International Journal of Engineering Research and Technology. ISSN 0974-3154, Volume 14, Number 5 (2021), pp. 410-418

Evaluation of Household Water Use Pattern and Determinants using Multiple Regression Models

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Abstract

The Offa community in Nigeria has been facing the challenge of municipal water supply inefficiency for some years. The people in the study area majorly rely on self-provided means of water supply. This research aimed at studying the characteristics of domestic water use and to investigate the role of education, gender, water allocated for bathing, monthly income, house type, household population, age distribution, time of collection, and source of water on the consumption rate of water in Essa wards, Offa using multiple regression models and simple frequency analysis. The data were analyzed using multiple regression models and statistical frequency analysis. The investigation revealed that bathing consumed 33% of total domestic water use at the Household (HH) level, cloth washing 14%, cooking 13%, toilet flushing 12%, car washing 10.48%, Dishwashing 9.08%, and drinking 7.99%. The result of the multiple regression shows that the volume of water usage can be predicted by 80% of the variables considered. The variables monthly income and level of education had the highest influence in determining the volume of water use components with 91.6% and 89.6% of the total variance eplanation.

Keywords: Water Use, Scarcity, Household, Multiple Regression Models, Frequency Analysis

I. INTRODUCTION

The significance of water to all living things is very high and its use cannot be avoided. It is vital for human continuous existence and survival as it defines wellbeing. Historically, water exploitation and usage for several purposes has positively impacted the lives of humans [1]. Water is the basic need of life, and it is likely to surpass the scarcity of many other commodities during the 21st century. The high dependency and exploitation of water through human activities have resulted in a decrease in the quality of water [2]. It is quite tasking to satisfy the rise in demand for consumption of water due to population and economic growth. There is a high decline in opportunities available to address the problem of insufficient potable water supply [3]. 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. Establishing the parameters to quantify HH water use while modeling a water distribution network system is challenging [4]. Concerning the daily requirements in the form of water, a typical human being will demand an average of 2.5 liters of water to suffice his drinking needs. The requirement for water usage also extends to several other purposes like cooking, washing, agricultural, commercial, religious, recreation, transportation, and hydro-electric power generation. The available water supply for a particular region is required to be able to adequately accommodate all the demands for water in terms of the accessibility, quality, quantity, and effective disposal of wastewater all delivered at a reasonable cost [5]. When investigating the quantity of water required at the HH level, it has been deduced that there is a problem in effective timing in supply and spatial distribution of water which is highly dependent on various factors [6]. Proper analysis of estimation of water demand uses variables such as income, population, and gender [7] while Al–Amin (2011) [8] stated that cultural behavior, settlement type, source of water, and supply mode can be used in evaluating water usage quantity in residential homes. The average HH water consumption rate varies depending on variables such as weather, the standard of living, the cultural way of life, available facilities, technology, and the state of the economy. There are no existing data that ascribes a particular amount of water usage to a minimum standard of living [1]. Romano et al (2014) [9] stated that the estimation of water demand is achievable through consideration of factors such as metering, population characteristics, HH characteristics, weather conditions. Although several authors have worked on the investigation of variables that predict HH water consumption, water scarcity reduces the accuracy and effectiveness of the prediction models in emerging environments.

Investigating the determinants of water demand rate requires consideration of the effects of charges and income and other factors such as weather conditions, locality, or population characteristics, and HH features. A lot of investigation has been done on variables affecting water consumption rate [9]–[12] such as weather, HH characteristics, location, population, pricing, family size, age yet water scarcity contributes to inaccuracy in water demand estimation quantification [7].

Domestic water demand evaluation requires information about the water consumption rate [13] and HH attributes are important in analyzing the relationship between population and domestic water consumption [14].

This study is carried out to evaluate the variables that affect domestic water usage rates in a growing urban center like Offa town and their predictive performance in the quantification of HH water use. This will help policy and decision-makers with the resourceful information in future water demand and supply planning and management of the study area.

