# Modelling of Residential Water Demand at Household Level in Ilorin, Nigeria

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## Abstract

Accurate estimation of water use is one of the challenges facing water supply sector in our society. This is due to lack of adequate and reliable supply and demand data. This paper examined and determined water demand at household level in some randomly selected houses within the city of Ilorin. The study evaluated household water consumption with the aid of structured questionnaire to sample people's opinion in the study area. Regression analysis was used to determine the variables that affect household water consumption. Based on the analysis the average daily consumption was found to be 86.22 l/c/d. The study also showed that income, education level, and sex have significant effect on water demand in the sampled households.

## Keywords

Modelling, water demand, residential, household

## 1. Introduction

Water is very important to life including animal growth, plant growth, as well as micro-organism and bacteria etc. Water is the source of man's existence in life. It is very essential in our daily activities. There are different sources of water among which are lakes, rivers, wells, springs and rain water. The amount of water needed to satisfy thirst is a few litres per person per day. Also the amount needed to grow enough food for that person is 50 times larger and the amount needed to run something close to a modern economy perhaps 100 times larger (Gleick, 1993). Despite this, the settings in developing countries characterised by a high level of poverty and lack of reliable access to clean water which create challenge of designing and planning urban water systems to meet the needs of both connected and the (usually poor) non-connected households for policy-makers (Basani, et.al.

2008). Stikker(1998) described a general overview of the fresh water scarcity that parts of the world are facing today and will increasingly face in coming decade. He particularly demonstrated why and how many countries, developing and newly industrialized regions in the Middle East, Africa, Asia and South America will be vulnerable to lack of water.

There are many factors that contribute to the total water consumed at household level. Arbues, et.al (2003) examined the main issues in literature on residential water demand. They analysed several tariffs and their objectives and identified water price, income or household composition as crucial determinant of residential water consumptions. The rate of water demand depends on the socio-economic standard of the people, the level of education and development, the nature of prevailing climate and hygienic characteristic of people (Gilg and Bars, 2006; Arbues, et.al, 2003; Schleich and Hillenbrand, 2009; Mohammed, 2008). Water demand is not limited to domestic use only, but it is of various forms and for other purposes such as, commercial, industrial, agricultural and public uses. Hence, water demand can be defined as the amount of water required to satisfy all human activities such as domestic, agricultural, industrial as well as fire fighting.

Water demand calls for planning with consideration being given to the use of non-conventional sources of supply. As a result, there will be a substantial increase in water costs and the problem of water supply can no longer be simply seen as development of new sources. Accordingly, levels of demand should be affected and anticipation of water problems and identification of control factors will depend on the forecasts of future water demand. The chosen procedure will depend upon the quality and quantity of data and the purpose of the forecasts. Lack of data has been identified as the principal factor that is hampering proper and adequate water demand estimation in our society. Lack of metering has been identified as one of the reasons behind the prevention of efficient use of water because, the consumers and planners have no proper bases and criteria in defining their actual water use (Bithas, 2008). The review of the literature on water demand showed that adequate data has been identified as necessary tools in proper planning and water demand management and studies (Alsharif, et.al 2008; Zhou, et.al, 2002; Schleich and Hillenbrand, 2008; Ruijs, et.al, 2008). This work will address the growing interest in the examination of water demand and the need to pay careful attention to modelling and forecasting water demand in the future based on the principal factors that have been identified at the household level. Demand models provide simplification or abstraction of complex physical reality and the processes involved in it, and serve as tools in the solution of





demand forecasting problems. The choice of an appropriate approach to water demand modelling play a vital role in making planning and management decisions in water supply sector.

The demand for water depends on variables linked to human needs and behaviour and changes over time and space. It has been known that the variation in water demand is due to some factors, such as geographical location, types of community, population, cost, water management and economic status of the communities' as well as the demographic characteristic of the area (Bouwer, 2000). Estimating water demand requires an important amount of data (Garcia and Reynaud, 2004). Hence, for effective water demand study, planning and designing, the total water is usually estimated from the aggregate of maximum water plus losses that may be envisaged. Several studies have identified the numerous factors that will assist the policy-makers in proper water demand management (Mohammed, 2000; Randolph and Troy, 2008; Gilg and Barr, 2006; Gomez-Limon, et.al, 2000; Gumbo, et.al, 2003; Renwick and Green, 2000; Mulwafu, et.al, 2003).

