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Investigations into the Residential Water Demand and Supply in Enugu Metropolitan Area, Nigeria

Ezenwaji E. E.[1,*], Eduputa B. M.[2], Okoye C. O.[2]

[1]Department of Geography and Meteorology, Nnamdi Azikiwe University, Awka, Nigeria
[2]Department of Environmental Management, Nnamdi Azikiwe University, Awka, Nigeria
*Corresponding author: emmaezenwaji@gmail.com

Abstract The aim of this study was to investigate into the water demand and supply situations in Enugu Metropolitan area, Nigeria. To achieve the aim, data for the study were collected from 2000 randomly selected households in our identified 41 residential wards of the urban area within 6 months between April and September 2015 by the use of questionnaire designed for the purpose. The sampling technique adopted was the stratified random sampling which has the advantage of ensuring that no section of the population was excluded. Trend based method was employed in the estimation of the quantity of water demand and supply, while principal component regression was utilized in the analysis of the factors responsible for the quantities demanded and supplied and produced an equation that was used in the model estimation. Result shows that the quantity of water demanded and supplied in 2014 were estimated at 144,491,774 litres per day (LD) while supply was 67,091,096 LD which satisfied only 44.0% of demand. On the basis of findings, we recommended that institutional reforms, water demand management technique and supply measures as well as professional community based management option be urgent employed to meet the sustainable Development Goal (SDG) target date of 2030 of ensuring access to water and sanitation for all.

Keywords: *demand, sampling, ward, measures, access*

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1. Introduction

The existence and growth of urban communities are largely dependent in part upon continuously and plentiful water supply. This realization has recently awakened the interest of scholars in the field to the study of water produced and supplied by the urban water supply authorities in relation to demand by the municipal and industrial users.

Since after the Nigerian civil war of 1967 – 1970, water supply in Nigerian cities has continued to decrease in quantities relative to demand [1,2,3,4]. However, among all the urban sectors, the residential sector seems to be worst hit by this shortage. It is in this regard that Anyadike & Ibeziako [5], Ezenwaji [6] and other several researchers in the field undertook the study of residential water demand and supply in several urban areas of Nigeria and found that this shortage is indeed widening. The reasons given by some of them for these shortages apart from the well-known increases in urban population include:

(i) inability of many urban water works to source enough water from their urban areas, leading to the often recourse to the transfer of water from distant sources.
(ii) persistent breakdown of old and dilapidated water supply infrastructure,
(iii) great water losses as a result of broken-down and leaking water transmission and distribution lines, and
(iv) inability of the nation's public electricity supply company to provide enough power for the operation of the water works.

The consequences of lack of adequate water supply to the urban residential areas as a result of the above reasons are grave. For example, residents living in many urban areas obtain water supply from supplemental sources of doubtful quality which usually include shallow wells, ponds, lakes, rivers or rainwater often collected from dust infested corrugated iron or asbestos coated roofs or some combinations of these. The result of water consumption by residents from these unwholesome sources is the spread of water-borne and water-based diseases such as diarrhoea, cholera, typhoid, and paratyphoid fever, hepatitis ameobiasi etc.

In Enugu urban area, water supply from the Greater Enugu water supply scheme is delivered to residents in a most intermittent manner. This intermittent service is not as a result of the fact that the construction of the water scheme was originally deficient, but rather it is due to lack of proper maintenance of the equipment at the head works, silting of water sources and channels, as well as, heavy water losses from the water transmission and distribution lines. The above have resulted in the following problems among residents.

(i) First, is the absolute and relative water shortages in the residential sector between the amounts demanded and supplied most especially as a result of poor funding and damaged infrastructure.
(ii) Second, the parlous water supply situation found in many parts of the town has forced residents to rely more on polluted water supply sources, [7].
(iii) Third, is the often – reported cases of motor accidents and occasional deaths involving children and women who daily fetch water by walking and crossing the high vehicular traffic streets on their way to and from water sources.
(iv) Fourth, children and women who form a high percentage of the group that fetch water spend enormous amount of time and energy searching for it in the urban area [1]

The above are results of high level of water scarcity in the residential sector of Enugu despite some intervention programmes. The summary of the reasons for the water scarcity could be stated as the growing disparity between decreasing effective supply and increasing demand for water. A necessary first step towards realising the degree of this disparity is the knowledge of total amount of water demanded and supplied in the sector and an assessment of the factors involved and management practices. Also the study will focus attention at ascertaining the level of commitment of the State Government and the Water Corporation and the national and international bodies towards improving the water supply and controlling demand in the urban area, with a view to achieving the Sustainable Development Goals (SDGs) by 2030, the target date for complete access to water and sanitations for all. A close examination of these issues will provide answers that will enable us explain the present state of water supply shortages and its associated problems in the urban area as a basis for proffering solutions. These, specifically form the basis of this paper.

