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in Collaboration with
National Water Resources Institute, (NWRI) Kaduna &
Department of Civil Engineering, University of Ilorin, Ilorin

THEME:

CHALLENGES OF WATER RESOURCES DEVELOPMENT AND QUALITY MANAGEMENT IN NORTH CENTRAL NIGERIA

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HOUSEHOLD WATER USE SURVEY METHODS: CHALLENGES AND PROSPECTS

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1.0 INTRODUCTION

The conventional practices of planning, designing and managing water supply systems requires regular review and adjustment. Determining how much is needed is one of the first steps in providing that supply. Providing enough water to meet everybody's needs may be difficult in the short-term so water can be made available in stages. Providing water is never free; the water needs to be collected, stored, treated and distributed. Providing too much water is a waste of money. Taking too much water from a limited source may deprive people elsewhere of water and have adverse environmental and health impacts (Reed, 2005). Hence, evaluation of municipal water use becomes very essential and needs to be reviewed on regular basis. There are many factors that contribute to the total water consumed in a community and households. Arbues, et.al (2003) examined the various factors that affect residential water demand. Several tariffs and their objectives were analysed and water price, income or household composition were identified 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 (Bouwa, 2000; Arbues, et.al, 2003; Gilg and Bars, 2006;; Schleich; Mohammed, 2008 and Hillenbrand, 2009). 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 firefighting.

Davis (2003) established a work plan for developing a water demand forecasting model which proposes a systematic methodology for forecasting municipal and industrial, (residential and non-residential, public and self-supplied) water demand throughout the state (by planning, area or country) based on an assessment and analysis of available data. It was stated that the selection of a water demand forecast methodology is a function of: planning objective, available data and available resources (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). A key input in water supply management and planning for municipal services is the accurate estimation of present and precise prediction of future water demand. Water demand estimates are used to calculate peak demand in order to assess and determine municipal water distribution system requirements which in turn determine water authority budget and capital investment needs. The expansion of urban areas, the continuing development taking place in major city of Nigeria and constant need for portable water services have created a need for more accurate water demand estimates. Inaccurate estimation leads to a deficiency in assessment of present situation of supply as well as deficiency in basic design information which are the root causes of inadequate service or inadequate water distribution. This work will serve as a tool for planners and designers of water supply and it will also contribute to larger water policy literature on the benefits of expanding access to safe drinking water in the developing world. *The work will therefore address the growing interest in the evaluation of* household water consumption and need to pay careful attention to its modelling and forecasting in the future based on the principal factors that have been identified to affect the consumers. Such models provide simplification or abstraction of complex physical reality and the processes involved in it, and *serve as tools in the solution of forecasting problems. The* choice of an appropriate approach to water consumption modelling play a vital role in making planning and management decisions in water supply sector.

Amount of water consumed in a household contribute significantly to the water demand in such a household. Hence, consumption or use of water is the driven force behind the hydraulic dynamics occurring in water distribution systems. Anywhere that water can leave the system represents a point of consumption, including a costumer's faucet or tap, a leaky main, or an open fire hydrant (Walski, et.al, 2003). 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 use. In other word, water demand is the amount of water required to satisfy all human activities such as domestic, agricultural, industrial as well as fire fighting. The essence of accurate estimation of water demand is for successful planning, designing, improvement and implementation of water supply system in order to ensure uninterrupted supply for human needs and for other various purposes. 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 large (Gleick, 1993). Gleick (1996) stated that a minimum of 15 l/p/d for bathing and 10 l/p/d for cooking is needed by human. He therefore suggested an overall basic water requirement of 50 litres per person per day as a new standard for meeting the four domestic basic needs of a person (cooking, drinking, bathing and sanitation), independent of climate, technology, and culture. While billions of people lack this standard today, it is a desirable goal from both a health perspective and from a broader goal of meeting a minimum quality of life. The situation in most developing countries is characterized 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 (Basani, et.al. 2008). Stikker (1998) provides 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. A common characteristic of water demand in urban areas worldwide is its inexorable rise over many years, and projections of continuing growth over coming decades. The chief influencing factors are population growth and migration, together with changes in lifestyle, demographic structure and the possible effects of climate change (Largo, et.al, 1998). For the study area, the availability of data on parameters which have significant effect on water consumption has been identified as a principal challenge for a proper planning of municipal water supply management. Lack of data and metering of water use has been identified as one of the reasons behind the prevention of efficient use of water because; the consumers and planners have no clear criteria to be used in defining actual water use (Bithas, 2008). The few places that have records have many other parameters such as household income, water bill among others that can be used for proper estimation and modelling which are missing out, not to mention the reliability of the available one. The literature, on water supplied has identified availability of good and reliable data as necessary tools in proper planning of water supply (Alsharif, et.al 2008; Zhou, et.al, 2002; Schleich and Hillenbrand, 2008; Ruijs, et.al, 2008).