## 2. Materials and Methods

The study was carried out in randomly selected households within Ilorin metropolis. Ilorin is the capital city of Kwara state, Nigeria. Data was collected with the use of structured questionnaire. The questionnaire method involved the design, distribution and administration which in turn yielded the data on water demand of the area. The questionnaire was designed based on the information needed to really ascertain the quantity of water used in the household. The data was collected and collated from the various answers given by the respondents. The information was given by the head of each family, or other persons in the household where the household head was not available. The information includes number of occupants, type of house, and other relevant factors that affect water consumption. The questionnaire was administered to those that are capable of given the right information required from each household sampled. The data collected was analysed using Microsoft Excel, SPSS and Stata8 Software. Statistical tools such as mean, standard deviation and regression, etc were the analysis performed on the data.

In order to establish the structural relationship between the variables and household water demand and to reveal the determinants of the variation of water use and consumption, multivariate statistical analysis was performed. The model of the following form was used to establish the said relationship

(Zhang and Brown, 2005),

$$Q = f(X_1, X_2, \ldots X_n) + E \tag{1}$$

where Q is a dependent variables or household water consumed per day, f( ) denotes the function of explanatory independent variables and E is standard error.

## 3. Results and Discussion

The model summary table reports the strength of the relationship between the regression model (predictors) and the *Total Water Demand.*

Table 1 shows the statistical summary of the data on the water demand and other variables obtained from the analysis of respondents to the questionnaire. Table 2 shows the values of the model predictor parameters. From Table 2, the probability value for the F-test statistic (0.000) is less than 0.05 (5% level of significance), which indicates that the model is adequate. This means that the combination of the predictors significantly combine together to predict Average Water Demand.

Table 1: Means and Standard Deviations of Total Water Demand and the predictors

| Variable | Mean | Standard Deviation |
|---|---|---|
| Average Water Demand(L/c/d) | 86.22 | 30.350 |
| Predictor Variables | | |
| Respondent as head of household | 0.58 | 0.497 |
| Sex | 1.32 | 0.468 |
| Age of respondent | 42.01 | 10.579 |
| Education | 1.92 | 1.187 |
| Income level | 3.71 | 0.857 |
| Occupation | 1.26 | 0.441 |
| Yrs of staying | 6.20 | 1.067 |
| Type of House lived in | 1.15 | 0.681 |







Table 2: summary of model predictor parameters

| F-statistic | Prob. (F-statistic) | R | R-squared | S.E. of Multiple regression | S.D. of Total Water Demand | Durbin-Watson Statistic |
|---|---|---|---|---|---|---|
| 6.615 | 0.000[s] | 0.641 | 0.410 | 24.498 | 30.350 | 1.840 |

[s]- Significant

The multiple correlation coefficients, (R) is the linear correlation between the observed and the model-predicted values of the dependent variable (Average Water Demand). The value of R was obtained to be 0.641 and R Square (0.410), the coefficient of determination, is the squared value of the multiple correlation coefficients (R). It shows that about 41.0% of the variation in Average Water Demand is explained by the model.

As a further measure of the strength of the model fit, the standard error of regression 24.498 (Table 2) was compared with the standard deviation of Average Water Demand value of 30.350. The mean Average Water Demand (litres) was 86.22 litres with a standard deviation of 30.350. With the multiple regression models, the error of the estimate was considerably lower, about 24.498.

For K = 9 (Number of predictors including the intercept) and N = 85 (No of Respondents), dL = 1.448, dU = 1.857. Where dL = Durbin lower limit and dU = Durbin upper limit. The Durbin Watson Statistic of 1.840 falls below the Upper Durbin Watson Limit (1.857) which implies that we probably have some elements of serial correlation.

A linear multiple regression model is formulated from Table 3. The regression equation is presented as follow:

$$Y = -31.352 + 19.646X_1 + 36.309X_2 + 0.570X_3 + 9.137X_4 + 2.063X_5 + 1.370X_6 + 1.363X_7 + 0.091X_8 \tag{2}$$

where $X_1$ is Respondents as head of household; $X_2$ is Sex; $X_3$ is Age; $X_4$ is Education; $X_5$ is Income; $X_6$ is Occupation; $X_7$ is Year of staying; $X_8$ is Type of house.

The $\beta$ values can be used in comparing the contribution of each predictor (independent variables). The largest $\beta$ coefficient is 0.560 which is for Sex.