II. RELATED WORK

HH water consumption forms an integral part of waterworks supply usage because it is accountable for over 50% of the entire amount of community consumption in various countries [15], [16]. McKenzie et al. (2003) [17] noted that large numbers of HHs in cities around the developing world have limited access to safe drinking water. Quality in terms of portability and availability are key requirements in the standard of HH water supply which usually incurs high production cost. The need to deliver water in a suitable drinking quality is directly related to consumer's health. According to UNDP, the water scarcity effect touches more than 40% of humans with an expected increase due to future climate changes. The scarcity of drinking water is still a challenge faced by every continent on earth despite the improvement in records of about 2.1 billion people's assessment to clean water since 1990. The is an urgent need to improve on the status and provide a safe water system in the world. Evaluation of factors that directly or indirectly affect the rate of water usage has been a subject of several studies as reported by Grafton et al (2011) [10] whose study captured the effect pricing and non-pricing related factors on water demand of several sampled HHs from ten different countries. The result of the study showed the relevance of the cost of water in volumetric quantity has high predicting power on the rate of water consumption of the studied HHs. Morote et al., (2016) [18] discovered a decline in the trend of HH water consumption due to factors that include water metering & pricing, raised public awareness on conservation policies and benefits, drought, economic breakdown and, wastewater reclamation use. Fan et al. (2013) [11] discovered domineering factors related to the pattern of the water supply of the study area. Dagnew (2012) [19] found status of house ownership, educational background, and monthly spendings are highly relevant in determining the water demand and consumption rate. Domene and Saurí (2006) [20] investigated the link between urbanization and the level of HH water consumption rate and found out that income rate, type of HH, number of HH members, and availability of outdoor water facilities such as swimming pools and gardens. Arbués et al. (2003) [21] reviewed the literature on several variables that influence water demand and found out the most significant of them are water rate in monetary terms, HH income, and population of HH members. The study also showed that water demand has remained inelastic despite charging for water consumption. Hummel and Lux (2007) [22] highlighted the essence of the clean water supply of water as it contributes significantly to health and mortality. The authors further explained that a region's existing water supply system serves as an attraction for more settlement and relocation. While on the other hand, an increase in population can cause poor economic, social, and infrastructural effects water supply system. Corbella and Pujol (2009) [23] mentioned age range in a HH as a useful driving force of domestic water consumption and explained that the elderly in the society usually demand less quantity of water in comparison to younger people. They further added that families residing with their relatives and immediate dependants can be assumed to consume more water, basically related to outdoor uses and recreational use. Smith and Ali (2006) [24] made use of data retrieved from the 2001 UK census and found out that level of water use correlated more with religious involvement than with ethnicity. Akpinar et al. (2018) [25] investigated the behavior of water consumers as regards water conservation using factor analysis. The study revealed that decision-makers can exploit and improve on factors such as creating awareness during any water crisis, water rating and costing, alleviating fears about water scarcity, and HH characteristics. Klein et al. (2006) [26] confirmed the belief that water demand is most times price inelastic as noted also by Arbués et al. (2003) [21] unlike the popular belief that increase in water pricing will increase water conservation practices thereby reducing water demand. Uncertainties in general factors used in predicting water demand such as price and non-price strategies, weather conditions, data scarcity, HH characteristics are elaborately explained in study by Klein et al. (2006)[26].

III. MATERIALS AND METHODS

III.I Study Area

This study will be carried out in Essa wards in the Offa metropolis. Offa is a town located in Kwara State in Nigeria with a population of about 120,000 according to (National population projection of 2016). The study area is geographically located between Latitude 8˚08'49.20N and 4˚43'12.00"E. The study area is well recognized for its rich cultural heritage and agricultural activities. The area is covered by savannah vegetation which allows productive cultivation and animal rearing. The main source of water for the study area is from the Oyun River catchment area, covering an estimated area of about 452.80km^2 [27]. The Oyun waterworks is the municipal water supply system majorly depended on by the people in the study area. According to Damilola (2014) [28], the spatial distribution coverage of the Oyun Waterworks water supply is minimal and little or no reliability in terms of availability. This has made the people of the community depend on other sources of water for their daily activities and livelihood. Figure 1 below shows the map of the study area and its location in Nigeria.