2.0 METHOD AND MATERIALS

The research methodology comprises of both field work and data analysis. Preliminary work conducted involved the review of the literature and development of data collection techniques and instruments before the commencement of field work. Reconnaissance survey preceded field data collection which involves discussions with the respective stakeholders on the city water supply.

2.1 Data Collection and Sampling Technique

The data was collected with the aid of structured questionnaire to obtain household water use in selected houses consisting three land use patterns which include: planned area (e.g. Irewolede Housing Estate was selected); unplanned residential area (Oloje, Agboba and Ipata residential area) and; Government Reserved Area (G.R.A.) which represent the low density area as well as high income residential area (Ayanshola, 2013). This will allow for the sampling of the different patterns of water resource characteristics among the various segments of the city. The sample survey carried out was limited to 250 households. This gives an approximate of about 78,000 households in the study are (i.e. at average of 8 people per household). This is at 95 % confidence limit and an accuracy level of less than 7 % error. The study also involved metering of selected Households to capture the average volume of water being supplied to the households by KWWC. Super Italy water meters with multi-jet impeller (Figure 1) were installed in selected houses whose locations were determined with the Global Positioning System (GPS). Ilorin, the capital city of Kwara State is located between latitudes 8^{0} 25^{I}N and 8^{0} 32^{I}N longitudes $4^{0}30^{\prime}$E and $4^{0}41^{\prime}$E (Figure 2). The town is located at southern part of Kwara State. Ilorin metropolis presently occupies an area of about 89 Km^{2} (Adeleke, 2010). According to Ayanshola (2013), the population of Ilorin was estimated to be 606,533 in 1996 with a growth rate of 2.83% and in 777,667 in 2007 comprising three local governments (Ilorin East, Ilorin South and Ilorin West). This figure shows that the growth rate is about 2.82%, which follows the growth rate as proposed by NPC (2006). Three main rivers flow through the city: Oyun, Asa, and Moro rivers as shown in Figure 3 (Ayanshola, 2005).

2.2 Data Analysis and Evaluation of Water Consumption

The data used for the analysis were collected with the aid of structured questionnaire and reading from the installed water meters. The data was analysed using Statistical Packages to establish the structural relationships between the variables at household and its water use. Water consumption models were formulated from data obtained from both questionnaires and reading from meter and the models is of the form as expressed by May and Tungs (1992) and ESCWA (2005):

$$D = f(x_1, x_2, \cdots, x_n) + E \qquad 1$$

Where: D denotes demand

f is the function of explanatory variables $x_1, x_2, \ldots, x_n$

E is a random error variable describing the joint effect on D of all the factors not explicitly considered by the explanatory variables.

