Factors Contributing to High Demand of Safe and Clean Supply of Water for Population Health in Lagos, Nigeria to Enable to Sustainable Developments

Abstract

The growing urban population in developing countries has worsened the concerns surrounding issues on equal water availability and sustainable management. This study investigates household water demand patterns in Lagos, Nigeria, focusing on the socio-economic and spatial inequalities that influence water usage. Using survey data from 294 households, the study adopted Geographic Information Systems (GIS) for the spatial analysis and Factorial ANOVA to look into the impact of socio-economic characteristics, namely income, gender, education, and occupation, on volumetric water consumption. The spatial analysis covered the mapping of the minimum, maximum and average water demand while also showcasing the demand patterns for public and private water sources. The results from the spatial analysis showed significant differences in water demand between the metropolitan areas and the peri-urban areas. Also, urban areas had increasing public water demand due to improved municipal infrastructure, whilst peri-urban areas depended heavily on private water sources such as boreholes and private vendors. The results showed that income levels had a significant influence on water use. Higher-income households consumed more, while demand of lower-income households is limited since it relies on irregular and costly informal water sources. Gender and age showed minor impacts on differences in volumetric demand, with female-headed households having a modest preference for public water systems over private sources. The study recommends a reduction in reliance on boreholes in peri-urban regions in order to avoid groundwater depletion and environmental degradation. This research adds to the worldwide efforts towards attaining Sustainable Development Goal 6.

Keywords: Waterdemand, Public water, Household consumption, Sustainabledevelopment, Lagos

1. Introduction

Water is crucial for human health, economic progress, and environmental sustainability. However, in developing countries around the world, issues such as inadequate infrastructure, rising urbanization, and population growth have led to challenges in meeting household water demands. While water scarcity is a worldwide problem, it is more pronounced in developing countries, which are characterized by socioeconomic disparities.

Comprehending the socio-economic and geographical determinants that affect household water consumption is crucial for formulating strategies that tackle these issues. Research indicates that socio-economic inequalities significantly influence water accessibility in emerging nations. Affluent families often have superior access to municipal water infrastructure, whereas low-income households rely on alternative sources such as informal sellers and uncontrolled boreholes. Tesfay Abraha et al. (2024) asserts that economic inequalities in water access worsen social disparities, with lower-income families incurring higher water expenses. These disparities are further worsened by inconsistent service delivery in underprivileged communities. Moreover, high-income households generally use more water due to the volume of water used for nonessential activities, such as landscaping and recreational purposes. Hassan et al. (2024) noted that in Saudi Arabia, wealthier families consume much more water.

Urbanisation also increases water challenges, particularly in informal areas where infrastructure is often poor or absent. The population increase in the urban areas of developing countries has exceeded the capacity of existing water supply infrastructure, resulting in significant service delivery deficiencies. In rapidly urbanized areas, infrastructure frequently lags behind demand for water, and this problem intensifies inequality. Siddika and Sresto (2025) observed that in Khulna, Bangladesh, infrastructure gaps have resulted in urban resilience difficulties, with residents of low-income areas suffering from irregular water supplies and resorting to other sources, which are sometimes of inferior quality. As Ashrit and Kapila (2024) highlighted in India, urban slums usually lack basic water infrastructure, forcing inhabitants to rely on pricey private water sources. This demand on resources often outpaces the capacity of urban planners to build fair and sustainable water systems. In Mexico City, Medina-Rivas and Morales-Novelo (2024) described a drop in per capita water usage due to old infrastructure and supply limits. Their spatial study reveals that enhanced infrastructure might better manage urban water demand concerns in megacities.

The interaction between climate vulnerability and socioeconomics is becoming crucial. Muse et al. (2024) note that in dry places such as Somaliland, water consumption changes periodically owing to harsh weather conditions, and economic restrictions impede households' capacity to cope with these seasonal shortages. Households often turn to storing water from less dependable sources, aggravating the hazards of waterborne infections. Haile et al. (2024) posit that climate-induced water stress would disproportionately harm lower-income households, who are less able to adjust to price spikes or infrastructural modifications. This study stresses combining socioeconomic resilience with climate planning in water management.

In addition to environmental considerations, cultural and gender norms also impact water access and water use practices (Dorji et al., 2021; Nthenge et al., 2017). For instance, in places with extensive agricultural linkages, such as sections of India, water is vital to both everyday life and commercial operations. Kunwar et al. (2024) examine groundwater depletion in India, emphasizing that cultural dependency on agriculture amplifies demand and stresses water supplies. Gender roles also affect water demand and access, especially in low-income communities where water-fetching responsibilities are commonly given to women and children. In many African communities, women have the major burden for water collection, restricting their socio-economic options (Thomas-Possee et al., 2024). This dynamic influences water consumption patterns, as Acey (2008) reported that women in these groups spend substantial time fetching water, which diminishes family production and adds to restricted water availability for everyday activities (Acey, 2008). Also, Yasuharu, Satoshi, and Hiroaki (2024) discovered in Myanmar that access to piped water reduced the time spent by women collecting water, underlining the socioeconomic advantages of better infrastructure.

Education has also been identified to have a major impact in determining water consumption patterns. As observed by Zhang (2024) in China, educated households use water more effectively and adopt conservation measures more than uneducated households. Therefore, higher educational achievement corresponds with improved awareness and implementation of water-saving methods. Hence, Odwori (2020) revealed that water consumption patterns in Kenya's Nzoia River Basin were substantially influenced by gender and education level. Graham et al. (2024) observed in sub-Saharan Africa that women typically bear the principal burden of water collection in low-income homes. This is a big obstacle that restricts their financial and educational prospects. Addressing these gendered inequalities is crucial for boosting household water security and broader socio-economic development.