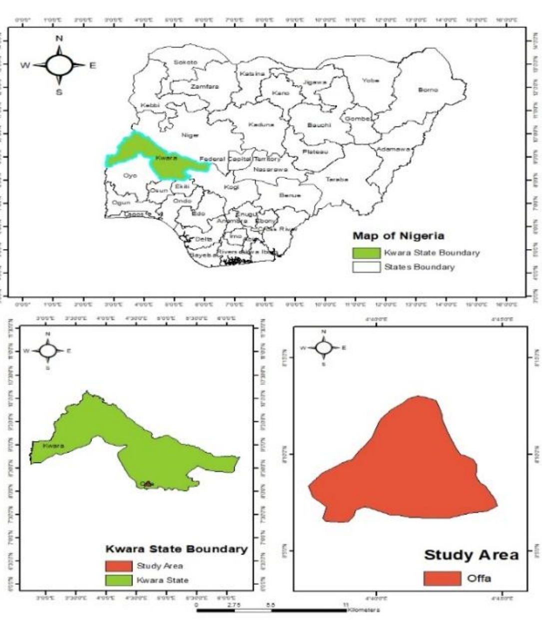

Fig. 1. Map of the Study Area showing its location within Nigeria

III.I Methodology

The methodology approach adopted in this study was obtained from insights from past literature's methodology. Some literature although not directly relevant to this research but will provide helpful ideas on the structure of this research. This chapter will present the research design, the population of the study area, the number of HHs considered sampling techniques, data collection method, and methodology of data analysis. This survey method aims to understand the influence of selected variables on the level of water consumption in Essa wards in Offa metropolis, Nigeria. The population of the study will cover HHs in Essa wards in Offa metropolis, this research will specifically focus on the age group from 18 to 65years, they will be able to give reliable information on their corresponding HH water usage pattern. The sampling techniques procedure that is suitable for this research work is stratified sampling, the selected sample from the population is based on easy availability and accessibility probability sampling (random selected) of the HH in the study area. Given the research, a structured questionnaire will be administered to a sample of 76 (seventy-six) HHs in the study area. The person targeted to respond to questions will be the HH head who will give the needful information for the analysis. The questionnaire will be handed to the willing and educated respondent who can answer independently while a face-to-face interview will be granted to respondents unwilling to fill out the form and majorly uneducated respondents. The method to be used in the presentation, analysis, and interpretation of data collecting will be frequency analysis and multiple regression models (multivariate) (SPSS VERSION 25).

IV DATA ANALYSIS, RESULT, AND DISCUSSION

The data presented in this chapter were based on questionnaires administered to the HH in Essa wards in Offa. The seventy-six copies of questionnaires were distributed and filled where appropriate and subsequently returned properly answered.

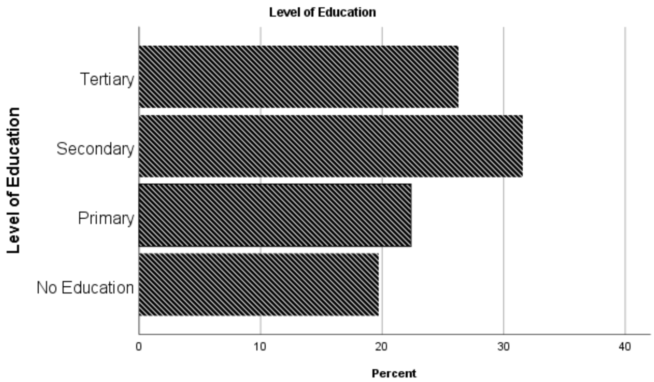

Fig. 2 Results of respondents on distribution by the level of education

Figure 2 above shows that about 19.7% are not educated, 22.4% are primary level education certificate holders, and 31.6% are secondary level certificate holders while the remaining 26.3% are tertiary level, certificate holders. The influence of education on water use consumption can be linked to conservation awareness and understanding of policies in the pricing of water, but this has not been proven against the volumetric amount of water consumption in the study area. This might be because there is no evidence of water metering devices to corroborate the investigation of water conservation and limited municipal water supply in the area.

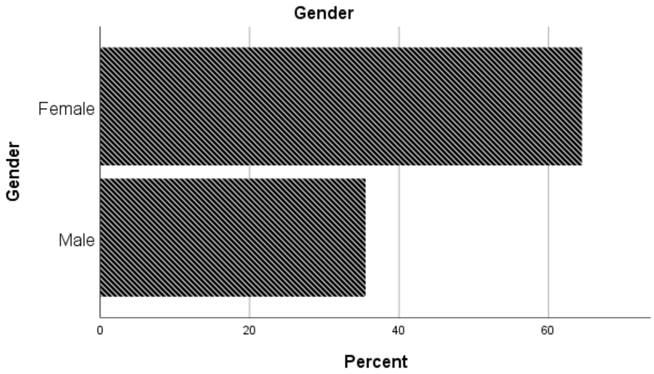

Fig. 3 Results of respondents on gender distribution

Figure 3 above shows that the composition of the respondents comprised of more females with 64.5% with male respondents comprising only 35.5%. The feedback on the interview and answered questionnaire showed that women were more informed about major HH activities and their willingness to share information.

