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Domestic Water Consumption Pattern and its Driving Factors in Developing Countries: A Case Study of Adolor Community of Egor LGA, Benin City, Edo State, Nigeria

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ABSTRACT

This study evaluated the domestic water consumption pattern and its driving factors in the Adolor community of Egor LGA in Benin City, Edo State, Nigeria. Data on socio-demographic characteristics such as gender, age, education status, occupation status, monthly income, house type, and household size; household characteristics such as source of water, time to collect water from outside the premises, and pattern of water use were collected by using a questionnaire survey. The data were analyzed using frequency analysis and multivariate statistics (principal component analysis and multiple linear regression). Principal component analysis (PCA) was used to evaluate each variable's correlation with the quantity of domestic water consumption, and multiple linear regression was used to evaluate the predictors of domestic water consumption. Results of the frequency analysis indicated that at the household level, the water used for bathing, cloth washing, toilet flushing, car washing, cooking, dish washing, other domestic uses, and drinking constitutes about 27.39%, 20.42%, 14.19%, 11.27%, 7.96%, 6.56%, 6.17%, and 6.06, respectively, of total domestic water consumption. The result of the multiple linear regression analysis shows that the quantity of domestic water consumption can be predicted by 88.5% of the variables considered. The gender, education status, occupation status, and source of water were the most significant factors influencing the quantity of domestic water consumption components, accounting for 95.7%, 95.2%, 92.8%, and 90.7%, respectively, of the total variance explained. Hence, these factors should be considered in devising a water demand management strategy for the Adolor community to efficiently manage water demand and promote sustainable usage.

1. INTRODUCTION

Water is a fundamental human right and it is essential for human health, well-being, and development (WHO, 2019). However, millions of people worldwide still lack access to safe drinking water, even basic water (UNDP, 2015; Dinka, 2017). Contaminated water is responsible for more deaths than cancer, AIDS, wars, or accidents, according to a report by the Third World Academy of Sciences (TWAS, 2002). Around 50% of all diarrheal deaths worldwide are believed to be caused by inadequate drinking water and sanitation facilities (Prüss-Ustün et al., 2014; Dinka, 2017; Ahmad and Daura, 2019; WHO, 2022). Hence, as a criterion, an adequate, reliable, clean, acceptable, and safe drinking water supply has to be available for various users (Bos et al., 2016). Moreover, everyone needs access to safe water in adequate quantities for drinking, cooking, personal hygiene, and sanitation facilities that do not compromise health or dignity.

Many people in Nigeria lack access to safe and sufficient water for their domestic needs. According to a survey by UNICEF, the average amount of water each person receives in Nigeria is 9 liters per day, which is below the minimum acceptable range of 12 to 16 liters per day (UNICEF, 2020). This is mostly related to the ever-increasing population growth in developing countries and the inability (or unwillingness) of governments (local and national) to provide adequate water supply facilities in these countries (UNESCO, 2015). The water supply sector in Nigeria faces many challenges, such as poor infrastructure, low coverage, inadequate funding, and weak governance (NBSN, 2023, and the World Bank, 2021). Moreover, increased anthropogenic activities due to population growth and urbanization have polluted most of the water resources.

Meeting the increasing demand for water consumption due to population and economic growth is a challenging task that requires significant resources and infrastructure (Mudashiru et al., 2021). Thus, water resource management is essential to addressing water challenges. Supply-side solutions are more expensive as the easily accessible options have been fully developed and new options are becoming difficult to find (WRC, 2016). Therefore**,** water demand-side management strategies are emerging as key interventions to help address local and national water challenges (WRC, 2016; Brears, 2023). These strategies are designed to improve water services by inducing changes at points of use with the aim of increasing end-use efficiency and reducing waste (water conservation).

The domestic sector uses one of the largest portions of water in cities (Arbon et al., 2014). Concerns about domestic water consumption patterns and levels are becoming crucial, as they will positively influence water conservation and enable water authorities and policymakers to design, effectively implement, and enforce water demand management strategies. Additionally, it will help to generate predictive water demand models, which will allow water authorities to optimize water distribution systems.

