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ANALYSIS OF THE IMPACTS OF RAINFALL VARIABILITY ON PUBLIC WATER SUPPLY IN ILORIN, NIGERIA

IFABIYI, IFATOKUN PAUL AND ASHAOLU, ENIOLA DAMILOLA
Department of Geography and Environmental Management
Faculty of Business and Social Sciences, University of Ilorin, PMB 1515, Ilorin, Nigeria
E-mail: damash007@yahoo.com

Abstract: Several studies have revealed the impacts of rainfall variability on water resources across the world. This paper makes an analysis of the impacts of rainfall variability on public water supply in Ilorin. The data used in this study are mainly rainfall amount for 30 years (1981-2010), which was obtained from NIMET and the quantity of water supplied by Kwara State Water Corporation, which was only available for 11 years (2001-2011). These data were interpreted using both descriptive and analytical methods. The analytical procedures include time series analysis, reduction pattern analysis and Pearson moment correlation. The results of the trend analysis show that rainfall and water supply in Ilorin have been on the increase at the rate of 0.27mm per annum and 0.20 million (m^3) per annum respectively over the period of study. The results of reduction pattern analysis carried out revealed the variability and the percentage changes in rainfall and water supply over time in Ilorin. The result of Pearson moment correlation coefficient revealed that strong negative relationship (-0.6) existed between monthly rainfall and monthly water supply at 0.05 significant level. This shows that as rainfall increases, water production in the treatment plant decreases. This is expected in view of the increasing cost of water treatment in rainy seasons. It was concluded that increase in rainfall poses water treatment challenges. It was therefore recommended that the capacity of treatment plants be increased. This would enable proper management of the abundant surface water and in turn increase water supply in the city.

Keywords: Rainfall variability, public water, supply, trend

INTRODUCTION

Several studies over the years have revealed the spatio-temporal variability in rainfall received in West Africa and Nigeria in particular (Adefolalu; 1986, Hayward and Oguntoyinbo; 1987, Olaniran and Summer; 1989, Olaniran; 1990, Ati et al.; 2002, Niasse; 2005, and Odjugo, 2005). According to Niasse (2005), the West Africa region has experienced a marked decline in rainfall from 15% to 30% depending on the Area. Also, Odjugo (2005) reported that rainfall decreases from 1350 mm to 1276 mm in Nigeria in the period 1941-2002. The studies of Adefolalu (1986) and Olaniran (1990) revealed that the mean monthly rainfall and rain-days were decreasing in Nigeria. The Nigeria Meterological Agency reported that the annual rainfall is expected to decrease over many parts of the country with some parts experiencing increase in rainfall. However, decrease in rainfall can lead to water shortages in lakes, dams, rivers for both hydroelectric generation and irrigation (Muhammad, 2009).This is an indication that rainfall received in West Africa and Nigeria in particular is decreasing over time. This has an implication on water availability and accessibility by households that determine their survival and development.

Cubasch et al., (2001) in IPCC report argued that changes in the total amount of rainfall and in its frequency and intensity directly affect the magnitude and timing of runoff and the intensity of floods and droughts. They stressed that it can have major impacts on water resources, affecting both ground and surface water supply for domestic and industrial uses, irrigation, hydropower generation, navigation, etc. This suggested the implications of decrease or increase in the amount of rainfall received in an area and its importance to every facet of human's live. Water is the lifeblood of the planet, and the state of this resource affects all natural, social and economic systems. Water serves as the fundamental link between the climate system, human society and the environment (UN Water, 2010). The aforementioned were trying to establish the linkages between rainfall, water and human society. As rainfall received varies over time and space so do water availability varied over time and space which determines the variation in sanitation and development of people all over the world. The results of the work of Ishaku and Majid (2010) revealed that water accessibility is dependent on rainfall variability in the Northeastern Nigeria and this affects household's access to water supply.

The World Health Organisation (2004) and UNICEF (2005) reported that 12% of the world's population consumes 80% of the available water; this signifies that about 1.1 billion people are without access to adequate water supplies. The food and Agriculture Organization reported that 48 countries, including Nigeria would face water shortage by 2025. Nigeria estimated population according to the National population commission, has risen from 150 million to 168 million. The implication of this according to FAO is that there will be a further pressure on available water resources in Nigeria (Ifeanyi, 2012b).The minister of water Resources in Nigeria, Sara Ochekpe reported that the current water supply service coverage in the country is 58 percent, which is about 87 million people, this means over 70 million Nigeria lack access to potable water. She further stressed that this has resulted to water borne diseases such as cholera, typhoid, diarrhea, river blindness etc. in many part of the country especially the rural area where only 42 percent have access to potable water supply (Ifeanyi, 2012a).