The scenario in Nigeria is not different from the circumstances described by other nations in the developing world. Household water demand in metropolitan settings like Lagos is recognised to be influenced by socio-economic features such as income, education, and occupation, and it is these elements that dictate consumption patterns and access. Also, these variables cause variability in water usage, as affluent families frequently have better access to other water suppliers than the lower-income groups (Sheka, Boniface, & Wilson, 2022). For instance, Okeola and Moore (2022) claim that high-income families tend to have more consistent access to water because of their capacity to invest in private sources, such as boreholes or water vendors. Meanwhile, lower-income families rely on the intermittent public water supply (Oyerinde& Jacobs, 2022). The study also suggested that larger households tend to demand more water.

High-income families are more likely to participate in discretionary water usage, such as gardening and vehicle washing, contributing to greater consumption levels. Conversely, low-income households tend to prioritize vital water needs, like cooking and cleanliness. Ichukwu et al. (2024) noted that in Benue State, Nigeria, wealthier families used almost double the water volume of poorer households, which indicates inequalities in lifestyle and financial capabilities. Again, higher-income families often have better access to upgraded water sources, such as piped water supply. On the other hand, low-income households generally rely on water vendors or unimproved sources, which are less trustworthy and more expensive. For instance, Ogunbode et al. (2025) observed that in Iwo, Nigeria, higher-income families used public water services more frequently, whereas lower-income households were dependent on boreholes and water sellers due to financial limitations.

Gender, education level, and occupation also play roles, as better-educated households are likely to have a better awareness of water conservation, affecting their demand (Aminu &Nyor, 2021). While access to clean water is vital for public health and well-being, sustainable solutions involve careful consideration of the demand dynamics, especially in low-income urban areas.

Fagbohun and Ajetomobi (2018) conducted their investigations in low-income neighbourhoods of Lagos and found that not only economic capacity but also environmental factors, such as access to dependable public water infrastructure, influence water consumption. Households in rich towns generally suffer less unpredictability in supplies, whereas impoverished places have frequent shortages, prompting people to purchase water from vendors at higher rates (Okeola& Moore, 2022).

Thus, this study focuses on examining household water demand patterns employing the many socio-economic aspects that affect public water services in Lagos, Nigeria. The study intends to identify trends of volumetric water demand and to investigate the correlations between socio-economic factors, such as age, gender, income, occupation, and education, and the volumetric household demand for water.

2. Methodology

2.1 Study Area

Lagos is located in the southern section of Nigeria, near the Atlantic coast. The research region is located between latitudes 6°27' N and 6°37' N and longitudes 3°22' E and 3°42' E as shown in Figure 1. Lagos is part of the coastal plains of Nigeria and has access to both freshwater and saltwater water bodies, which impact its hydrological dynamics.

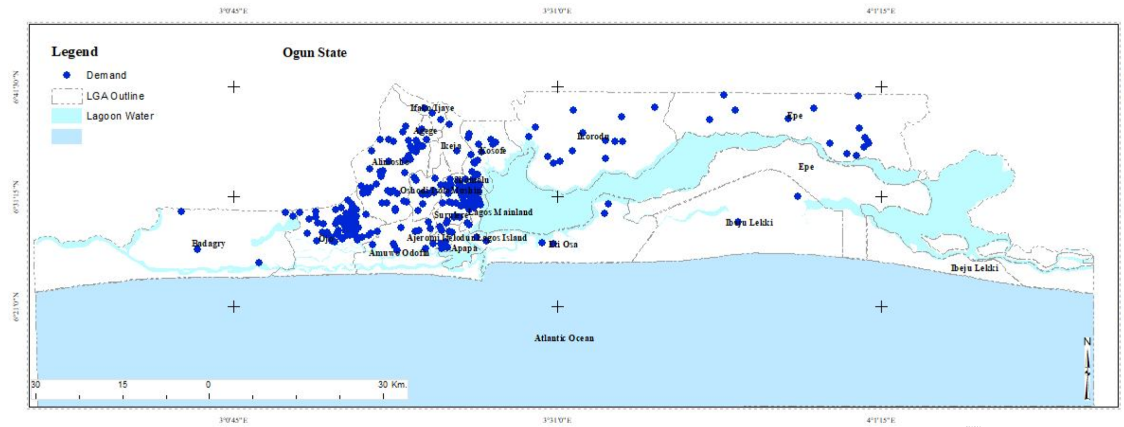

Figure1: Map of study area showing sampling locations

Lagos experiences a tropical savanna climate, characterized by two main seasons: the wet season from March to October and the dry season from November to February. Rainfall in Lagos can reach up to 2,000 mm annually, with the heaviest rains occurring between April and July. The study area is characterized by high humidity, which averages between 70% and 80%, and temperatures ranging from 25°C to 35°C. It falls within the lowland rainforest zone, characterized by swampy mangroves and tropical rainforests, but much of this vegetation has been replaced by urban infrastructure. The geology is dominated by sedimentary formations, largely composed of alluvial and coastal plain sands. The soils are generally sandy and porous.

The population is estimated at over 15 million, and the city's population density is among the highest globally, with an estimated 6,871 people per square kilometer. The rapid population growth is driven by rural-urban migration and high birth rates, which put immense pressure on the city's already inadequate water infrastructure. Despite its proximity to abundant water sources, the city's potable water supply is unreliable, leading to households seeking alternative solutions, such as water vending or boreholes (Oyerinde& Jacobs, 2022). Faced with a diverse socio-economic status, there are affluent areas with access to private boreholes and reliable water supply, while in the densely populated informal settlements, residents rely on water vendors or untreated surface water for their daily needs.