2. Materials and Methods

2.1. Area of Study

Enugu urban area is located approximately between latitudes 06°.30'N and 06°.40'N and longitudes 07°.20'E and 07°.35'E and covers an area of about 145.8sqkm (Ministry of Lands, Survey and Urban Development 2010). Its geology shows that the urban area lies in the eastern Nigerian sedimentary basin which is underlain by such rock formations as Enugu shales, Mamu formation (lower local measure) and Ajalli formation (false bedded sandstone). Total annual rainfall in 2014 was 1944mm, more than three quarters of which fell between the months of July and September. This seasonal rainfall pattern has some implications for water resources of the urban area. First many rivers and streams dry up during the period of November to March when the area experiences virtually no rainfall and the water sources that survive in this period experience low stage. Second as the rains come, the river waters begin to rise and progress until they reach a peak discharge in the middle of October. Furthermore, rainfall determines to a larger extent the water availability in rivers and wells for water supply. Under drainages, the area has an ample presence of rivers and streams, dominant among which are the Ekulu and Asata rivers. The 2014 population of the town was 988,442 which was projected from the 2006 census base figure. The residential structure of the town shows that the town has 41 residential wards which are grouped under the 3 Local Government Areas that constitute the urban area (Figure 1).

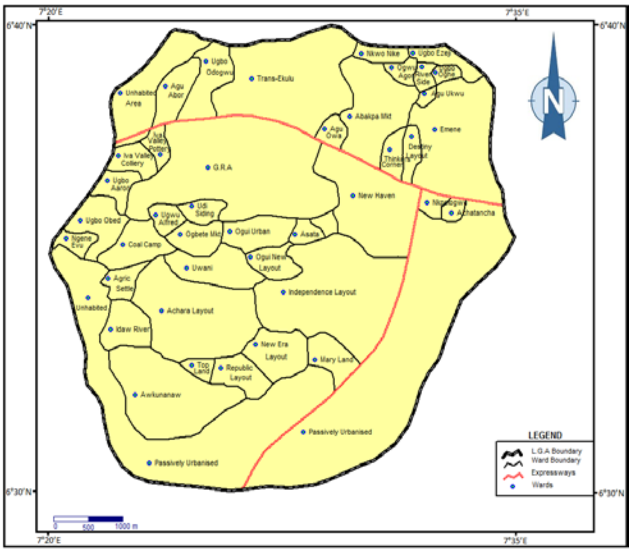

Figure 1. Enugu Metropolitan Area showing 41 residential wards

2.2. Data Collection and Analysis

The data on water demand and supply was achieved through the designing and administration of 2000 questionnaires to households in 41 residential areas of the town between April and September 2015. The sampling technique adopted for this distribution was the stratified random sampling in which each wards was a stratum, while individual houses within each ward were sampled randomly with random numbers. From the questionnaire responses a total of demand 29 variables were isolated while 11 supply variables were determined from the data. The definition, labelling and parametization of the variables are presented in Tables 1 and 3.

Table 1. Variables used in the Analysis of Water Demand Variables – Residential Sector

S/N	NAME OF VARIABLE	VARIABLE LABEL	Variable Code	METHOD OF PARAMETIZATION
1	Whether or not water runs in residence	RUNS	X_1	If water runs in residence the variable was assigned the value of one (1). If on the contrary, the value of zero (0) was assigned to it.
2	Number of hours taps run in the residence	HOURS	X_2	The average number of hours taps run in residence was indicated by the respondents. If it did not run at all, the lowest value of zero (0) is assigned.
3	Number of flush toilets in the house	FLUSH	X_3	Where flush toilets existed, the number 1 (one) was assigned, where none exists, the value of zero (0) was assigned.
4	Number of showers in the house	SHOW	X_4	The number of showers in the house was recorded. Where none existed, the value of zero (0) was assigned.