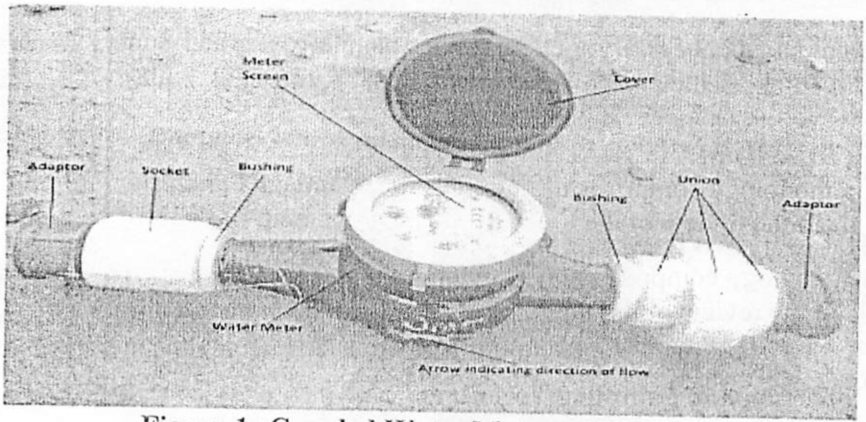

Figure 1: Coupled Water Meter with Fittings

Figure 2: Map of Nigeria Showing the study Area

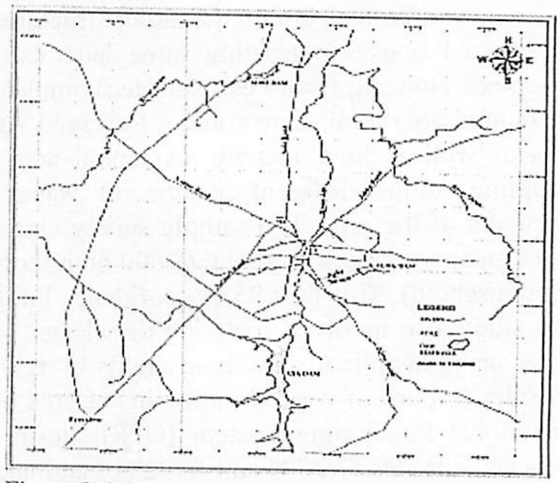

Figure 3: Map of Ilorin Showing the Dams and the Rivers

3.0 RESULT AND DISCUSSION

3.1 Demographic Profile of the Study Area

The family size of each household surveyed ranged between 1 and 10 people with a mean family size of 6 people per household as shown in Figure 3. The minimum age of the respondents was 22 while the maximum age was 65 with the mean age to be 46 years. People in the study area were of middle class with fairly high standard of living which is due partly to their literacy level. On the average, it was found that majority were learned people. Analysis showed that about 61 % of the total respondents were university graduates while 26 % had postgraduate degree qualifications and only 1.82 % was identified without any form of education (Figure 4). The types of the houses in the city varied as shown in Figure 5. Bungalows were the most dominant type of house with highest percentage of about 39 and closely followed by Block of Flats with 32 % of the total sample. Only a single Traditional house type was found in the survey conducted. For those that are paying rent, it was found that the rentage cost ranges between ₦3,000 and ₦6,000 has the highest frequency. Households paying less than ₦1,000 and those paying between ₦10,000 and ₦15,0000 were the least in number among the sampled households (Figure 6). All these factors are the socio-economic factors of the household. As the level of income increases, the probability that a household would adopt and pay for improved services also increases.

Also, the water use patterns were evaluated. Approximately 70 % of total sampled households were connected to municipal supply out of which 13 % indicated satisfaction in terms of sufficiency and 87 % used alternative sources to augment water supply. Those that were connected to the municipal water supply and usually get water supply in the morning period were 8.8%, daytime period, 21.3% and evening period, 70%. All respondents reported that their primary source of water supply was municipal connection. Only 23.8% of the respondents have wells and boreholes as their secondary sources.