2.2 Data Collection and Analysis

Data were collected through structured household surveys and geospatial mapping. A total of 294 households were selected using a stratified random sampling technique to ensure representation across income levels, household sizes, and geographic locations. Additionally, geospatial data were obtained to analyze the spatial distribution of water demand. Geographic Information Systems (GIS) tools were employed in the mappingof household water demand and visualise spatial disparities. Maps depicting volumetric water demand by household, highlighting differences in minimum, maximum, public, and private water use, were derived. The study assessed the patterns and variabilities in the household water demands using the inferential statistical analysis of variance (ANOVA). Factorial ANOVA was used to assess the effects of socio-economic variables (e.g., income, household occupation) on water demands. The model also evaluated interactions between these variables to understand their combined influence. Moreover, where appropriate, effect sizes, such as Cohen's d, were reported to quantify the strength of relationships.

Two water sources were used in the study, namely purified public water and private water sources, which are usually not purified. The study therefore differentiated between these sources in the categorising of the demand component. Four subscales were used in the study for public water demand, and these are the minimum per capita demand (Min_PCD), maximum per capita demand (Max_PCD), minimum household demand (Min_HDD), and maximum household demand (Max_HDD). The fifth subscale was privately sourced water. All the volumetric demand subscales were measured in litres.

3. Results and Findings

3.1 Socio-economic characteristics

From the basic descriptive statistics, 44% of the gender were attributed to male while the female counterpart accounts for 52%. Figure 2 depicted 62.7% of the age group to be "18-30 years," while the age "30-50 years" accounts for 29%. The marital status from the same figure revealed the singles constitute the largest proportion, accounting for 67%, while the married occupy less than 30%, and the divorced account for the balance of less than 3%.

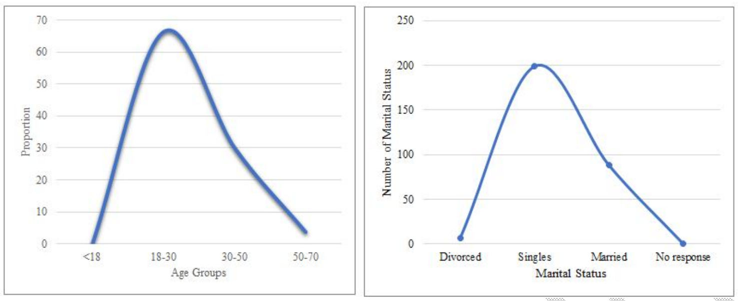

Figure-2: Graph showing Age and Marital status of respondents

The educational characteristics showed that about 90% of the respondents attained the tertiary level, while secondary accounts for a paltry 6%. Income level-wise, the statistics lie on the two extremes, with households with incomes less than N30,000 accounting for 29% while those with N90,000 and above trailed behind with 18%, and other income groups, N50,000-69,000 and N70,000-89,000, merely account for a paltry 7%, respectively.

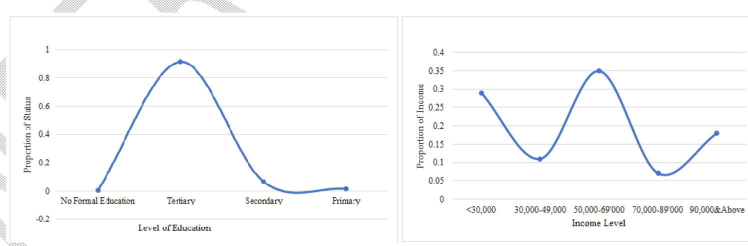

Figure 3: Graph of percentage comparison of educational status and income

In Figure 4, the employed shared almost the same proportion of 34.7% in occupational status, including the unemployed, who accounted for 34.3%. This is evident in the graphic display with a double peak, while self-employed followed behind them with 27%. Similarly, in the same figure, households who engaged in private work, with 20%, inched closer to private businessmen and women who accounted for 22% of the employment type. Furthermore, the public servant category followed with 19%, and the artisan occupies the balance with slightly above 6%.

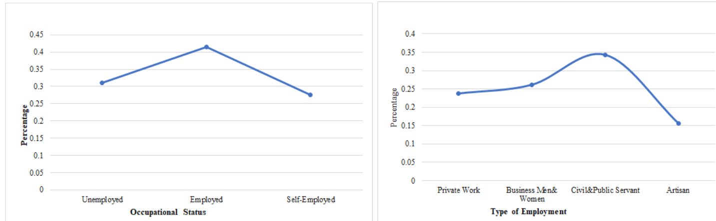

Figure4: Graph of percentage comparison of occupational status and type of employment

3.2 Spatial patterns of household demand for water

The study found spatial trends in domestic volumetric demands for the two water sources under study. Figures 5–9 depict the observed patterns in map renderings.