Accurately quantifying the amount of water demanded by a particular region is the force that drives the changes in the hydraulic processes of the water distribution system. The accurate quantification of water demand will improve the analysis and present effective predictive simulation models. Determining the factors that influence domestic water use is therefore crucial when modeling a water distribution network system (Mudashiru et al., 2021), as the requirement for water usage extends to several purposes like drinking, cooking, washing, agricultural, commercial, religious, recreation, transportation, and hydroelectric power generation, among others. A large number of factors have been reported to influence water consumption (Cominola et al., 2023). While some of these factors (household family size, occupants' age, and occupants' income) are well-researched, well-represented, and especially useful for practitioners on a tight budget, others are not and therefore require further study to better understand them and compare or contrast the scant research that has been done on them (Cominola et al., 2023).

In developed countries, studies have investigated domestic water consumption patterns and variables affecting domestic water consumption (Lins et al., 2010; Fan et al., 2013; Croucha et al., 2021; Zeroual et al., 2021). However, in developing countries, such studies are limited (Nauges and Whittington, 2009; Government of Canada, 2023). According to Nguyen and Teller (2018), cities in developing countries are finding it difficult to provide their inhabitants with basic amenities, especially clean water, due to the rapid population growth in many of these locations. Because of the variation in factors such as (1) cultural, community norms, and religious customs; (2) climate and environmental conditions; (3) technology advancement (at both the individual and network level); (4) water pricing structures and legislation; and (5) environmental education, specialized country- and location-based research is necessary. Hence, this study aims to evaluate the domestic water consumption pattern and its influencing factors in the Adolor

Community, Nigeria. The study's findings will provide policymakers and water authorities with valuable information to predict future water demand so as to plan and manage water supply in the study area.

2. METHODOLOGY

2.1. Study Area

Adolor is a community located in Egor LGA of Benin City (Figure 1), which lies between latitude 6° 21' 27" north and longitude 5° 34' 32east of the central province of Edo State, covering an area of 93 square kilometers (Mapcarta, 2023; Manpower, 2023). The region experiences a mean annual rainfall of between 1500mm and 2500mm and a mean monthly temperature varying from 25°C to 28°C (Ancient Benin Kingdom and Edo State, 2018; Manpower, 2023). The geology of the region is marked by reddish earth composed of ferruginized or literalized clay sand (Ikhile, 2016). It is underlain by the sedimentary formation of the South Sedimentary Basin and constitutes part of the Benin formation, which is made up of over 90% massive, porous, coarse sand with thick clay and shale interbeds having high groundwater retention capacity (Ikhile, 2016; Adegbite et al., 2018). The population of Adolor Community is a blend of individuals from different ethnic groups in Nigeria, with the Bini-speaking people of Edo State being the most populous. The majority of the inhabitants are engaged in various occupations such as civil service, trade, farming, artisan work, and transportation.

Figure 1: A map showing Adolor community (Source: Google Earth, 2023)

2.2. Data Collection and Analysis

The study collected data via questionnaires using a cross-sectional descriptive survey method. A simple random sampling technique was used to constructively administer a total of 420 technically designed, pre-tested, semi-structured questionnaires to households in the Adolor community. These households consist of single-family houses and apartments. Household heads were targeted as respondents because they are best suited to provide the required information in the questionnaire. The questionnaire was structured to capture information on selected observable variables (socio-demographic characteristics such as gender, age, education status, occupation status, monthly income, house type, household size; household characteristics such as source of water, time to collect water from outside the premises, and pattern of water use) identified by Mudashiru et al. (2021) and which have not been well studied to understand their influence on the level of domestic water consumption in the Adolor community in Benin City, Nigeria. About 15% of the questionnaire was ascertained for validity using the face validity method and reliability (using Cronbach's alpha statistics).