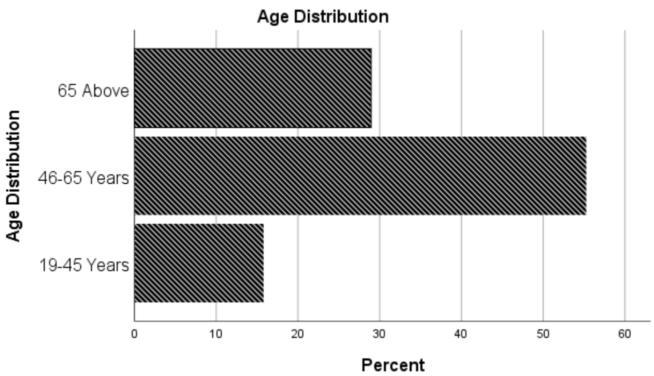

Fig. 4 Result of respondents on the age distribution

Figure 4 above shows that respondents with an age range between 46-65 years were 55.3%, 15.8% were of 19-45years age range while 28.9% were 65years and above.

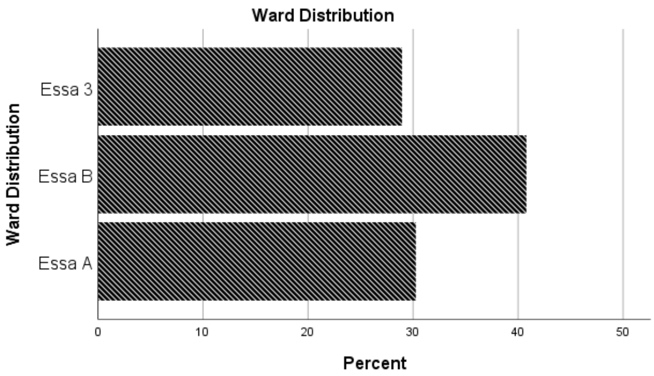

Fig. 5 Result of respondents on the ward distribution

Figure 5 shows that 30.3% of respondents originate from Essa A, 40.8% of the respondent from Essa B while the remaining 28.9% of respondents are from Essa C.

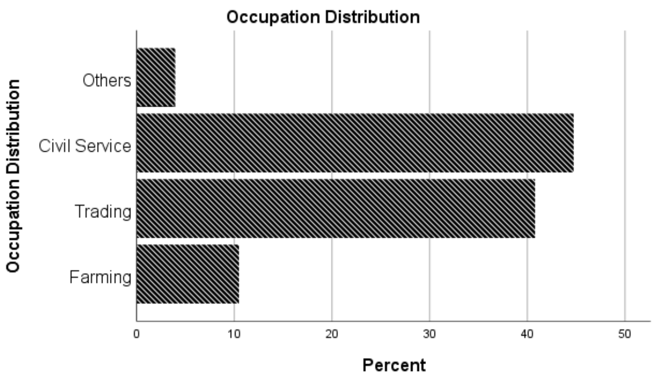

Fig. 6 Result of respondents on the occupation distribution

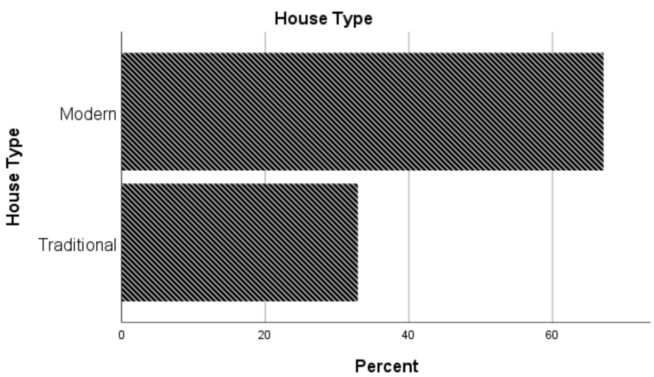

Fig. 7 Result of respondents on the house type

The results from Figure 6 indicate a larger percentage of the HH respondents are employed in the civil service which represents 44.7% of the total respondents. 44.7% of the respondents are involved in trading, 10.5% of the respondents are into farming while 3.9% of the respondents are involved in other categories of occupation. Figure 7 shows a significant percentage (32.9%) of the settlement HH types are still made up of old houses. Modern houses are built with new water appliances that come with water-saving devices in some cases and in other cases, modern houses are built with outdoor facilities like swimming pools, lawns, and gardens. These facilities require more usage of water, therefore from his study, the HH type has little significance on the volume of water used.