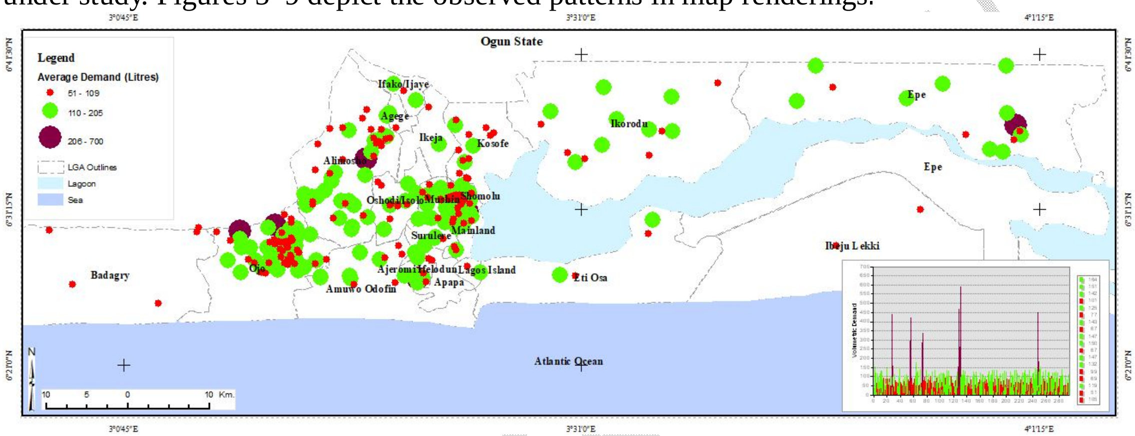

Figure 5: Average volumetric household water demandin the study area

Figure 5 depicts the average volumetric water demand for the study area, which includes both necessary and nonessential water applications. Core areashave higher average water consumption due to the dense populations and better access to public water infrastructure. Such communities are distinguished by homes that have consistent access to water, either through municipal connections or private boreholes, allowing for both essential and discretionary consumption. Therefore, the higher average demand observed in such locations is caused by a combination of high population density, dependable water supplies, and higher income levels, which allow for more discretionary consumption. Meanwhile, areas in the periphery have lower average water demand, which indicates restricted access to public water infrastructure and economical limits on use. Such areas usually rely on less dependable sources, such as boreholes or water vendors, leading to limits in total water consumption.

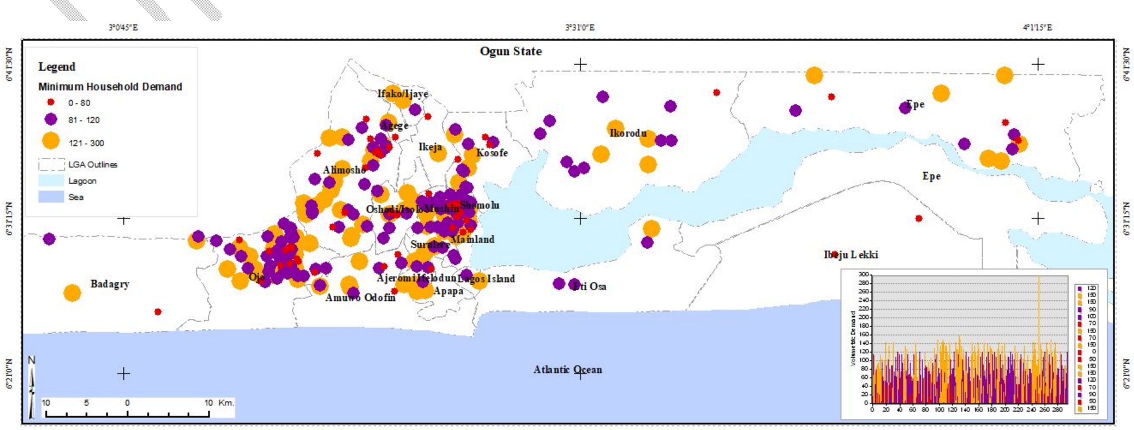

Figure 6: Minimum volumetric household water demand in the study area

Figure 6 shows the regional distribution of the minimal water demand required for family sustenance throughout the research area. Urban areas such as Ikeja and Surulere have moderate minimum water demand, indicating a larger household density and regular basic consumption for vital requirements such as cooking, drinking, and sanitation. Areas in the suburbs have lower minimum water demands. Such areas often have lower population densities and may have limited access to dependable water sources, limiting their capacity to satisfy even basic water requirements.

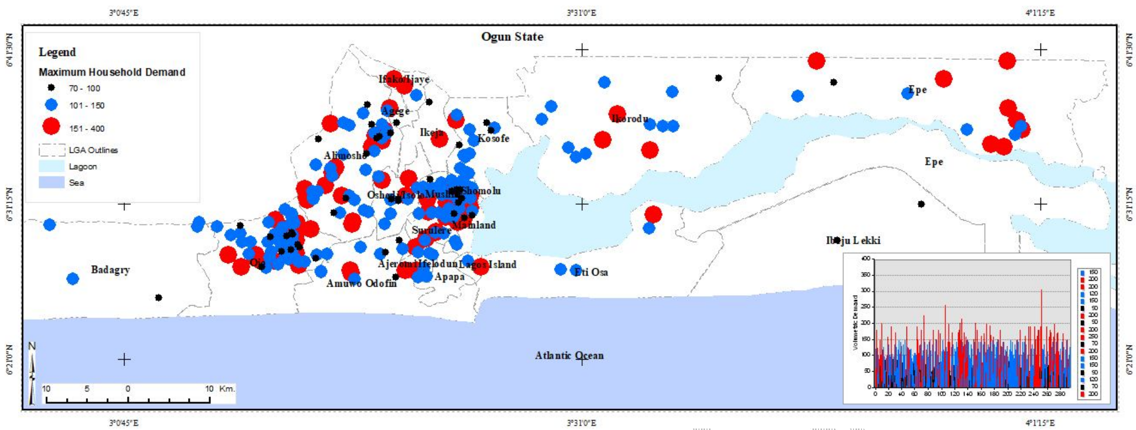

Figure 7: Maximum volumetric household water demand in the study area

Figure 7 depicts the maximum water usage in the study area, which include both necessary and nonessential applications. High maximum demand is concentrated in wealthy metropolitan regions like Eti-Osa and Lagos Island, where larger houses and water-intensive lifestyles (e.g., gardening, vehicle washing, and swimming pools) are prevalent. On the other hand, the peripheral regions have a substantially lower maximum water demand. This pattern reflects the low economic capability and infrastructure in these places, limiting water consumption to critical needs.

In comparing Figures 6 and 7, the results revealed that urban and peri-urban areas have higher minimum demand due to denser populations and more access to basic water infrastructure, whereas peripheral locations have lower minimum demand due to lower population densities and limited access. Furthermore, metropolitan centers have the highest demand, which is driven by socioeconomic considerations and nonessential applications, whereas remote locations have minimal demand owing to financial and infrastructure constraints.

3.3 Volumetric demands for public water sources

Figure 8 shows the volumetric public water demand in the research region.

