World Dev. 2021;137:105158. https://doi.org/10.1016/j.worlddev.2020.105158.
23. Stoler J, Weeks JR, Fink G. Sachet drinking water in Ghana's Accra-Tema metropolitan area: past, present, and future. J Water Sanit Hyg Dev. 2012. https://doi.org/10.2166/washdev.2012.104.
24. Wutich A, Budds J, Eichelberger L, Geere J, Harris LM, Horney JA, Jepson W, Norman E, O'Reilly K, Pearson AI, Shah SH, Shinn J, Simpson K, Staddon C, Stoler J, Teodoro MP, Young SL. Advancing methods for research on household water insecurity: Studying entitlements and capabilities, socio-cultural dynamics, and political processes, institutions and governance. Water Security. 2017;2:1–10. https://doi.org/10.1016/j.wasec.2017.09.001.
25. Young, M. Unbundling Water Rights: A Blueprint for Development of Robust Water Allocation Systems in the Western United States. NI R 15-01. Durham, NC: Duke University. 2015, http://nicholasinstitute.duke.edu/publications
26. Tsai AC, Kakuhikire B, Mushavi R, Vořechovská D, Perkins JM, McDonough AQ, Bangsberg DR. Population-based study of intra-household gender differences in water insecurity: reliability and validity of a survey instrument for use in rural Uganda. J Water Health. 2016;14(2):280–92. https://doi.org/10.2166/wh.2015.165.

27. Jepson W, Wutich A, Collins S, Boateng GO, Young SL. Progress in household water insecurity metrics: a cross-disciplinary approach, 2017**,** Wiley Interdisciplinary Reviews Water. https://doi.org/10.1002/wat2.1214
28. Ogunbode TO, Ifabiyi PI. Determinants of domestic water consumption in a growing urban centre in Osun State, Nigeria. Afr J Environ Sci Technol. 2014;8(4):247–55. https://doi.org/10.5897/AJEST2013.1627.
29. Angoua ELE, Dongo K, Templeton MR, Zinsstag J, Bonfoh B. Barriers to access improved water and sanitation in poor peri-urban settlements of Abidjan, Côte d'Ivoire. PloS one. 2018;13(8):e0202928. https://doi.org/10.1371/journal.pone.0202928.
30. Amoah A. Estimating averting expenditure in domestic water use: evidence from Ghana. J Water Sanitation Hyg Dev. 2020;10(4):894–904. https://doi.org/10.2166/washdev.2020.197.
31. Olajuyigbe AE, Olamiju IO, Ola-Omole CM. Vulnerability of hand-dug wells in the core area of Akure, Nigeria. Urban Water J. 2017;14(8):797–803. https://doi.org/10.1080/1573062X.2016.1254257.
32. Ogunbode TO, Akinola OT. Hydrochemistry and water quality index application in the assessment of groundwater quality in Oyo state, Nigeria. Int J Hydrol Sci Technol. 2019;6:657–74.
33. Jepson W, Stellbauer M, Thomson P. Revaluing multiple-use water services for food and water security. FAO Land and Water Discussion Paper No. 19. Rome, FAO. 2023, https://doi.org/10.4060/cc7317en.
34. WaterAid Nigeria. Annual Report. 2017, www.wateraid.org.
35. WHO. UNICEF progress on sanitation and drinking-water—2014 update. Geneva: World Health Organization; 2014.
36. Ogunbode TO, Ifabiyi IP. Domestic water utilization and its determinants in the rural areas of Oyo state, Nigeria using multivariate analysis. Asian Res J Arts Soc Sci. 2017;3(3):1–13. https://doi.org/10.9734/ARJASS/2017/34096.
37. Ogunbode TO, Ifabiyi IP, Suleiman MY. Achieving sustainable water supply in the rural areas using water poverty index (WPI): a case of rural communities In Oyo State, Nigeria. Nigerian J Water Res. 2020;6(1):54–69.
38. Ogunbode TO, Esan VI, Akande JA. Water resources endowment and the challenge of underutilization in a tropical community in Nigeria. Sustain Water Res Manag. 2024;10:72. https://doi.org/10.1007/s40899-024-01061-y.
39. Amori A, Makinde A. Evaluation of access to public water supply in two major cities in Nigeria. Am J Environ Eng. 2012;2:148–51. https://doi.org/10.5923/j.ajee.20120206.01.
40. Lawal O, Bashorun J. Access to safe water in Akure: a paradox in Nigerian urbanized regions. Int J Emerg Knowl. 2013;3:39.
41. Kulinkina AV, Kosinski KC, Liss A, Adjei MN, Ayamgah GA, Webb P, Gute DM, Plummer JD, Naumova EN. Piped water consumption in Ghana: a case study of temporal and spatial patterns of clean water demand relative to alternative water sources in rural small towns. Sci Total Environ. 2016;559:291–301. https://doi.org/10.1016/j.scitotenv.2016.03.148.
42. Gabr ME, El Shorbagy AM, Faheem HB. Assessment of stormwater quality in the context of traffic congestion: a case study in Egypt. Sustainability. 2023;15:13927. https://doi.org/10.3390/su151813927.
43. Berg SV. Best practices in regulating State-owned and municipal water utilities. Project document, economic commission for Latin America and the Caribbean (ECLAC). Santiago, Chile: United Nations.; 2013.
44. Adeoti O, Fati BO. Barriers to extending piped water distribution networks: The case of Ekiti State, Nigeria. Utilities Policy. 2020;63:100983. https://doi.org/10.1016/j.jup.2019.100983.
45. Uitermark J, Tieleman I. From fragmentation to integration and back again: the politics of water infrastructure in Accra's peripheral neighbourhoods. Trans Inst Br Geogr. 2021;46(2):237–524. https://doi.org/10.1111/tran.12420.
46. Uneke CJ, Ogbonna A, Ezeoha A, Oyibo P, Onwe F, Ngwu B. The Nigeria health sector and human resource challenges. Internet J Health. 2008;8:1–5.
47. Ogunbode TO, Oyebamiji VO, Oluwole OA, Akande JA. Analysis of household daily water consumption dynamics in the tropical environment. Scientifica. 2023. https://doi.org/10.1155/2023/9956847.