Cronbach's alpha coefficient measures the internal consistency or reliability of a set of survey items. It determines whether a collection of items consistently measures the same characteristic and quantifies the level of agreement on a standardized 0–1 scale (Goforth, 2022; Frost, 2023). Three hundred and eighty (380) completed copies of questionnaires were retrieved (estimated sample size). Hence, three hundred and eighty (380) copies of questionnaires were analyzed. The retrieved questionnaires and Cronbach's alpha reliability were analyzed using the Statistical Package for the Social Sciences (SPSS, version 26.0, 2018). Frequency analysis and multivariate statistical methods (principal component analysis and multiple linear regression) were employed to analyze responses, and results were presented using descriptive charts and tables. Principal component analysis (PCA) was used to evaluate each variable's correlation with the quantity of domestic water consumption. PCA reduces the number of dimensions in large datasets to principal components that retain most of the original information (Lever et al., 2017; IBM, 2023). It does this by transforming potentially correlated variables into a smaller set of variables called principal components (IBM, 2023). One of the major requirements for conducting PCA is to check for data suitability, as this will determine whether or not to proceed with the analysis. This is because a sample size of data must be large enough to allow correlations to converge into mutually exclusive factors. The Kaiser-Meyer-Olkin (KMO) and Bartlett's tests are used to assess the suitability of data for PCA. KMO assesses the overall sampling adequacy of your data, while Bartlett's test checks whether the variables in your dataset are correlated enough to proceed with PCA (IBM, 2023; Datapott, 2024). Multiple linear regression was used to evaluate the predictors of domestic water consumption. The sample size used for the study was determined using Equation 1 (Yamane, 1967):

$$n = \frac{N}{1+N(e^2)} \tag{1}$$

Where: n = Sample size, N = Population under study, and e = Margin error=0.05

3. RESULTS AND DISCUSSION

The results from the study are presented in two sections, as indicated below.

3.1. Pattern of Domestic Water Consumption in the Study Area

The results obtained in this section of the study are presented in Tables 1 to 4. Table 1 indicates Cronbach's alpha for the reliability of the questionnaire; Table 2 shows the socio-demographic characteristics of respondents; Table 3 shows household characteristics; and Table 4 shows the pattern and quantity of daily domestic water consumption in the Adolor community. From Table 1, the statistics of more than 70% revealed by the Cronbach's alpha statistics suggest that the questions in the questionnaire are all similar and pertinent to the subject matter of the survey. It therefore suggests a very good questionnaire. Of the 420 questionnaires administered to households, 397 were retrieved (estimated sample size) for analysis, giving a response rate of 100%.

Table 1: Cronbach's alpha for reliability of questionnaire

Cronbach's Alpha	No. of Items
0.759	16

Table 2 indicates that the respondents comprise an equal proportion of males (50%) and females (50%). This might imply that men, like women, are also more informed about water management at the household level and that women are not denied major decision-making roles for water supply at both local and national levels. The majority of the respondents were aged between 18 and 45 years (46.8%), 32.4% were aged between 46 and 65 years, and 20.8% were 65 years and older. About 14.2% had primary education, 78.2% were educated beyond the primary level (secondary: 36.1%; tertiary: 42.1%), and only 7.6% have no education, indicating a high level of literacy among household heads. All the respondents earned a living;

they are involved in trading (37.4%), the private sector (22.4%), other kinds of jobs (21.1%), the government sector (10.8%), and farming (7.4%), indicating economically viable households as none of them were idle. Further, results showed that the majority of the households were middle-income earners (41.6%), followed by high-income earners (31.6%), and 26.8% were low-income earners. In terms of house type, most (82.1%) of the settlement household types are modern houses, while 17.9% are made up of old houses. Most (56.3%) of these houses housed between 4 and 6 members; 22.1% had below 3 members, and 21.6% had above 6 members.

Table 2: Socio-demographic characteristics of the respondents (n=380)

Variable	Number of respondents	Percentage
	Gender	
Male	190	50.0
Female	190	50.0
Total	380	100.0
	Age	
18-45 years	178	46.8
46-65 years	123	32.4
Above 65 years	79	20.8
Total	380	100.0
	Educational status	
Primary	54	14.2
Secondary	137	36.1
Tertiary	160	42.1
No Education	29	7.6
Total	380	100.0
	Occupational status	
Farming	28	7.4
Trading	142	37.4
Civil Servant	41	10.8
Private Worker	85	22.4
Others	84	21.1
Total	380	100.0
	Monthly income	
Low Income Earner (Below #30,000)	102	26.8
Middle Income Earner (#30,000-#100,000)	158	41.6
High Income Earner (Above #100,000)	120	31.6
Total	380	100.0
	House type	
Traditional	68	17.9
Modern	312	82.1
Total	380	100.0
	Household size	
Below 3	84	22.1
Between 4 and 6	214	56.3
Above 6	82	21.6
Total	380	100.0