5	Whether or not water stand-pipes exists in the compound.	STAND	X_5	If water stand-pipe existed in the compound, the value of one (1) was assigned, where none existed, the value of zero (0) was assigned.
6	Distance of street stand-pipe to the house	DIST	X_6	The distance of street stand-pipe to the house was measured and recorded in kilometres.
7	Distance of supplementary sources of water to the house.	SUPP	X_7	The distance of supplementary sources of water to the house was recorded in kilometres.
8	Number of rooms occupied by the household.	ROOMS	X_8	The average number of rooms occupied by the household was recorded
9	Number of pipe leakages in the distribution system inside the residence	LEAK	X_9	The average number of leakages inside the residence as reported by the respondent was recorded.
10	Number of water using appliances in the house other than baths showers and toilets	APPL	X_{10}	The number of water using appliances in the house was recorded. Where none existed, the value of zero (0) was recorded.
11	Quantity of water used for cooking by the households per day	COOK	X_{11}	The quantity of water for cooking was estimated by respondents in units of 25 litre jerry cans.
12	Quantity of water used for washing cloths by the households per day	CLOTH	X_{12}	The quantity of water was estimated by respondents in units of 25 litre jerry can.
13	Quantity of water used for washing plates and general house cleaning by households a day.	CLEAN	X_{13}	The quantity of water used in washing plates and general cleaning was estimated by respondents in 25 litres jerry can.
14	Quantity of water used to water vegetable gardens and flower beds by households per day.	GARDEN	X_{14}	The quantity of water used for the watering of vegetable gardens and flower beds was estimated by respondents in units of 25 litre jerry cans.
15	Number of day time hours all members of the household were found in the house.	ALLMEB	X_{15}	The number of hours was estimated by respondents and recorded.
16	Number of hours about half of the members of household are found in the house.	HALF	X_{16}	The number of hours was estimated by respondents and recorded.
17	Number of hours when no member of household is found in the house a day.	NOMEB	X_{17}	The number of hours was estimated by respondents and recorded.
18	Number and size of water containers in the house.	CON	X_{18}	The number and size of containers in the house recorded by the respondents. If none existed zero (0) was recorded.
19	Total capacity of water containers used as water reservoir by the house per day.	CAPA	X_{19}	The combined capacity of the containers used as water reservoir in the households estimated by respondents per day were recorded.
20	Number of persons per household.	NUMB	X_{20}	The number of persons in the household was supplied by the respondents and recorded.
21	Occupation of Head of Household.	OCCU	X_{21}	The occupation of the head of household shows the status of the household. When the head is in top position in public or private establishment, the value of ten (10) was assigned, when in the middle position the value of five (5) and when in the lower position, the value of one (1) was assigned.
22	Educational level of head of household.	EDUC	X_{22}	The selection of this factor in studying urban water demand is based on the assumption that the higher the level of education attained by the head of the household, the more the amount of water to be demanded by household. It is considered that as the number of years the respondents spend obtaining formal education, the higher the level of education. The variable was parametized as follows: (1) No formal education = 0 (2) Primary school education 6 (3) Secondary education = 11 (4) Ordinary Diploma INigerian Certificate in edu. = 14 (5) Bachalor Degree/Higher National Diploma = 16 (6) Higher degrees 20
23	Number of persons below the age of 18 years in the household.	BEAGE	X_{23}	The number of persons below 18 years was recorded from household. The value of zero (0) was assigned where no person was below the age of 18 years.
24	Number of persons above 18 years of age in the household.	ABAGE	X_{24}	The number of persons above 18 years was recorded from every household sampled.
25	Cost of water supply to the household from the water vendors a day.	VEND	X_{25}	The cost of water per drum was supplied in Naira by the respondent and recorded.
26	Cost of water supply from other supplementary sources a day.	SUCO	X_{26}	The cost of water from other sources per drum was supplied in Naira by the respondents.