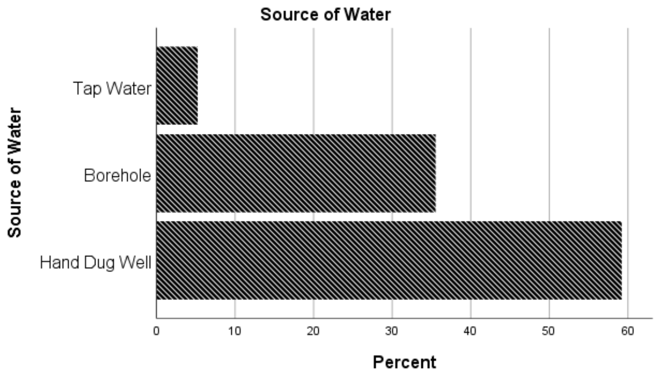

Fig. 8 Result of respondents on the water source

Figure 8 above shows that 59.2% of the respondents depend on hand-dug well for their source, 35.5% of respondents depend on borehole (private and community) for their water source while just 5.3% of respondents depend on tap water due to the low availability of tap water (municipal water supply) in the study area. The municipal water supply has not been constant due to maintenance issues. This has a significant effect on the amount of water used by the people of this community. The ease of getting water and its availability is a major factor in the water consumption rate and this study has proven that. Water is majorly sourced by the individuals in this community rather than have water supplied directly into their buildings, they perform journeys to the nearest available sources which are hand-dug wells and the government-provided borehole. Few respondents (majorly the upper-class income earners) have their source of water installed in their HHs.

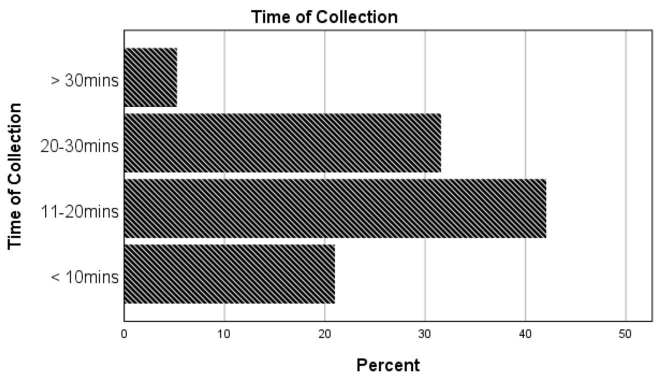

Fig. 9 Result of respondents on the time of collection of water

Figure 9 above shows that 5.3% of the respondents used more than 30 minutes in collecting water they need, 31.6% of the respondent used 21-30minutes, 42.1% of the respondents used 11-20minutes, and 21.1% of respondents used less than 10 minutes to collect water for domestic use.

Table 1. Pattern of water use in the sampled HH in Essa wards in Offa metropolis

S/N	Water use	Essa A		Essa B		Essa C			
		Total(L)	**%**	**Total(L)**	**%**	**Total(L)**	**%**	**Overall total(L)**	**%**
1	Drinking	347	7	479	8	520	9	1345	8
2	Cooking	562	12	742	12	844	14	2148	13
3	Bathing	1771	37	1908	32	1885	32	5563	33
4	Cloth washing	684	14	927	15	806	14	2417	14
5	Dish washing	433	9	547	9	547	9	1528	9
6	Toilet flushing	570	12	798	13	699	12	2067	12
7	Car washing	471	10	638	11	654	11	1763	10
8	Others	0	0	0	0	0	0	0	0
	Total	**4838**	**100**	**6039**	**100**	**5954**	**100**	**16831**	**100**