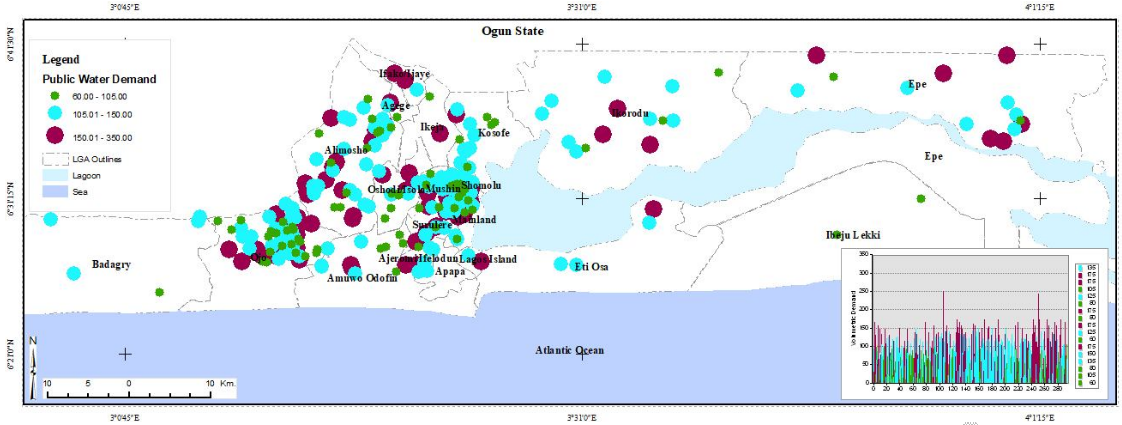

Figure 8: Volumetric public water demand in the study area

Figure 8 shows the spatial distribution of public water demand within the study area. Urban locations have higher public water demand. This trend implies improved infrastructure coverage, such as piped water networks, which are more common in highly populated and economically buoyant parts of Lagos. In contrast, peripheral and peri-urban communities such as Ikorodu, Epe, and Badagry have lower public water demands. These areas are typically underserved by public water infrastructure, which causes the reliance on other water sources.

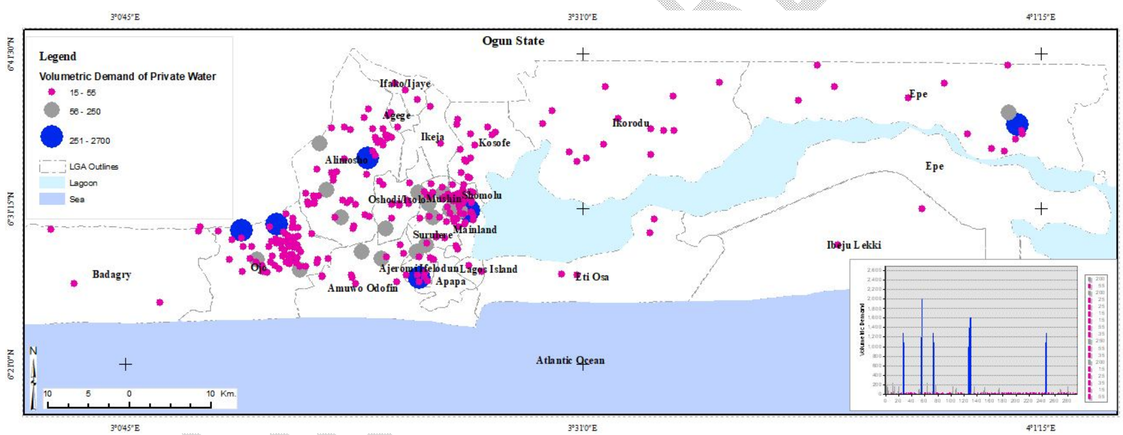

Figure 9: Volumetric private water demand in the study area

From Figure 9, private water demand is highest in outlying locations like Ikorodu, Epe, and Badagry, where public water supply is not available. These areas rely mainly on private water sources due to infrastructural shortages. Private water consumption is generally mild in metropolitan areas such as Ikeja and Surulere, indicating that it serves as a supplement when municipal supply is insufficient to fulfill residential demands. The study indicated significant discrepancies in water demand between urban and outlying locations. Urban areas such as Ikeja and Alimosho have increased public water demand, most likely owing to improved socioeconomic position and infrastructural coverage. However, periphery communities such as Epe and Badagry relied more on private sources, such as boreholes, likely indicating insufficient municipal supplies.

3.4 Assessment of volumetric water demand based on socio-economic variables

The result presented is an assessment that employed a two-way ANOVA to verify the effects of levels of water demand combined with the socio-economic characteristics of respondents on volumetric differences in household water demand. The socio-economic variables such as age categories, income levels, gender types and occupations of households were used in the analyses. Purified public water and water from private sources form the variable levels for the first independent factor. Purified public water source is further categorised into two subclasses, which are per capita and households, each comprised of minimum and maximum levels.

In the assessment that investigated the combined effect of levels of demand and gender types on volumetric differences in water sources demand among the households, results shown in Table 1 revealed the main gender effect was not significant $F_{0.05}(1,1330)$ =0.0777 with p-value =0.78, $t_{0.05,134}$= 1.9778, η_p^2= 0.175, ω^2 = 0.0308, η^2 =0.007, r= 0.1749, and the interaction effect was also not significant $F_{0.05}(4,1330)$ =0.98538, p-value =0.4144, ω^2 =0.031, suggesting that sources by gender were not significant, an indication that gender and sources of water do not combine to cause any effect to occur in volumetric differences among households. Therefore, no significant differences or variations in volumetric demands among households result from differences between men and women and water sources. However, there was a significant effect attributable to watersources demand (treatments) $F_{0.05}(4,1330)$= 10.5333, p-value <.05, ω^2 =0.031

Table 1: Two-Factor ANOVA with replication comparing volumetric water demands of households from public and private water sources based on gender types

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	1421.19403	1	1421.19403	0.077119851	**0.781282281**	3.848460096
Columns	776427.1642	4	194106.791	10.5330352	**2.11E-08**	2.378619575
Interaction	72636.26866	4	18159.06716	0.985385893	**0.414369325**	2.378619575
Within	24509747.39	1330	18428.38149			
Total	25360232.01	1339				

Furthermore, as shown in Table 2, a post hoc test based on the Tukey approach detected significant volumetric differences within the levels of public water demand, that is, between minimum per capita demand (mean= 96.7, std. =40.3) and maximum household demand (mean= 154.3, std.= 44.69) due to male gender $t_{stat.}$= 4.942 >$t_{0.05,134}$= 1.9778, reflecting an effect size that is higheron the side of maximum household demand than per capita demand by two-fifths of a standard deviation (Cohen's d= 0.4238, 95% confidence limits:34.3 and 80.7, r_{pb}= 0.5456) (Table 2).