From Table 3, results showed that 61.3% had access to boreholes (private and community), 21.1% had access to private in-house connections, 15.3% had access to hand-dug wells, and only 0.5% obtained their source from rainwater, implying that the respondents depend on various sources for portable water supply, with the majority of the sources being from the private sector (private and community boreholes, hand-dug wells, etc.), as noted by some researchers in other parts of Nigeria (Mudashiru et al., 2021; Oyerinde and Jacobs, 2021). This may probably be due to the inadequacy and inconsistency of portable water supply by the agencies (state water corporations and boards) responsible for urban water supply in the country. Hence, instead of having water delivered directly to their buildings, the majority of the respondents source their own water by traveling to the closest accessible sources, which are community boreholes and hand-dug wells. Regarding time to collect water outside the premises, it was observed that the majority (52.9%) of the respondents used less than 10 minutes to fetch the water they needed for domestic use; 17.4% used 11–20 minutes; 15.0% used more than 30 minutes; and 14.7% used 21–30 minutes.

Table 3: Households characteristics

Variable	Number of respondents	Percentage
Source of water		
Borehole	233	61.3
Well	58	15.3
Tap water	80	21.1
Rain water	2	0.5
Others	7	1.8
Total	380	100.0
Time to collect water outside the premises		
<10mins	201	52.9
11-20mins	66	17.4
21-30mins	56	14.7
>30mins	57	15.0
Total	380	100.0

From Table 4, results revealed that the pattern of domestic water use practiced daily at households is bathing, which accounts for 27.39% of the total daily domestic use, followed by cloth washing (20.42%), toilet flushing (14.19%), car washing (11.27%), cooking (7.96%), dish washing (6.56%), other domestic uses (6.17%), and drinking (6.06). Regarding the quantity of daily water use, households used 32620 liters for bathing, 24322 liters for cloth washing, 16897 liters for toilet flushing, 13424 liters for car washing, 9480 liters for cooking, 7807 liters for dish washing, 7346 liters for other domestic uses, and 7203 liters for drinking. This result indicates that the water used for bathing was greater compared to other practices. Studies have also reported a similar pattern of domestic water use at household levels (Sadr et al., 2015; Narmilan et al., 2021; Mudashiru et al., 2021).

Table 4: Pattern and quantity of daily domestic water consumption in Adolor community

Activities	Quantity of water used (Litres)	Percentage (%) water used
Drinking	7203	6.06
Cooking	9480	7.96
Bathing	32620	27.39
Dish washing	7807	6.56
Cloth washing	24322	20.42
Car washing	13424	11.27
Toilet Flushing	16897	14.19
Others (handwashing, cleaning, brushing of teeth, ablution etc.)	7346	6.17
Total	119, 099	100.01

3.2. Factors Determining Domestic Water Consumption in the Study Area

The results obtained in this section of the study are presented in Tables 5 to 8. Table 5 indicate KMO and Bartlett's test of sample adequacy and sphericity, Table 6 shows communalities for selected variables for the quantity of domestic water consumption, Table 7 shows the total variance explanation for the selected variables for the quantity of domestic water consumption, Table 8 shows regression model summary and

Table 9 presents the Analysis of Variance (ANOVA). From Table 5, a KMO value of 0.666 indicates acceptable sampling adequacy, and the Bartlett's test with a p-value of 0.000 less than 0.05 suggests that there is enough correlation between variables and thus further exploration of PCA.