Table 1 shows that in Essa wards in Offa the pattern of domestic daily water use at HH level are bathing which accounts for 37% of total domestic use, 14% is for cloth washing, 12% is used for cooking, 12% is used for toilet flushing, 10% is used for car washing, while 10% and 7% are used for dishwashing and drinking water respectively. The pattern in Essa ward A, Essa ward B, and Essa ward C show similar trends with bathing constituting the highest water use of 37%, 32%, and 32% respectively, 14%, 15%, and 14% was used for clothes washing, 12%, 12% & 14% were used for cooking, 12%, 13% & 12% were used for toilet flushing, respectively. Car washing, dishwashing, and drinking constituted the lower percentages of the total volume of water consumption in all the wards. This was because 10%, 11%, and 11% were used for car washing, 9% each for all three wards was used for dishwashing, and 7%, 8%, and 9% was used for drinking in Essa ward A, B, and C respectively. In terms of quantity of daily water use, 5563litres was used for bathing, 1590litres was used for cloth washing, 1413litres was used for cooking,1360litres was used for Toilet flushing, 1160litres was used for car washing, 1005litres was used for dishwashing and 885 was used for drinking water, respectively. A summary of the pattern of water use in the study area is shown in Figure 10.

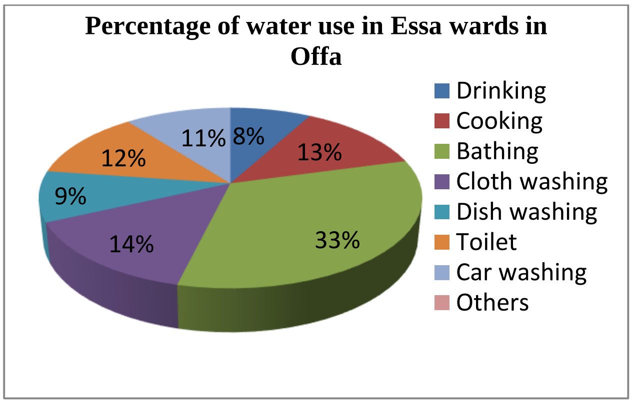

Fig. 10 Pie chart showing the percentage of water use in Essa wards in Offa

IV.I Components Determining Level of Water Use

Factor Analysis is a general expression for a set of statistical procedures that examines the correlations between variables in large sets of data to check if a small set of underlying variables or factors can explain the variation in the original set of variables. Thus, factor analysis can be viewed as a way of summarizing or reducing data, to a few underlying dimensions. Factor and analysis were performed on all the components and the volume of water consumption in the study area. The result of the analysis is presented and discussed here.

The Determinant of the R-matrix value should be greater than 0.000001 and the value obtained from the test is 0.063 as shown in Table 5 which indicates all components do not suggest multicollinearity. The result for Kaiser-Meyer-Olkin Measure of sampling adequacy is 0.725 as shown in Table 2 which is acceptable, and Bartlett's Test of Sphericity showed a p-value of 0.000 less than 0.05 which showed that the factor analysis test procedure can be proceeded with. Table 3 explains the amount of each variable's variance that can be explained by the remaining factors on the volume of water used. The monthly income accounted for 91.6% of the variance of the volume of water use which is the highest. This can be supported by an investigation by Shan et al. (2015) [29] which related monthly income to property ownership with outdoor facilities characteristics that consume more water through activities like irrigation of gardens and lawns. The source of water indicated a percentage variance of 81.4%, this implies the difficulty or ease at which people who source water from borehole and hand-dug well respectively affected their water consumption rate. Level of Education accounted for 89.6% as education plays a significant role in water conservation and water use efficiency. The composition of the gender accounted for 71.8%. According to the report by Shan et al. (2015) [29], gender had an effect on water consumption as a result of the study indicated adult males and children took lesser shower time than adult females. Time of collection accounted for 73.3%, ward distribution 70.2%, occupation distribution 62.9%, house type 78.8%, age distribution 69%, and HH population explainable by 68.4% of the analysis on the volume of water is explainable by these factors.