Also from Table 2, a significant difference was reflected in the means between the private water demand and maximum public water demand, with volumetric size for public demand (mean= 154.3, std. = 44.69) being higher than the private source (mean=97.3, std.= 331.66) demand, showing an effect size that is slightly above 40%, reflecting, almost two-fifths of a standard deviation difference between the means (d= 0.419, 95% confidence limits:34 and 80.2, r_{pb} =0.5433,).

Table 2: Same Gender pairwise differences: Tukey HSD post hoc significance test of volumetric difference among demand for water sources at the level of male gender

Demand		Min_PCD	Private_ Source	Min_HHDD	Max_PCD	Max_HHDD	**Critical Tukeyw** =45.9 **S**ignificant ?
	Means	96.7	97.3	114.4	128.8	154.3	

Min_PCD	96.7		0.5597	17.68	32.09	57.54**	``
Private_Source	97.3			17.13	31.53	56.98**	``
Min_HHDD	114.4				14.40	39.85	``
Max_PCD	128.8					25.45	``
Max_HHDD_	154.3						

*** Differences were significant*

Moreover, it was a reverse situation for the female in that at the level of female gender, the volumetric differences that occurred were between the maximum per capita demand (mean = 150.3, std. = 58.23) of public water sources and private source (mean=75.4, std.=241.38), $t_{stat.}$= 4.8945 >$t_{0.05,134}$= 1.9778 (Cohen d= 0.39, r_{pb} =0.5297, 95% confidence levels are:29.8 and 80.6) indicating a standardised mean difference of about 40% or nearly two-fifth of standard deviation; between maximum household demand of public water source(mean=151.1, std.=45.14)and private (mean=75.4, std.=241.38)sources. The magnitude of effect was higher on the side of public water source by 50% or nearly two-thirds of a standard deviation, d= 0.557, r_{pb} =0.598 with 95% confidence limit 52.7 and 76.2 than it was for private sources cf. Table 3. This effect size is greater than that of the male by about 10%.

Table 3: Tukey HSD post hoc significance test of volumetric difference among demand for water sources for the female gender

Demand	Means	Min_PCD 109.1	Max_PCD 150.3	Min_HHDD 115.8	Max_HHDD 151.12	Private_ Source 75.4	Critical Tukey w = 45.9
Min_PCD	109.1		41.19	6.72	42.01	33.69	Significant?
Max_PCD	150.3			34.48	0.82	74.89**	``
Min_HHDD	115.8				35.3	40.41	``
Max_HHDD_	151.12					75.71**	``
Private_Source	75.4						

***Differences are Significant*

Households appeared to show greater preference for public water sources over private sources, and this is reflected in the two gender categories. Nevertheless, the female gender was slightly higher than their male counterpart with a difference in effect size amounting to 10%.

In summary, there is evidence indicating that slight volumetric differences exist within each gender between the households' demands for public water and private water sources, representing about two-fifths of a standard deviation in difference. For instance, while for the men, a small difference is reflected between volumetric demands for public and private water sources, the difference is moderate for the womenfolk. Whereas it is statistically determined that gender types do not interact with water sources to cause any significant difference in volumetric demands to occur among households, and that the significantresult obtained with respect to the water sources is by implication, we cannot emphatically place strong, decisive policy directives on the determining role of gender in households' water decisions and that its role reflects more in the individual water source rather than in combined sources.

3.5 Combined effects of water sources and age on volumetric differences

A hypothesis was tested which investigated the combined effect of water sources on volumetric differences in water demands of households across age categories. Evidence from the statistical analysis as represented in Table 4 showed that volumetric differences in sample means were not significantly different $F_{.05}(2,165)= 1.273$, p =0.283, $t_{(\mathbf{0.05,165}).}$ =2.1788; and the interaction effects were also not significant. $F_{.05}(2,165) = 0.65$, p =0.73.

This suggests that interactions of age of household members with households' water sources do not cause or lead to significant differences in volumetric water demand of households or that differences in households' volumetric demands are not resultant from the combined influenceof age and households' sources of water. On the other hand, there is statistical evidence from the same Table 4, giving us the confidence to conclude that volumetric differences in average demand for water source variables are significant $F_{.05}(2,165) = 39.01$, $p< .05$, $\omega^2 =1.759$, $\eta_p^2 =0.0297$, $\eta^2 =0.47$.