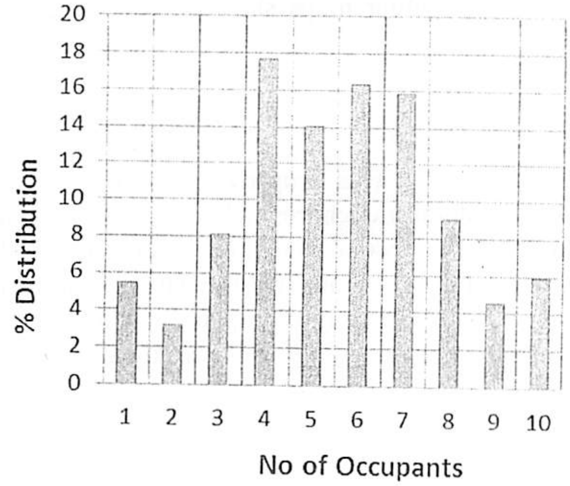

Figure 4: Household Population Distribution

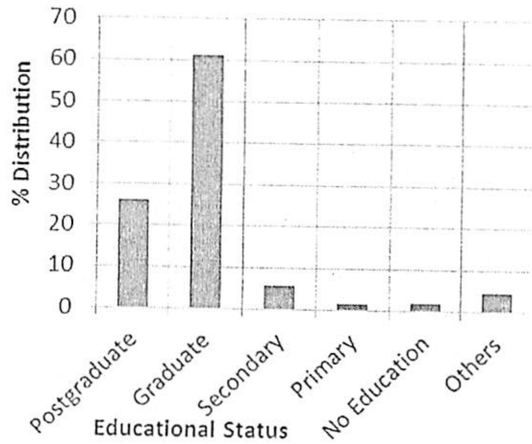

Figure 5: Educational Status of Household Head

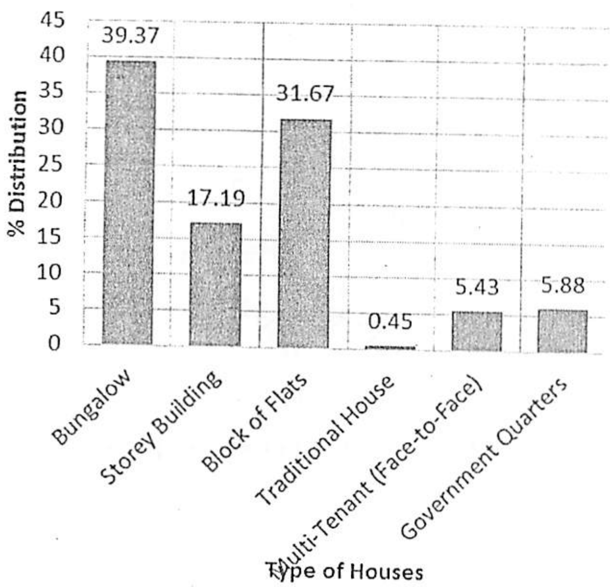

Figure 6: Type of Houses

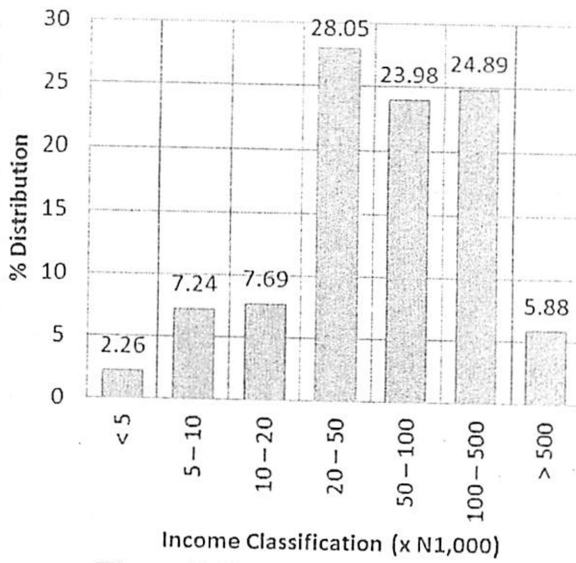

Figure 7: Income Classification

3.2 Water Consumption Rate and Frequency of Supply

Estimated average daily water consumption was 86.22 liters/capita/day which is lower than W.H.O. standard of 120 liters/capita/day for developing nations while the measurement from installed water meters indicated that average water consumption can be as high as 139.44 liters/capita/day. This is contrary to the recognition of Tanverakul and Lee (2013) as well as findings of Inman and Jeffrey (2006). Metering of houses enabled us to determine daily water use variation as shown in Figure 8. It can be seen from the Figure that the graph does not show any definite pattern. Moreover, the measurement also revealed that, water is supplied to various locations at different numbers time in a week as shown in Figure 9. Analysis showed that there is no household that had 100 % supply (i.e. every day of week). However, 25% of the households' survey received water five times per week. Also, only 10% of the households were served once a week. Results from metering (Figures 10 and 11) also revealed that availability affects the consumption rate because, the contour maps show similar variation and pattern.

Average daily households' daily water consumption was further evaluated as presented in Figure 12. The first week showed the period of low supply, hence demand had built up. Consumption increased over the weekend when there was improvement in supply. Households used the opportunity to use water for domestic chores which had not been attended to in the previous days due to low supply. The second and third week witnessed regular supply ranging between 344.74 and 1544.74 l/d. It is obvious that the data is short and it may be difficult to make concrete statement on the daily consumption pattern. This is as a result of irregularity in supply because at a time there was no supply for more than a month and the reading could not be continued.