Table 3: Table of coefficients for predictors of Average Water Demand

| Model | B (coefficient) | Std. Error | $\beta$ | t-value | Sig. (p-value) |
|---|---|---|---|---|---|
| Constant | -32.352 | 29.338 | - | -1.103 | 0.274 |
| Respondent as head of household | 19.646 | 7.886 | 0.322 | 2.491 | 0.015* |
| Sex | 36.309 | 6.708 | 0.560 | 5.413 | 0.000* |
| Age of respondent | 0.570 | 0.280 | 0.199 | 2.035 | 0.045* |
| Education | 9.137 | 3.345 | 0.357 | 2.732 | 0.008* |
| Income level | 2.063 | 3.907 | 0.058 | 0.528 | 0.599 |
| Occupation | 1.376 | 8.370 | 0.020 | 0.164 | 0.870 |
| Yrs of staying | 1.363 | 2.945 | 0.048 | 0.463 | 0.645 |
| Type of House lived in | 0.091 | 4.391 | 0.002 | 0.021 | 0.984 |

*Significant at 5% level.
Dependent variable: Average water consumption (Demand)

This means that this variable makes the strongest unique contribution to explaining the dependent variable, when the variance explained by all other variables in the model is controlled for. The $\beta$ value for Years of staying in the house was 0.002 which made the least contribution.

For each of these variables, the value in the column marked sig. (p-value) was checked. This showed whether this predictor made a statistically significant contribution to the Average Water Demand (consumption). This depends on which variables that is included in the equation. If p-values is less than 0.05, the variables made significant contribution to the prediction of Average Water Demand. For values greater than 0.05, variables did not make significant contribution to the prediction of the Average Water Demand. In this case, Respondents as head of household, Sex, Age and Education made statistically significant contribution to the prediction of the Average Water Demand.

The variable respondents as head of household had a level of significance of 5%. This predictor is positively related to Average Water Demand, i.e. Respondents who were not Head of Households tend to demand for more water than respondents who were Head of households. Perhaps, this could be because head of households were not always around for them to have been able to know the actual daily demand for water, unlike others that may probably be more available and involved in sourcing for water at home. From Table 4. This is supported by results which show that heads of households as the respondent reported a mean total of 85.64 litres of water consumption per day with a minimum of 23 and maximum of 198 litres per







day while respondents who were not heads of households reported a mean total of 87.00 litres of water consumption with a minimum of 42 and maximum of 200 litres daily.

The variable **Sex** had a level of significance of 5%. **Sex** is positively related to the Average Water Demand. Often female respondents demand for more water than males. This could be as a result of the involvement of female's in house work than male. From Table 5, female respondents reported a mean total of 108.27 litres of water with a minimum of 64 and maximum of 200 litres per day while male respondents reported a mean total of 75.95 litres of water with a minimum of 23 and maximum of 112 litres daily.

The variable **Age** had a level of significance of 5%. **Age** is also positively related to the Average Water Demand. The result implies that the higher the age of the respondents, the more they demand for water. The variable **Education** had a level of significance of 5%. **Level of education** is positively related to the Average Water Demand. This implies that the higher the level of education of the respondents, the more they demand for the water. All other predictors: Occupation, Years of Staying in the house and Type of house lived in were not significant at 5% level. This implies that they do not make significant contribution to the Average Water Demand.

Table 4: Average water consumption by relationship of Household head

| Respondent as | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| Otherwise | 87.00 | 30.464 | 42 | 200 |
| Head of HH. | 85.64 | 30.569 | 23 | 198 |
| Total | 86.22 | 30.350 | 23 | 200 |

Table 5: Average water consumption by sex

| Sex | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| Male | 75.95 | 18.024 | 23 | 112 |
| Female | 108.27 | 39.031 | 64 | 200 |
| Total | 86.22 | 30.350 | 23 | 200 |

## 5. Conclusion

The analysis of the household survey data showed that the various regression equations for the domestic water use are adequate. It was found that, Respondents as head of household, Education, Age, Sex are significant at 5% level. This totally implies that level of Education, Age, Sex tend to lead to more water consumptions. However, duration or years of staying in the house and type of house lived in are not significant at 5% level. This model will be a very good predictor of water demand in the study area and at other areas with similar demographic and socio-economic characteristics. The outcome of the work also identifies the following:

- For accurate estimation of water demand, the factors such as income, population, sex, etc. should be taking cognisance of.
- Metering of pipe supply to house for accurate data on water consumption is desirable.
- Since, the estimated water consumption is about 86.22 l/c/d, which is below the baseline of 120l/c/d as set by WHO standard, it is recommend that more water should be provided to the populace in the study area.
- There are other sources of water supply; further study should be carried out to look into how these sources can be harnessed.
- Water demand management should be encouraged since this is one of the global trends so as to optimise water use in our cities.

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