27	Cost of water supplies to the house from the public water supply a day.	PUWA	X_{27}	The cost of water from this source was supplied in Naira by the respondents.
28	Income level of the head of household per annum.	INCO	X_{28}	The type of house lived by different categories of respondents was used to determine the level of income of a household. Duplex = 5 Morden Bungalow = 4 Flats = 3 Old Bungalow = 2 Single Rooms = 1
29	Total yearly Household income.	TOHCOM	X_{29}	This variable was parametized taking cognizance that few persons can disclose their net income. This made us to employ the type of house as a proxy variable to estimate the total income of households. For example, a household living in modern and sophisticated house was valued an amount equal to the level of a Commissioner in the State Public Service which is about Three Million Naira (₦ per annum, while households living in simple modem Houses were valued amounts of money equal to the middle income Civil Servants, which earn about one million, two Hundred Naira (₦1,200,000.00) per annum. finally those persons living in slum and squatter settlements are valued amounts of money equal to the least paid Civil Servant who earns about one hundred twenty thousand Naira (₦120,000.00) per annum.

The major analytical technique used was the Principal Component Regression. This was employed to develop a robust regression model from the 29 variables already isolated from the questionnaire. This technique was, however, employed because of the observed severe auto correlation found among our variables when we ran a multiple correlation analysis (result of multiple correlation not included). The statistical package used was the Minitab version 16, while the result obtained by running a regression analysis on the calculated principal components was quite clear.

3. Results

The PCR for water demand produced 9 components with varying information content, segregated coefficients and different percentage of the variables explained (Table 2). With these criteria, component VIII with 92.0% of the explained variation ranks above all and was selected for further analysis.

Table 2. PCR for Water Demand in Enugu

S/N	Variables		Components								
	Label	Code	I	II	III	IV	V	VI	VII	VIII	IX
1	Runs	X_1	-0.084	0.009	0.010	-.120	-0.088	0.280	0.302	0.011*	0.012
2	Hours	X_2	0.002	0.011	0.184	0.030	-0.092	0.300	0.294	-0.419*	0.029
3	Flush	X_3	0.046	0.041	0.071	0.028	0.010	0.080	0.116	0.320*	0.144
4	Shows	X_4	0.001	0.032	0.026	0.017	0.004	-0.029	-0.003	-0.293	0.006
5	Stand	X_5	0.058	0.000	0.006	-0.123	0.093	0.043	0.000	0.028	0.048
6	Dist	X_6	-0.114	0.138	-0.151	0.219	-0.042	0.0015	0.121	-0.092	0.002
7	Supp	X_7	-0.000	-0.204	-0.189	0.120	0.007	0.030	0.024	0.180	0.090
8	Room	X_8	0.077	0.081	0.070	0.002	0.085	0.114	0.003	0.086	0.101
9	Leak	X_9	0.016	-0.074	0.060	-0.001	-0.211	0.080	0.069	0.304*	0.088
10	Appl	X_{10}	0.014	0.040	0.005	0.071	-0.056	0.106	0.001	0.329*	0.010
11	Cook	X_{11}	0.004	-0.005	0.012	0.068	0.007	0.021	0.208	0.113	0.109
12	Cloths	X_{12}	0.073	0.069	0.001	0.003	0.090	0.053	0.002	-0.024	0.081
13	Clean	X_{13}	0.003	0.001	-0.046	0.008	-0.049	0.033	0.105	0.009	0.049
14	Garden	X_{14}	0.098	0.017	0.012	0.166	0.055	-0.056	0.004	-0.088	0.061
15	Allmed	X_{15}	0.031	0.022	0.059	0.111	0.013	0.044	0.080	0.633*	0.000
16	Half	X_{16}	-0.031	0.005	0.001	0.310	0.015	0.000	0.009	0.019	0.050
17	Nomen	X_{17}	0.000	0.091	-0.88	-0.020	-0.199	0.046	0.070	0.001	0.030
18	Cont	X_{18}	0.84	0.104	0.006	0.010	-0.105	-0.110	-0.003	0.020	0.003
19	Capa	X_{19}	0.007	0.051	-0.058	-0.000	0.004	0.211	0.020	-0.009	0.042
20	Numb	X_{20}	0.014	-0.020	0.077	0.001	-0.194	0.074	0.006	0.018	0.039
21	Occu	X_{21}	-0.09	-0.379	0.009	0.203	0.172	0.004	0.001	-0.051	0.066
22	Educ	X_{22}	0.006	-0.112	0.004	0.007	0.004	0.010	0.132	0.118	-0.202
23	Beage	X_{23}	-0.144	0.081	0.006	0.121	0.134	0.002	0.109	-0.116	0.052
24	Abage	X_{24}	-0.463	0.104	0.195	0.004	0.001	0.020	0.101	0.007	0.052
25	Vend	X_{25}	-020	0.009	0.451	0.202	-0.101	0.003	0.029	0.281*	0.018
26	Suco	X_{26}	0.003	0.004	0.009	0.002	0.123	0.226	0.019	0.022	0.070
27	Puwa	X_{27}	0.002	0.018	0.022	0.000	0.010	0.037	0.030	0.005	0.063
28	Inco	X_{28}	0.003	-0.140	0.161	0.003	0.195	0.008	0.002	0.416*	0.038
29	Tocom	X_{29}	0.000	-0.310	0.001	0.050	0.010	0.006	0.008	0.060	0.005
	Constant		6.284	7.304	7.296	6.722	6.891	7.640	8.112	-8.463	8.039
	R^2		0.429	0.483	0.573	0.644	0.690	0.744	0.769	0.920	0.710