Table 4: The result of ANOVA which tested the dependence of volumetric water demands from public and private sources on age groups

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	5955.83	2	2977.92	1.2729	0.283	3.051
Columns	365088.3	4	91272.08	39.015	5.79E-23	2.43
Interaction	12231.67	8	1528.96	0.654	0.7316	1.995
Within	385997.92	165	2339.38			
Total	769273.75	179				

A procedure credited to Tukey Kramer detected that within public water demand, families significantly differed in their volumetric minimum per capita demands from the maximum household demand by an effect size that is almost 1½ standard deviation (Cohen d= 1.490, r_{pb} =0.7736, CI: 28.9≤ d ≤ 31.9). Again, it was evidently displayed in Table 5 that volumetric demand from unsubstantiated private water sources was significantly lesser than the volumetric minimum per capita demand from public sources. This shows an effect size of about two-fifths of the standard deviation in difference (Cohen d= 2.22, r_{pb} =0.8303, CI: -28.2≤ d≤32.6). The table further highlighted there are significant differences existing among families between volumetric demands for unsubstantiated private water sources and households' volumetric demands for public sources. Such volumetric difference showed demand size for unsubstantiated private sources is evidently lesser than the maximum per capita demands, is also lesser than the volumetric minimum household demand (Cohen d= 1.890, r_{pb} =0.8087, CI: ≤-28.5289d≤ 32.3); is lesser than the maximum household demand by an effect size (Cohen d= 2.22, r_{pb} =0.8303, CI: -28.2≤ d≤32.6).

In real effect size terms, differences between demand for public water and unsubstantiated private sources were much higher than differences that were reflected between households' volumetric demands for public water sources. This implies that a greater preference for public water sources surfaced among households than for private sources (Table 5).

Table 5: Tukey Kramer's Honestly Significant Difference (HSD)-based post hoc, pairwise comparison of means

		MinPCD	MaxPCD	MinHHDD	MaxHHDD _	Private_ Source	**Critical Tukey**
Demand	**means**	118. 89	154.17	138.3	179.7	46.8	**q =54.6**

MinPCD	118.89	35.28	19.4	60.8**	72.08**	**Significant?**
MaxPCD	154.17		15.83	25.56	107.36**	``
MinHHDD	138.3			41.389	91.53**	``
MaxHHDD	179.7				132.92**	``
Private_ Source	46.8					

** differences were significant

A further step was taken to determine whether volumetric demands could help in explaining age differences in water sourcing. Evidence from the comparisons of main effects suggests that younger people demand the least in the public and private water sources, and adult people's volumetric demand from both sources is greater than the rest—older and younger age groups. The difference in the means between demands for private water is moderately higher for adults than younger people by standardised mean difference, Cohen's d=0.508, r_{pb}= 0.5804, % CI: 30.08≤ d ≤ 31.38); while it is minimal between the adults and the older people by a standardised mean difference, Cohen's d= 0.336, r_{pb}= 0.5015 and 95% CI: 30.45≤ d≤ 45.11; the older people are, on average, higher in private water sourcing than the younger people (age group) by Cohen's d= 0.84, r_{pb}=0.6757, 95% CI: 29.86≤ d≤31.6.

Thereis statistical evidence from the comparison of differences between the volumetric demands for private water sources of younger, adult and older people, which suggested that older people do not worry much about the difference between purified and unpurified water, and the concern seemed to be about the volumetric availability.

The comparisons of main effects of water sources on volumetric demand suggests that differences in the average volumes between minimum and maximum per capita demand for public water sources and for private sources were equally very high for the younger, the adult and more older people based on standardised mean difference, a Cohen's 'd' which ranged between 0.999≤ d≤ 2.79. In the same vein, differences in the means between the two components, household demands for public sources and private sources, were very high for the younger age, adult and older people, as the standardised mean difference based on Cohen's d lies between 1.48≤ d≤3.03.

3.6 Assessments of the combined effect of watersources and households' levels of income on volumetric differences

The analysis used a two-factor ANOVA design to test the hypothesis that volumetric differences in household water demand are independent of the combined effects of household income levels and water supply sources. In simpler terms, this means the analysis aimed to determine whether variations in average household water demand occur regardless of differences in income levels and sources of water supply. In the result of the analysis just described, the outcome indicated that the main effect (differences in sample means) of income was significant $F_{0.05}(2,765)$ = 3.01276, *p*-value= 0.0497, ω^2 = 0.031, η_p^2=0.019, invariably implying, income has an explanation. to offer to differences in households' water demand, and the main effect of demand was also significant $F_{0.05}(4,765)$ = 3.6686, *p*-value< 0.05, η^2=0.0012, r=0.035, d =0.000051, ω^2 = 0.00282. Nevertheless, the interaction effect was not significant $F_{0.05}(4,765)$ = 3.6686, p-value= 0.919, ω^2= 0.00137, an indication that differences in the means between income levels do not cause any significant volumetric difference to occur between the levels of demand due to public or private water sources among the households cf. Table 6.

In the post hoc analysis conducted to identify specific variables showing significant differences within the samples (focused on the income factor), Fisher's t-test revealed that none of the observed differences were statistically significant. However, a procedure that utilised a contrast of difference among the marginal means found overall that the volumetric difference that was detected between the income levels was significantly lower for the 80,000-119,999 group than for other income groups, $t'_{\mathbf{0.05(1,765)}}$ = 1.9718988. This is a reflection of the effect size measure in Cohen's d = 0.0107 or a marginal proportion of 1.1 percent between the groups.

Additionally, the main effect observed in water demand levels showed that households had a significantly greater volumetric demand for public water source compared to the unverified private water sources. This reflected an effect size of about 35% or nearly $2/5^{th}$of the standard deviation or a standardised mean difference of Cohen's d = 0.35296.Considering public water source demand, a significantly higher volumetric difference was reflected between the maximum household demand and per capita demand. This occurrence of volumetric difference was within a public water source, a reflection of an effect size based on standardised$d$ = 0.3469, or a proportion of almost 35 percent.