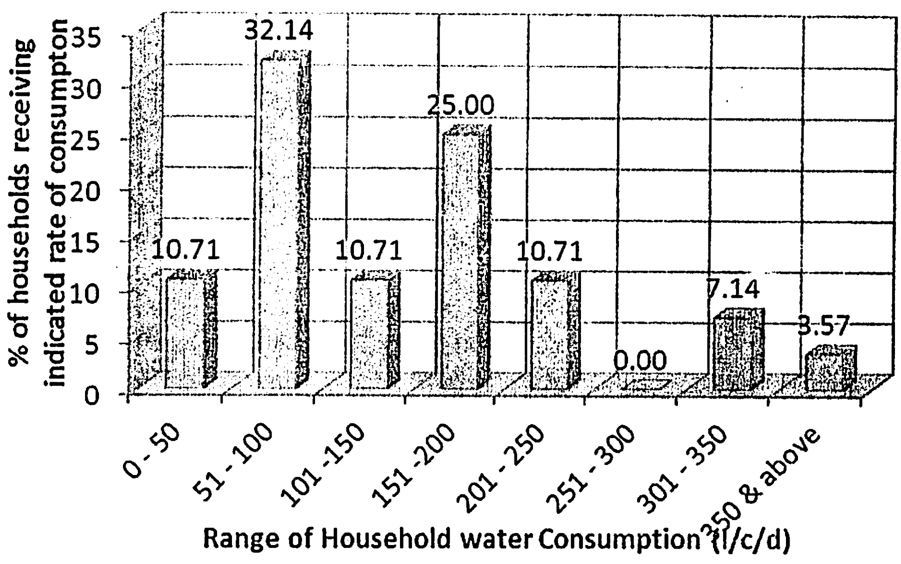

Figure 8: Average Percentage Household water consumption per capita per day

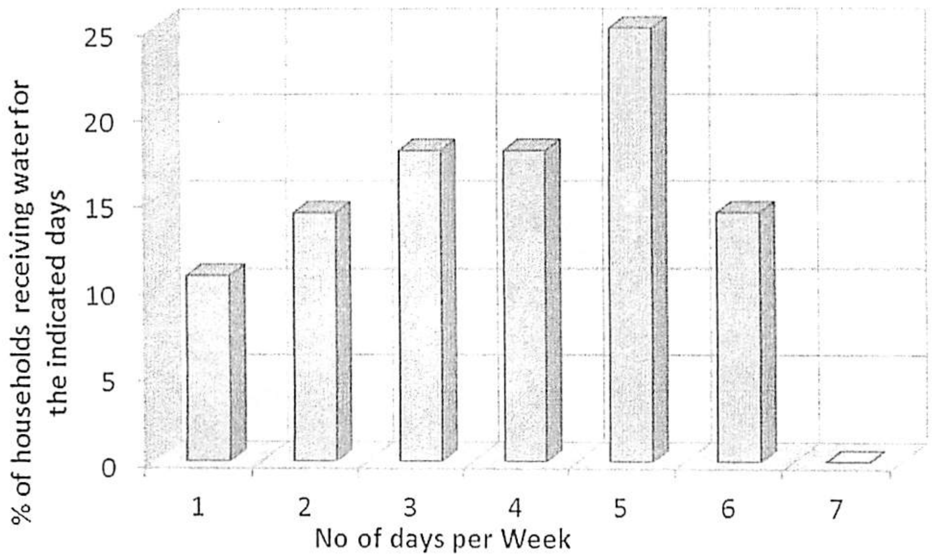

Figure 9: Average Percentage Number of Supply Days per Week

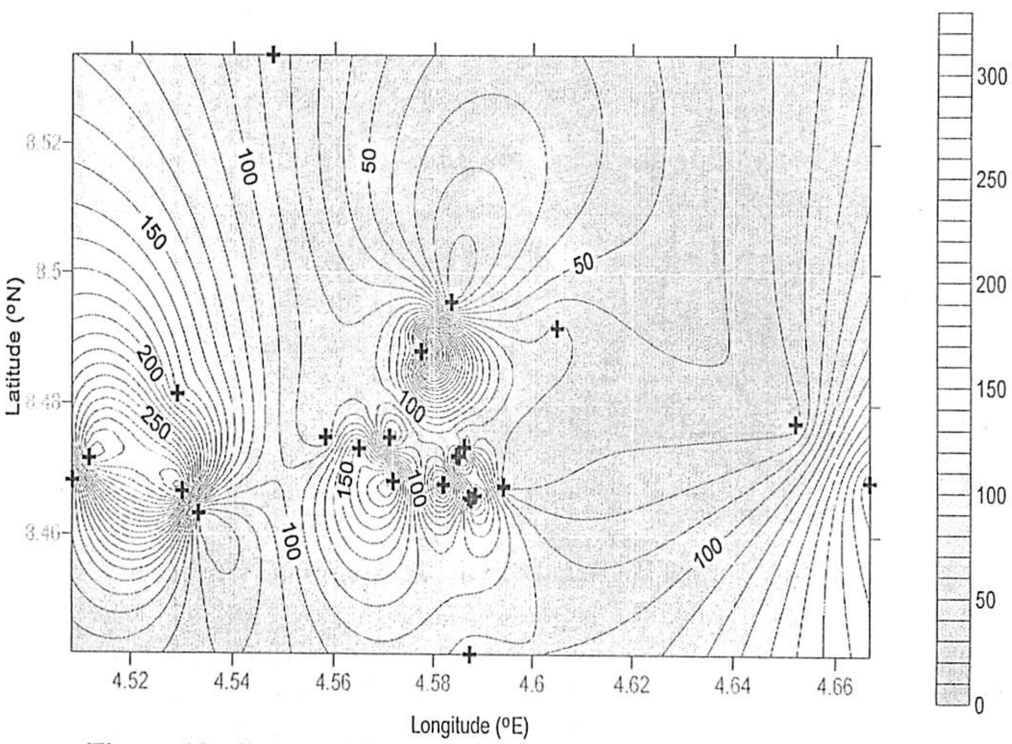

Figure 10: Contour Map of Household Consumption Rate (l/c/d)