* Variables with high coefficients on the selected component.

The selection of component reduced the amount of bias that inevitably crept into the estimates. From component VIII we built the residential water demand equation as follows;

$$(Y) - 8.463 + 0.011(Runs) + 0.419(Hours) +0.320(Flush) - 0.293(Shows) + 0.028(Stand) -0.092(Dist) + 0.180(Supp) + 0.086(Room) +0.304(Leak) + 0.329(Appl) + 0.113(Cook) +0.024(Cloths) + 0.009(Clean) + 0.088(Garden) +0.633(Allmed) - 0.019(Half) + 0.018(Nomen) +0.020(Cont) + 0.009(Capa) + 0.520(Numb) -0.051(Occu) + 0.118(Edu) - 0.116(Beage) -0.007(Abage) + 0.281(Vend) + 0.022(Suco) +0.005(Puwa) + 0.416(Inco) + 0.060(Tocom). \quad (1)$$

We also used eleven variables achieved from the questionnaire to develop the water supply model for the town. The variables and their labelling are contained in Table 3, while Table 4 shows the Principal Component Regression result achieved.

The resultant water supply model is presented in equation 2.

$$Water\ supply\ (Y) = 6.290 + 0.342(Dist) - 0.505(Hour) +0.001(Main) + 0.529(Numb) + 0.006(Prese) -0.206(Vehl) + 0.843(Fund) - 0.086(Dies) -0.528(Pipe) + 0.002(Pipe) + 0.002(Pumps) -0.006(Stream). \quad (2)$$

Table 3. Water Supply Variables used in the Analysis

S/N	NAME OF VARIABLE	VARIABLE LABEL	Variable Code	METHOD OF PARAMETIZATION
1	Distance of the source of Municipal Water to the Sectors.	DIST	X_1	The average distance of the source of Municipal Water Supply to the Sectors was measured and recorded in kilometres.
2	Number of Hours of Electricity per day.	HOURS	X_2	The average number of hours that the sect have electricity supply every day was observed and recorded.
3	Average monthly recovery of operations and maintenance Cost by the State Water.	MAIN	X_3	The Amount recovered by the Water Corporation every month was obtained and recorded.
4	Number of consumers in Residential, Commercial, Public Institutions and Industries who were connected to the Municipal supply through pipe lines.	NUMB	X_4	This number was collected from the field I recorded.
5	Number of storage reservoirs that serve the four sectors.	RESE	X_5	The Number of service reservoir that serve d four sectors in the town were observed and recorded.
6	Number of service vehicles, Cars and Tankers at the disposal of the State Water Corporation in 2010.	VEHL	X_6	The Number was supplied by the State Water Corporation and recorded.
7	Funds released to the State Water Corporation by the State Government in 2010.	FUND	X_7	The Amount of Funds released to the Corporation in 2014 for its activities supplied by the Water Corporation was recorded.
8	Average quantity of diesel purchased per day by the Water Corporation.	DIES	X_8	The average quantity was supplied by the Corporation and recorded.
9	Average number of Pipe leakages in 2007.	PIPE	X_9	The number of Pipe leakages in 2014 was obtained from the Water Corporation and recorded.
10	Number of faulty and unrepaired pumps recorded by the Water Corporation in 2010.	PUMPS	X_{10}	This number was collected from the Water Corporation and recorded.
11	Number of streams with poor access roads from where the State Water Corporation sources their supply by the use of tankers.	STREM	X_{11}	The number of these streams were observed m the field and recorded.