Table 6:Two-way ANOVA testing hypothesis that householdincome levels and supplysources have no combined effect on volumetric differences in demands

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	153531.54	2	76765.769	3.012	**0.04973919**	3.007494217
Columns	373909.74	4	93477.44	3.6686	**0.005720195**	2.383572056
Interaction	82067.179	8	10258.397	0.40	0.91933917	1.950488975
Within	19492323.1	765	25480.16			
Total	20101831.5	779				

3.7 Volumetric household water demand and occupation.

The goal of the two-way ANOVA given below was to explore if volumetric variations in household demand are influenced by families' occupational classes and water sources. The two independent variables are Factor 1, which includes occupational classifications (employed, self-employed, and unemployed), and Factor 2, which includes water sources (public and private).Table 7 shows that the major influence of occupation was not significant $F_{.05}(2,1035)$= 1.3779, p-value =0.252569, ω^2= 0.014, η^2= 0.019, and the interaction effect was likewise not significant, F.05(4,1035) = 0.666, p-value = 0.7217. The results showed a significant difference across water sources ($F_{.05}(4,1035)$= 4.768, p-value <.05, h2=0.01795, w2=0.0189), leading to the rejection of the null hypothesis.

Table 7 shows a two-factorial analysis of variance to test the hypothesis of independence between family occupation and water sources.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	62929.33	2	31464.67	1.3779	0.252569	3.00442
Columns	435527.71	4	108881.93	4.768	**0.0008159**	2.38053

Interaction	121686.86	8	15210.86	0.666	0.7217236	1.94733
Within	23634433.93	1035	22835.2019			
Total	24254577.83	1049				

A post-*hoc* test found a significant difference in marginal means between the three occupational classes (employed, self-employed, and unemployed), $t_{.05}(1,1035)$= 1.88, *p*-value=.05, reflecting an effect size *d*= 0.02314, representing a standardised difference of nearly 2½%). This indicates that employed class families have higher volumetric demand than other groups.

Furthermore, because the main effect of treatments(i.e., water sources) was significant, a method known as Holm's variant of the Bonferroni procedure revealed a significant difference between the household's maximum volumetric demand for public water and unsubstantiated private water sources, $t_{.005}(1,1035)$= 1.8823. This displays a standardised effect size of Cohen's *d*=0.34868, which represents a 35% difference between the two sources and a 95% confidence limits of 17.05 to 88.3. Baker and Lew (1987) found that the Bonferroni technique compared well with the Tukey method, and Maxwell (1980) testified that it was successful in controlling the familywise error rate (Howell, 2010).

In the unemployed occupational class, a Tukey HSD method revealed that maximum per capita demand was higher than maximum household demand, with a standardised effect size *d*= 0.486, indicating a 49% difference in volumetric difference (litres) and 95% confidence limits: 37.3 & 105.2. Similarly, a significant effect size in volumetric difference was found in the self-employed class. This demonstrates a standardised effect size *d*= 0.47, which is over half a standard deviation or a volumetric (litres) difference of nearly 50% with 95% confidence limits of 39.5 and 107.5.

Table 8: A Tukey-based post hoc test of significance for simple effects.

Occupational Classes	MinPCP	MaxPCP	MinHDP	MaxHDP	Private _Source	Diff. Signif.	Tukey hsd q= 65.58
Unemployed	91.43	122.7	111	151.57	78.07	**yes**	**73.5***
Employed	105	143.57	113.7	149.86	136.5	**no**	
Self-Employed	106.29	140.1	114.57	150.14	78.93	**yes**	**71.2***

Note: **“ ** ”** differences were significant

4. Summary and Conclusions

In the analysis to detect patterns in household demand for water sources and thus establish relationships between socio-economic variables, various patterns were detected that reflected volumetric differences in the means between public and private water sources on the one hand and within public water sources on the other. Among the socioeconomic factors, only income samplesshowed significant variations in volumetric needs. Invariably, wealth is a crucial influence in families' volumetric demand decisions. Nonetheless, it does not diminish the importance of the other three components, whose major impacts are not powerful enough to generate substantial disparities in average household needs.

In establishing the significance of income, the study notes that, at the point when households are making water decisions, households rarely choose what volume of water will go for the different age categories, nor do they attempt to isolate specific volume for men and women, nor do they set aside what amount will go for employed and unemployed people. However, judgements are made over how much is allocated for specific home water consumption functions. Thus, any water policy aimed at supporting home usage functions must, by definition, take families' income levels into account when calculating the potential water equation.

For the age summary, statistical evidence from comparing differences in demands for private water sources among younger adults and older people suggests that older people are less concerned about the difference between purified and unpurified water, and are more concerned with volumetric availability. The age effects on water demand are, between the minimum and maximum per capita demands for public water sources on the one hand, and minimum and maximum household demands for public water sources on the other. But for the demand for private water sources, large differences were found for all age categories.

The occupation's main effect and the interaction with demand levels were not significant, while the main effects of demand levels were. An examination of simple effects reveals a significant difference in marginal means between the occupational classes, revealing a significance between the employed class and the two other classes (that is, self-employed and unemployed). The effect size represents a standardised difference of nearly 2½%, indicating that employed class families were significantly different in volumetric demand from other occupational classes by about two and half percent.

The analysis of patterns and variables in this article revealed that household income appears to be repeating in virtually all of the patterns discovered. This socioeconomic feature of water consumers is also highly important in water policy design and implementation if the SDG 6 objective is to be met. The regional variations in water demand emphasise the significance of integrated urban water management in creating sustainable and resilient cities. Equitable infrastructure design and investment may help overcome these inequities and meet SDG 11.

The report emphasises the critical need to resolve inequities in water availability between urban centres and peri-urban areas. Expanding municipal water networks to underprivileged communities would minimise reliance on costly informal sources while also promoting equal access to clean water, which aligns with SDG 6 and in sync with SDG3 and 11. Furthermore, the high dependence on private boreholes in peri-urban regions raises worries about groundwater depletion, which endangers ecosystem health and long-term resource supply. Integrating sustainable techniques, such as rainwater collecting and greywater recycling, can help to avoid these risks and promote SDG 15.It is critical to educate the general public on water conservation and sustainable consumption techniques. Targeted efforts in high-demand regions can help minimise waste and increase efficiency.

Consent

As per international standards or university standards, respondents' written consent has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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