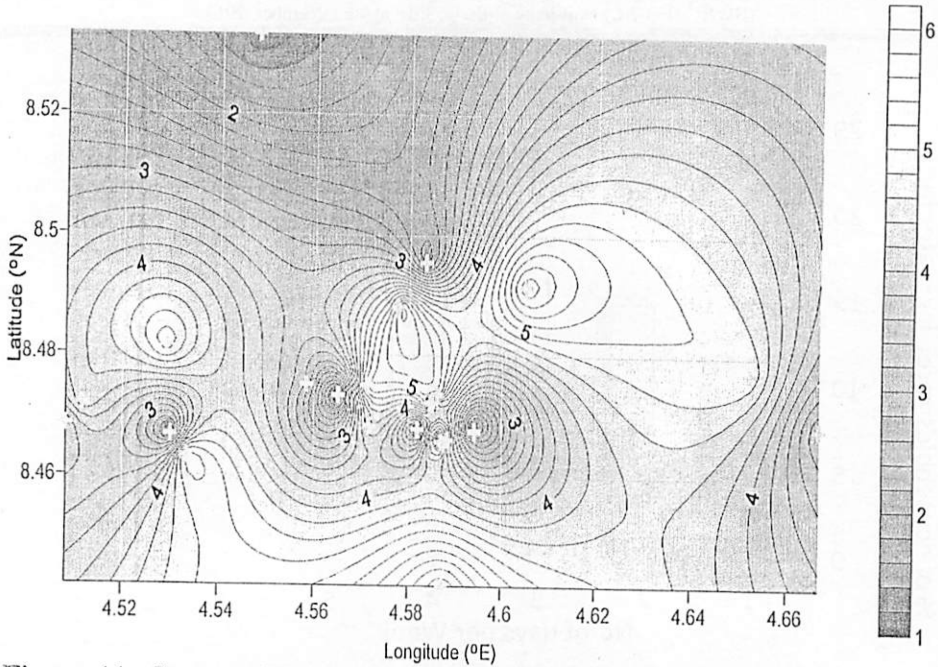

Figure 11: Contour Map of Average Number of Supply Days per Week

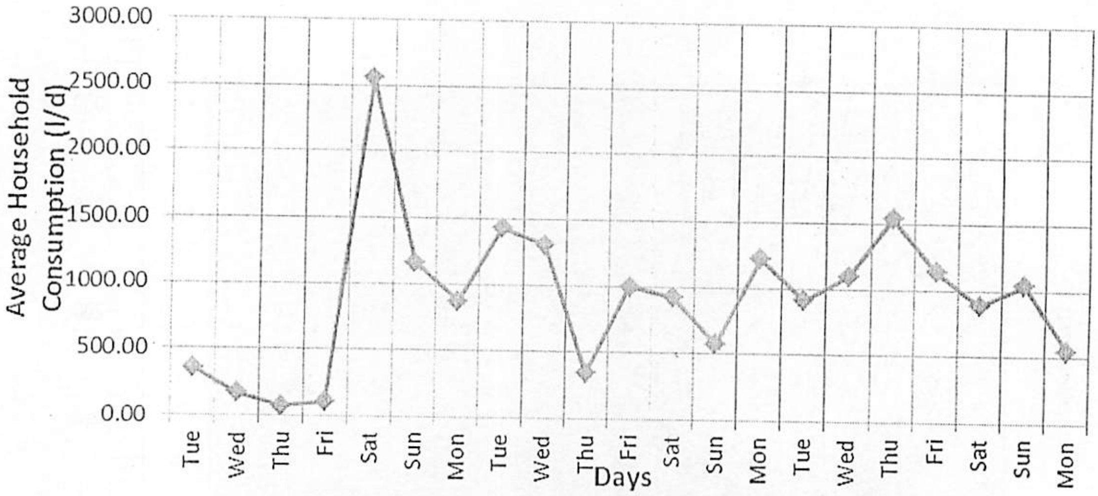

Figure 12: Average Household Daily Consumption Variation

3.3 Water consumption modelling based on questionnaire

From Table 1, 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, i.e. the combination of the predictors significantly combine together to predict *Average Water Demand.* 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), which shows that about 41.0% of the variation in *Average Water Demand* is explained by the model. The Durbin Watson Statistic of 1.840 falls below the *Upper Durbin Watson Limit* (1.857) which implies that there are elements of serial correlation.

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

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

Where: X_1 is Respondents as head of household; X_2 is Gender; 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 β values can be used in *comparing* the contribution of each predictor (independent variables). *Gender* with highest β of 0.56 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 β value for *Years of staying in the house* was 0.002 which made the least contribution. This depends on which variables that is included in the equation. The *Respondents as head of household, Gender, Age* and *Education* made a statistically significant contribution to the prediction of the *Average Water Demand* since their p-*values* is less than 0.05. The variables ***Age, Level of education*** are positively related to the *Average water Demand* at level of significance of 5%. All other predictors: *Occupation, Years of Staying in the house* and *Type of house lived in* are not contributing postively at 5% level of to the *Average Water Demand.* Tables 1 – 3 report the strength of the relationship between the regression model (predictors) and the *Total 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
Gender	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 (41.0%)	24.498	30.350	1.840

[s]- *Significant*

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

Model	B (coefficient)	Std. Error	β	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*
Gender	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)