Table 4. PCR for Water Supply in Enugu

S/N	Variables		Components		
	Label	Code	I	II	III
1	Dist	X_1	0.064	0.104	0.342
2	Hours	X_2	-0.069	0.500	-0.505*
3	Main	X_3	0.000	-0.069	0.001
4	Numb	X_4	0.008	-0.544	0.529*
5	Prese	X_5	0.070	-0.003	0.006
6	Vehl	X_6	0.210	0.442	-0.206
7	Fund	X_7	0.005	0.629	0.843*
8	Dies	X_8	-0.113	-0.123	-0.086
9	Pipe	X_9	-0.109	-0.484	-0.528*
10	Pumps	X_{10}	0.001	0.428	0.002
11	Stream	X_{11}	0.092	0.563	0.006
	Constant		2.860	5.860	6.290
	R^2		0.429	0.746	0.940

*Variables with high coefficients on the selected component.

4. Discussion

In order to evaluate the relative importance of the explanatory variables determining water demand (equation 1, Table 2). The principal regression performed indicates that $\mathbf{X_{15}}$ (the number of day time hours when all members of the household are found at home)**(0.633)** measured in standard deviation units is the largest factor determining the demand of water in Enugu urban area. This factor is followed by $\mathbf{X_2}$(number of hours taps run in a day)**(-0.419)**. The impact of $\mathbf{X_{15}}$ is however about one and half times greater than that of $\mathbf{X_2}$ and of the next factor $\mathbf{X_{28}}$(income level of head of household per annum)**(0.416)**. Then $\mathbf{X_{10}}$(number of water using appliances in the house), **(0.329)** is followed by $\mathbf{X_3}$ (number of flush toilets in the house) **(0.320)**, $\mathbf{X_9}$ (number of pipe leakages in the distributional system inside the house),**(0.304)** $\mathbf{X_4}$(number of showers and baths in the house) and $\mathbf{X_{25}}$(cost of water supply to the household from water vendors a day) reveal various importance. **(0.281)**Altogether, the model isolated only eight factors out of our 29 as those determining the water demand in Enugu.

On the Water Supply side, Table 4 shows the regression coefficients in which Component III was chosen because of the high stability of the coefficients, its high percentage of the variation explained and its high information content. The isolated variables with high coefficients are $\mathbf{X_7}$(funds released to the State Water corporation by the State Government in 2014)**(0.843)**whose impact is about one and half times that of the next variable $\mathbf{X_4}$(Number of consumers without taps)**(0.529)**. This variable is followed by $\mathbf{X_9}$(Number of pipe leakages recorded in 2014)**(-0.528)**, while $\mathbf{X_2}$(Number of hours of electricity on water works daily) (-**0.505**) has the least loading among important variables. Altogether, the model isolated the above four significant factors out of eleven factors from our chosen component III as influencing water supply in Enugu urban area.

Furthermore the Principal Regression model showed that all the demand factors have a combined contribution of 92%, leaving 8% unexplained which could be attributed to other factors not included in the analysis. A base constant value of -8.463 was achieved which means that in the absence of these factors operating, water demand will decrease by 8.5 litres per day. This shows that the factors included in the analysis are indeed very relevant as they tend to promote demand. Also for the water supply (Table 4) the model has a base constant of 6.290, while the variables contributed 94.0% to entire variation in water supply in Enugu urban area leaving 6.0% unexplained. The positive sign of the base constant indicates that in the absence of these factors, water supply will increase by 6.29 litres per day. It is in fact very necessary that the influence of these factors are checked to enable an improvement of water supply.

It could be seen that in the demand component apart from X_{15}, X_{28} and X_{25} which are socio-economic factors all other ones X_2, X_{10}, X_3, X_9, X_4 are purely physical bordering on infrastructural problems. Again in the factors influencing supply, it could be seen that apart from X_7 (funds releases to the State Water Corporation) all others are also physical revolving around infrastructural inadequacy. This shows that socio-economic factors can be handled by monitoring the costs and finance needed for sustainable water supply and overall service delivery. The State Water Corporation and the Ministry of Public Utilities representing the State government needs to know at any point in time the cost of sustaining water services in its jurisdiction, especially the source of funds required (Schouten and Smits, 2015). Again in order to achieve sustainable services, all sources of funds (transfers, tariff and taxes also called 3Ts) should be mobilized whether private or public. Furthermore, costs for providing services must be known, government or donor in order to ascertain how much is needed to achieve universal and sustainable coverage by 2030 as provided by the Sustainable Development Goals. Those who make funds available and how funds are eventually utilized to promote and maintain water infrastructure should be known (WHO, 2012).