Table 2. KMO and Bartlett's Test

KMO and Bartlett's Test		
KMO Measure of Sampling Adequacy		0.725
Bartlett's Test of Sphericity	Approx. Chi-Square	192.921
	df	45
	Sig.	0.000

Table 3. Communalities for selected Variables for Volume of Water use

Communalities		
	Initial	**Extraction**
Gender	1.000	0.718
Water allocated for bathing	1.000	0.591
Monthly Income	1.000	0.916
House Type	1.000	0.788
Household population	1.000	0.684
Age Distribution	1.000	0.690
Time of Collection	1.000	0.733
Source of Water	1.000	0.814
Level of Education	1.000	0.896
Ward Distribution	1.000	0.702
Occupation Distribution	1.000	0.629
Extraction Method: Principal Component Analysis		

. **Table 4.** Total Variance Explanation for selected variables for Volume of water use

Component	**Total Eigenvalue**	**Variance (%)**	**Cumulative (%)**
1	2.00	18.220	18.220
2	1.678	15.251	33.471
3	1.505	13.685	47.156
4	1.379	12.539	59.695
5	1.119	10.177	69.872
6	0.887	8.060	77.932
7	0.811	7.368	85.300
8	0.544	4.948	90.248
9	0.465	4.227	94.475
10	0.334	3.037	97.513
11	0.274	2.487	100.00

IV.II Modeling Volume of Water Use

Multiple linear regression model analysis was done and the result of the analysis shows an R^2 value of 80.0% of the volume of water used can be explained by gender, water allocated for bathing, monthly income, house type, household population, age distribution, time of collection, and source of water. Based on the ANOVA (analysis of variance) with ρ value of 0.000 < 0.05 which is shown in Table 6 suggests that changes in the predictor are associated with changes in the response. This also indicates that the volume of water use variables applied for the analysis is valid for the prediction of the determination of the volume of water consumed in the study area.

Table 5. Model Summary

Volume of HH water use model summary				
Model	R	R Square	Adjusted R Square	Standard Error of the Estimate
1	.895[a]	0.800	0.777	0.594

a. a Predictors: (Constant), Gender, Water allocated for Bathing, Monthly Income, House Type, Household Population, Age Distribution, Time of Collection, Source of Water

b Dependent Variable: Volume of water use

Table 6. ANOVA

ANOVA[a]

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	94.740	8	11.842	33.599	0.000[b]
Residual	23.615	67	.352		
Total	118.355	75			

Furthermore, the data were subjected to stepwise regression analysis to determine the optimum prediction variables. The optimum variables (consisting of seven variables which include the time of collection, house type, gender, source of water, household population, monthly income, and age distribution) resulted in an R^2 value of 0.800 and standard error of 0.589 as shown in Table 7 which was similar to what was obtained with the initial regression analysis with eight variables.

Table 7. Model Summary using stepwise regression analysis

Volume of HH water use model summary				
Model	R	R Square	Adjusted R Square	Standard Error of the Estimate
7	895[g]	.800	.780	.589

g Predictors: (Constant), Time of Collection, House Type, Gender, Source of Water, Household Population, Monthly Income, Age Distribution

h Dependent Variable: Volume of water use

Table 8. Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients	T	Significance
	B	Standard Error	Beta		
Constant	10.397	0.531		19.572	0.000
Gender	-0.806	0.085	-0.563	-9.461	0.000
Age Distribution	0.218	0.099	0.129	2.2000	0.031
House Type	-0.483	0.072	-0.400	6.7110	0.000
Monthly Income	-0.303	0.074	-0.233	-4.075	0.000
Source of Water	-0.758	0.078	-0.657	-9.761	0.000
Time of Collection	-0.962	0.096	-0.642	-10.058	0.000
Household Population	-0.662	0.089	-0.495	-7.455	0.000

IV CONCLUSION

Understanding the pattern of HH water use is very crucial in deciding and planning water resources and supply management in a region. The investigation of HH water use in Essa Wards in the Offa local government area of Nigeria has been evaluated using the qualitative method through the questionnaire survey method. An investigation into the assessment of water consumption patterns in Essa wards in Offa has been examined. The result of descriptive statistics shows that females comprise the highest percentage of the study group and monthly income has the highest significance on the total amount of water consumed. Furthermore, the pattern of water use in Essa wards shows that bathing, cloth washing, cooking, and toilet flushing consumed more water with 33%, 14%, 13%, and 12% respectively in the domestic water use rate of the study area. The result of the multiple regression shows that the volume of water usage can be predicted by 80% of the variables considered. It can be concluded that the consumption of water significantly depends on the variables considered in this study. The findings from the study also revealed the minimal contribution of municipal water supply service in the study area. It is recommended that water scarcity should be considered a great challenge that needs to be resolved to create a healthy environment for the people residing in the study area. Finally, further research can be carried out when a proper water supply scheme is in place in the study area to ascertain a reliable evaluation of water consumption and conservation activities.

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