Table 5: KMO and Bartlett's test of sample adequacy and sphericity

Kaiser-Meyer-Olkin measure of sampling adequacy		0.666
	Approx. Chi-Square	1201.114
Bartlett's test of sphericity	Df	136
	Sig.	.000

Results from Table 6 revealed that gender accounted for 95.7% of the variance of the volume of water use, which is the highest. This result contradicts the findings of Mudashiru et al. (2021), who found that monthly income was the highest determinant of domestic water consumption. This might be attributed to women's involvement in major decision-making roles for water supply and men's involvement in water management at the household level, as revealed by the questionnaire survey, which shows an equal proportion of males (50%) and females (50%) household heads. Gender is a significant variable in decision-making for water management at the household level, as it has been reported that water use varies significantly between people of different sexes. Jordán-Cuebas et al. (2018) and Shan et al. (2015) indicated that females take longer showers than men do. On the other hand, a study has reported that males are less likely to practice water conservation, especially at the household level, due to their limited knowledge about it (Reniko et al., 2020; Fink, 2011). Education level accounted for 95.2%, as education plays a significant role in water conservation and water use efficiency. High education increases people's understanding of water scarcity challenges and, as such, can increase or decrease domestic water consumption. High levels of education associated with a high level of income can reduce awareness of water conservation and efficient water usage because a smaller proportion of the income will be spent on water (Kavya and Raj, 2020; Reniko et al., 2020). On the other hand, education increases the knowledge of water conservation practices and thus reduces the levels of domestic water consumption (Narmilan et al., 2021). However, a study conducted by Collins et al. (2003) showed that people with no formal education use less water due to traditional patterns of water use (washing hands, showering, and sharing water between family members) and their ignorance of water appliances.

Occupation distribution accounted for 92.8%, indicating that the behavior of water usage can be very different among household members with jobs and no jobs. A report by Browne et al. (2014) suggested that occupation is one of the factors that can affect household water consumption, as results from the study found that households with a higher proportion of employed members tend to consume more water than households with a lower proportion of employed members. However, the authors note that the relationship between occupation and water consumption is not straightforward and may depend on other factors such as income, education, and household size. The source of water showed a percentage variation of 90.7%, which suggests that the ease or difficulty with which individuals sourced water from hand-dug wells and boreholes, respectively, influenced their rate of water use (Mudashiru et al., 2021). The easier the availability of fetching or getting water, the more water is consumed by households, and the greater the difficulty in getting water, the greater the efficiency of water use (Kavya and Raj, 2020). This is further influenced by income and the time taken to collect water outside the premises.

Water allocated for cooking accounted for 89.4%, water allocated for flushing toilets for 89%, and water allocated for dishwashing for 88.7%. Age indicated a percentage variance of 85.2%; this implies that the behavior of household members of different ages can vary in terms of water utilization. Young people are perceived to use water more recklessly, take more showers, and request more frequent laundry, whereas old people exhibit more frugal behavior (Nauges and Thomas, 2000). However, findings from the study conducted by Reniko et al. (2020) showed that old people consume more water than young people. Water allocated for other activities accounted for 88.3%.

House type showed a percentage variation of 79.7% as it determined the size, built-up area, and available household facilities. In certain circumstances, modern houses are constructed with water-saving equipment, while in other cases, they are constructed with outdoor features like gardens, lawns, and swimming pools, which require more water (Mudashiru et al., 2021). Water allocated for bathing and car washing indicated the same percentage variation as house type, which is 79.7%. Monthly income accounted for 79.1%, as income plays a vital role in the standard of living. Studies have indicated that an increase in household income is usually associated with an increase in water consumption (Hussein et al., 2016; Basu et al., 2017). This may probably be due to private ownership of water sources, an improved lifestyle, water use appliances, a garden, and a swimming pool (Oyerinde et al., 2021; Narmilan et al., 2021). Time of water collection accounted for 77.2%, indicating a significant factor in domestic water consumption. This can be supported by a study conducted by Howard and Bartram (2003), who concluded that as the time taken to reach the water source increased, the volume of water decreased proportionally. Water allocated for cloth washing and drinking accounted for 75.5% and 75.3% of the analysis on the volume of water.