However, more worrisome is the infrastructural problems both at household and city wide levels, which underscores the need for monitoring at various levels. Danert (2015) noted that country or city monitoring, led by governments, together with civil society organisations, private sector and households is essential for decision making and action to realise improved water services. Monitoring should be made an essential part of the water service provision, it should be developed in any water supply system so as to evolve over time. The Enugu State Water Corporation is, therefore, under obligation to establish a monitoring body at the city and household levels. According to Schouten and Smits [8] conceptually country-led monitoring is different from founder led, project driven monitoring. These tend to be temporally and spatially piecemeal and are undertaken mainly for the foreign constituencies that provide funds rather than for the consumers and institutions providing water services. It is, therefore, important that the incumbent public service manager of water supply in Enugu, (the Enugu State Water Corporation) should fashion a realistic city led monitoring of the condition of these infrastructure at defined period. In this wise, Community Based Organisations (CBOs) should be constituted by the Water Corporation in various districts of the Metropolitan area.

In addition to the above measures, the State Water Corporation should undertake various reform measures to reposition itself for effective management of the city's water supply.

Emerging trends in the residential water supply projection for the town is very worrisome. The water projection rates being used by the Water Corporation in the town assigned water demand a yearly growth rate of 5% and supply 2% [9]. However, we are aware that similar rates were arrived at by earlier researchers. For example Okoye, (2006) used statistical technique to arrive at the residential water demand rate of 4.6% and supply of 1.8%. While B&B consultants [10] calculated this rate to be 5.1% for demand and 2.2% for supply. We have decided to employ the rate of 5% (demand) and 2% (supply) adopted by the Water Corporation to project water demand and supply of the town from 2010 to 2015 (Table 5).

Table 5. Residential Demand and Supply Projection for Enugu Urban Area (2010 – 2015)

Year	Demand (Litres)	Supply (Litres)	% of Demand achieved by supply
2010	119,120,551	61,981,756	52%
2011	125,076,579	63,221,391	51%
2012	131,330,408	64,485,869	49%
2013	137,896,928	65,775,869	47%
2014	144,491,774	67,091,096	46%
2015	159,317,931	69,801,576	44%

Source: Personal computation.

From Table 5, it could be seen that from 2010 there has been gradual absolute increases in the gap between the quantity of water demand and supply. Properly presented water supply is increasingly being incapable of satisfying demand with the result that this year 2015 which is the end of MDG, water supply could only achieve 44% of demand. If we employ the national water demand and supply standard of 120 litres per capita per day (LCD) then it will be realised that with the residential population of 1,022,144 in 2015 for the town only 581, 680 persons or 44% had access. This is a far cry from the expectation Millennium Development Goals (MDGs)which requires that at least 50% of the population would have access by 2015. This therefore calls for more practical action to meet the expectation of 2030 SDG target.

Our field investigations revealed that there are many areas that need to be reformed to enable the SDG's expectation to be realised, however the starting point of these reforms will be the repositioning of the State Water Corporation because of its sole responsibility for the supply of water to residents of Enugu. Presently the Corporation is afflicted with numerous burdens which is why it is finding it difficult generating enough funds for its operation. Some of the problems are bloated staff, poor staff composition, poor work attitude of staff, high operating cost and low efficiency, poor organizational management, incessant government interference, poor billing and revenue collection system. These were the problems faced by the Lagos State Water Corporation before it began its water sector reforms about 10 years ago along the following lines;

(a) Assessing the performance level of the Corporation as an institution

(b) Estimating funds requirement for the upgrading of the entire system. In the Lagos State experience, funds requirement was estimated at $2 billion (i.e. N300 billion) (Abiodun, 2004) for the revitalization of the entire urban water sector.