3.4: Household Consumption Modelling Based on Meter Reading

Household water consumption is modelled based on the field measurement taken. The variables considered for the model include household population, ownership status, house type, number of rooms, toilets, bathrooms, method of bathing as well as type of toilet. Volume of water used by households was regressed against the above stated parameters to formulate the model shown in equation 3. Detailed regression analysis is as shown in Table 4 while Table 5 shows the Analysis of Variance (ANOVA) and other relevant statistics. The equation obtained is:

$$\mathbf{WU = 0.4046\ HP + 0.0492\ OS - 0.1316\ HT + 0.0787\ NR - 0.8769\ NT + 0.7218\ NB + 0.5091\ MB - 1.9237} \quad (3)$$

Where: WU = Household water consumption (m^3/d); HP = Household population; OS = Ownership status; HT = House Type; NR = Number of rooms in the house; NT = Number of toilets; NB = Number of bathrooms; MB = Method of bathing.

Among all the variables considered, type of toilet was dropped in the analysis. The regression analysis shows that the model is adequate because the probability value for the F-test statistic (0.0000) is less than 0.05 (5 % level of significance). Also about 87 % of the model is explained by the variables (since R^2 is 0.87).

Three variables were found to be significant at 5 % level of significance and they are: household population, numbers of toilets and bathrooms. The number of toilets showed negative contribution. Household population has the highest positive effect on the model (i.e. it has the highest beta value in Table 4). The average household population was found to be 6 people while the minimum and maximum were 2 and 22 respectively.

Numbers of bathroom is more significant and have positive effect while the number of toilets is less significant and had negative effects on the model. It should also be noticed that both toilet and bathroom facilities are the spaces where water fixtures are usually fitted in the houses, hence the model also confirmed this. Ownership status, house type, number of rooms and method of bathing were not significant at 5% level of significance. Only the house type out of the four non-significant variables has negative effect as it can be observed in Table 4.