Household size accounted for 65.9% of the variance in the volume of water use. Household size is a significant factor in the level of domestic water consumption, as water consumption varies with the household's size. A large household typically uses numerous household water-use appliances, resulting in higher water use than a small household. A study conducted by Crouch et al. (2021) noted that an increase in household size caused a similar increase in domestic water consumption. However, authors have reported that the higher the household size, the relatively lower the domestic water consumption within the household, as some forms of economies of scale relating to the optimization of water use are especially practiced in bigger households than in smaller households (Guhathakurta and Gober, 2007; Kanda et al., 2017; Vannavong et al., 2017).

Table 6: Communalities for selected variables for the quantity of domestic water consumption

	Communalities	
Variable	Initial	Extraction
Age	1.000	0.852
Gender	1.000	0.957
Educational Status	1.000	0.952
Occupational Status	1.000	0.928
Monthly Income	1.000	0.791
House Type	1.000	0.797
Household Size	1.000	0.659
Source of Water	1.000	0.907
Time to collect water	1.000	0.772
Water allocated for drinking	1.000	0.753
Water allocated for cooking	1.000	0.894
Water allocated for bathing	1.000	0.797
Water allocated for cloth washing	1.000	0.755
Water allocated for dish washing	1.000	0.887
Water allocated for car washing	1.000	0.790
Water allocated for toilet flushing	1.000	0.890
Water allocated for other	1.000	0.883

Extraction method: principal component analysis

From Table 8, the multiple linear regression analysis that was carried out based on Table 7 indicates an R^2 value of 88.5% of the quantity of domestic water consumption can be explained by the following factors: water allocated for dish washing, education status, time to collect water, occupation status, gender, water allocated for car washing, age, water allocated for cooking, water allocated for toilet flushing, source of water, and water allocated for bathing.

Table 7: Total variance explanation for the selected variables for the quantity of domestic water consumption

Component	Total Eigen value	Variance (%)	Cumulative (%)
1	3.198	18.814	18.814
2	1.877	11.041	29.855
3	1.627	9.571	39.426
4	1.357	7.982	47.408
5	1.151	6.772	54.181
6	1.083	6.373	60.554
7	0.932	5.485	66.038
8	0.868	5.105	71.143
9	0.794	4.673	75.817
10	0.75	4.414	80.231
11	0.625	3.677	83.908
12	0.56	3.297	87.205
13	0.522	3.072	90.277
14	0.496	2.919	93.196
15	0.476	2.798	95.994
16	0.362	2.132	98.126
17	0.319	1.874	100

Table 8: Regression model summary

Quantity of domestic water consumption model summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.941[a]	0.885	0.882	34.094

a. Predictors: (Constant), Water allocated for dish washing, Education status, Time to collect water, Occupation status, Gender, Water allocated for car washing, Age, Water allocated for cooking, Water allocated for toilet flushing, Source of water, Water allocated for bathing

The results from Table 9 indicate that the p-value is 0.00, which is less than the significance level of 0.05. This implies statistical significance, suggesting that changes in the predictor variable are correlated with variations in the response. Furthermore, the water consumption variables employed in the analysis are valid for predicting the quantity of water consumed in the study area.

Table 9: Analysis of variance (ANOVA)

ANOVA[a]						
Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	3302107.398	11	300191.582	258.259	.000[b]
	Residual	427751.073	368	1162.367		
	Total	3729858.471	379			

4. CONCLUSION

This study has assessed the domestic water consumption pattern and its driving factors in the Adolor community of Egor LGA in Benin City, Edo State, Nigeria, using the questionnaire survey method. The result of the descriptive statistics indicated that females and males comprise an equal percentage of the study group, which may suggest that women are instrumental in major decision-making roles for water supply in the study area. Also, the pattern of domestic water consumption shows that bathing (27.39%), cloth washing (20.42%), toilet flushing (14.19%), and car washing (11.27%) consumed more water in the study area. The result of the multiple regression analysis shows that the quantity of domestic water consumption can be predicted by 88.5% of the variables considered, which are water allocated for dish washing, education status, time to collect water, occupation status, gender, water allocated for car washing, age, water allocated for cooking, water allocated for toilet flushing, source of water, and water allocated for bathing). Therefore, these variables significantly affect the domestic water consumption in the study area.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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