(c) It engaged the International Financial Corporation (IFC) as its principal advisor with the mandate to attract international water companies through competitive bidding. By this effort, the Corporation achieved the following; setting up of the structure of PSP project, mobilization of consultants to conduct due diligence on the Corporation, preparation of strategic options, call for expression of interest and prequalification of water companies.

(d) The corporation abandoned a central water works arrangement and opted for mini works. There are currently seven of such works at Iwaya, Ikeja, Oworonshoki, Dolphine, Onikan, Ojo, Otto, Awori.

These efforts were made by the Lagos State Water Corporation to open up the water sector to private sector participation and this arrangement is advocated for the Enugu State Water Corporation. Also it was found during the field work that Small Water Enterprises (SWEs) dominated the water supply of the town. We saw that this category of water providers supply about 60% of the total water in Enugu urban area in 2008 [6]. The Corporation will ensure that this category of water suppliers is included in its water reform agenda.

Another Measure is for the Corporation to adopt the integrated water resources planning. This approach is necessary as the water supply and water demand components of the residential urban water system is expected to be integrated for effective water delivery and rational consumption patterns. For example GIS/ automated data generation and retrieval system can be put in place and used advantageously to present data on water flow rates and pressures to any ward or residential sector to aid the Water Corporation to rationally supply water to consumers. This will enable network managers ascertain areas where water supply pressure is high and reduce them while increasing areas of low pressure. This balancing of supply will enable water to get to as many consumers as possible in the town.

5. Conclusion and Way Forward

The severe and prolonged water supply shortages (the wide demand – supply gap) being experienced in Enugu and how to solve them through improved water supply and better management practices to meet the SDGs by 2030 on water supply provoked this study. The result of the work has extended our understanding of residential water demand and supply situation in the town. The work determined that the water demand – supply gap for 2010 in the residential sector was 54.3%which has gone down to44.0% in 2015. The relevant demand and supply factors that gave rise to these deficiencies were isolated and critically examined. The issue of the presence of collinearity of data was solved by the use of the Principal component Regression (PCR) which is a model that combines Principal Component Analysis (PCA) and Multiple Linear Regression (MLR). The model isolated 8 water demand factors out of 29 factors used in the analysis, and 4 water supply factors out of 11 factors employed for analysis. Some of the contending issues such as lack of funds, use of outdated maps and absence of integrated Water Resources planning were discussed.

We also saw that using the prevalent growth rates, demand was calculated as 159,317,931 litres per day in 2015 as against the supply quantities of 69,801,576 litres per day, making supply to achieve only 44% of demand

(Table 5). Also it was found that if we continue at the present growth rates of supply and demand, only 581,680 persons or 44% of the consumers will have access to portable water supply. The influence of supply factors are made manifest when the regression model produced a base constant of 6.290 which indicates that in the absence of the factors operating, the supply will increase by 6.3 litres. This means that extra attention is needed to remove the isolated factors that give rise to downward slid in supply. Total water supply to the town is short by 50% required by the MDGs for 2015 and to tackle this problem, we advocated the reform of the entire water sector of the town along the Lagos State Water Corporation model and also emphasize the need for integrated water resource planning of the town. It is our hope that when reform is carried out in these identified areas in close association with proper water demand management practices, the water supply of the town is bound to improve to meet the requirements of the MDGs by 2015 and its post SDG target.

The way forward would, therefore, be for the Enugu State Water Corporation to respond to the suggested reforms aimed at improved water supplies and for residence to adopt water wise demand management. The literature on urban water demand and supply are full of studies aimed at assessing the effectiveness of most of the suggested strategies [12,13,14]. Some of the measures required are;

(i) Reorganising the State Water Corporation especially in the management of funds, personnel and materials at their disposal to prepare it for eventual collaboration with private companies.
(ii) Building relations with international donor agencies such as the World Bank, ADB, IMF etc.
(iii) Unbundling the water supply system and decentralizing the water delivery responsibilities in the service area.
(iv) To ensure that the supply side and the demand side of the water management are integrated for better service delivery.
(v) Promotion of Small Scale Water Enterprises and ensuring adequate regulation of their operations. Lessons from some African countries such as Kenya, Tanzania and Uganda that are patronizing this category of supplies are necessary for the improvement of water services in the town.
(vi) Establishing city-led monitoring of the service infrastructure.
(vii) Building an information line for the Water Corporation and relevant agencies to monitor funds needs, releases and utilization.

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