3.5 Challenges encountered in the methods of survey

There are quiet numbers of challenges associated with the two methods of household water use survey employed. In administering the questionnaires, the responses from the targeted audience are not encouraging. People are not willing to give correct response to the questions and this has limited the number of questionnaires that are useful for the analysis. Results from reading also indicated that actual consumption could be more than the amount reported by the respondents. The following were some of the problems associated with the installation and use of water meter:

1. Getting permission from household heads to allow the installation of water meter in their service pipe was difficult as many people were not willing to allow the installation of water meter on their connection-line.
2. The other issue that posed a challenge was getting the location of the pipe-line, as the State Water Cooperation could not provide a general layout of lines running into individual houses.
3. Galvanized Iron (GI) pipe line used in some household also posed a problem of having to spend extra time and energy to get the meter installed compared to the PVC pipes.

Table 4: Household Water Usage Regression

Household Parameters	Coefficient	Standard Error	t	P>|t|	Beta
Population	0.4046	0.0527	7.6800	0.0000*	1.2265
Ownership Status	0.0492	0.3871	0.1300	0.9000	0.0113
House Type	-0.1316	0.2107	-0.6200	0.5390	-0.0633
No. of Rooms	0.0787	0.1948	0.4000	0.6910	0.1543
No. of Toilet	-0.8769	0.2517	-3.4800	0.0020*	-1.8060
No. of Bathroom	0.7218	0.2232	3.2300	0.0040*	1.0526
Type of Toilet	(dropped)				
Method of Bathing	0.5091	0.3071	1.6600	0.1130	0.1449
Constant	-1.9237	0.8241	-2.3300	0.0300	

*Singnificant

Table 5: ANOVA Table and Statistical Summaries

Source	SS	DF	MS
Model	56.24	7	8.04
Residual	8.52	20	0.43
Total	64.76	27	2.40

Number of observation	**= 28**
F(7, 20)	**= 18.85**
Prob > F	**= 0.00**
R – square	**= 0.87**
Adj R – squared	**= 0.82**
Root MSE	**= 0.65**

4.0 CONCLUSION

This study has shown that the present water supply to the city of Ilorin by KWWC is grossly inadequate and the system needs to be improved in order to meet the basic social need of the populace. It has been established that there is no enough coverage because, out of the sampled households, about 70 % were connected to municipal supply. Out of the total connected to municipal supply, about 13 % has indicated satisfaction in term of sufficiency of water while the remaining use alternative sources in order to make up their water needs. Having studied the hourly, daily and weekly water situation, the results also revealed that water supply is erratic and the city is under water stress. The average minimum and maximum volume of water used as recorded by the connected water meters were 0.82 and 372.14 l/c/d respectively while the average consumption was 139.44 l/c/d. A model for prediction of water use was also formulated. All the variables used in the model were evaluated and it has been shown that household population has the highest effect among all other significant variables. This study also evaluated water consumption with the aid of questionnaires at household level in some randomly selected houses within the metropolitan city of Ilorin. The average daily consumption was found to be 86.22 l/c/d which was higher than the basic minimum of 50 l/c/d as suggested by some researchers, but it is lower than WHO standard rate of 120 l/c/d. The variables such as age, income, education level, and gender were found to have significant effects on water demand.. This model will be a very good predictor of water demand in the study area and at other area that are of similar setting. From the result obtained in the water demand analysis in the study area, the following suggestion is recommended for the result. However, the following recommendations are made based on the findings from this study.

1. Metering of pipe water supply to houses for accurate data on water use is desirable. This will serve as a baseline data on water demand and it will also allow for proper planning for short and long term structural and non-structural strategies for the reliability and sustainability of the system.
2. 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; and average measurement using water meter is about 139. 44 l/c/d using water meter which is slightly above the baseline set by WHO standard, it is recommended that minimum of 140 l/c/d demand rate be used for designing and planning purpose.
3. The formulated models be used for the prediction of household water consumption in the study area other areas with similar demographic pattern.
4. Further research study is also recommended on water demand management in order to develop useful strategies for optimum water use for various other urban localities in the state and Nigeria nation in general because of the precarious situation of urban water supply and sanitation.

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