World Bank (2001) stated that access to water is measured by the number of people who have reasonable means of getting an adequate amount of water that is safe for drinking, washing and other essential household activities expressed as a percentage of the total population. Sule et al., (2010) reported that residential water use in Ilorin varies from 46 litres per capital per day to 115 litres per capital per day. Aderibigbe et al., (2008) claimed that only 62.9% of sampled population in Ilorin had access to pipe borne water (public water) and 65.4% used less than 40 litres of water daily for domestic purposes. They concluded that water is fairly available in Ilorin metropolis but it is inadequate with poor quality in terms of biological component. Adedayo and Ifabiyi (1999) reported that the actual amount of water supplied and amount demanded indicated that Ilorin metropolis had a water deficit of over 1,000,000 litres per capita per day. According to Ifabiyi and Ahmed (2011) water supply in Ilorin is erratic, inefficient, rationed and unreliable.

Public (pipe borne) water supply in Ilorin is mainly provided by the Kwara State Water Corporation which has a statutory responsibility for providing water in good quality and sufficient quantity for industrial and domestic use of the entire citizen. The major source of public water supply available to the Water Corporation is surface water. Since surface water is the source of water available to the Corporation, any increase or decrease in rainfall would affect the quantity of water available for the Corporation to supply to the community. Also, excessive rainfall which might leads to flood can increase the turbidity level of the water thereby affecting its quality. It is important to note that the coverage of public water supply in Ilorin is limited to some area while others lack access to this service, the implication of which is poor sanitation and hence water related diseases in those areas lacking access to public water. This present study therefore seeks to analyse the impacts of rainfall variability on public water supply in Ilorin with the view to ascertain if the problem of water supply in Ilorin is as a result of rainfall variability.

THE STUDY AREA

Ilorin the Kwara state capital is located on latitude 08°32' North and longitude 04°33' east. The landscape ranges in elevation in the western part from 273m to 333m and in the eastern part from 273m to 364m. Sobi hill is the dominant landform, it is an inselberg, and it is the highest point in the city (394 m above sea level.) Ilorin has a tropical wet and dry climate. Wet season is experienced from May to November and dry season from November to March. Days are hot during the dry season from November to January when temperature ranges from 33.0°C to 34.6°C. Between February and April, temperature values are frequently between 34.6°C to 37°C. Mean monthly temperature is high in the city in dry season. Rainfall condition in Ilorin exhibits greater variability both temporarily and spatial. The annual mean rainfall is about 1,200mm, exhibiting the double maximal pattern between April and October of every year. Relative humidity varies seasonally with an average of 79.7%.

The city is underlain by Precambrian Basement complex; comprising mostly gneiss, granite, schist, undifferentiated meta-sediments rocks and overburden that are composed mainly of clay, sand and silt soils. The underlying pre-Cambrian igneous-metamorphic rock of basement complex is neither porous nor permeable except in places where they are deeply weathered or have zones of weakness. Some part of the town is also laid by Sedimentary rocks, which contains both primary and secondary laterites and alluvial deposits.

Groundwater on the alluvium is recharged directly by rainfall or the adjoining overflowing river system. In the dry season, the alluvium sustains considerable subsurface groundwater flow. The alluvial deposits have been exploited, with successful wells and boreholes in Ilorin metropolis and its surrounding. The drainage system of Ilorin is dendritic in nature, and is dominated by Asa River, which flows from south to north and divides the city into two parts, the western and eastern parts. The western part represents the indigenous area. The eastern part coincides with the modern layout. Major rivers draining the city are: Asa, Agba, Alalubosa, Okun, Osere, Aluko.

Ilorin is one of the fastest growing urban centers in Nigeria. There has been a huge increase in the population of Ilorin since it became the state capital in 1976. The population growth rate is much higher than other cities at 2.5 percent of the national growth. The 2006 census put the population of Ilorin city to about 847,582 (NPC, 2006 provisional results). Water supply system of Ilorin is based on surface water drawn from Agba, Asa and Moro Rivers. These three rivers have dams constructed across them. They also have treatment plants to supply water to the metropolis and its environment. The dams have total reservoir capacity of about 46 million m^3/day with total treatment plant full capacity operation of about 82,276 m^3/day (Ayanshola and Sule, 2006).

The first water supply scheme completed in 1952 was the Agba dam project even before the corporation was created with an output of 3,100 cubic meters per day (685,000 gallons). The output was raised to 1.2 million gallons per day in 1974. According to Kwara Water (2010) the water need at that time was about 7.2 million gallons which meant a deficit of 6.0 million gallons. This prompted the construction of Asa dam on river Asa which is a three phase project and currently has an output of 25.5 million gallon per day (Kwara Water, 2010). See Fig. 1 for the map of Nigeria showing Kwara State and Ilorin incest.

MATERIALS AND METHODS

The data needed for this study are rainfall data and data on quantity of water supplied. The rainfall data collected from Nigeria meteorological Agency span from 1981-2010 (30 years) and the data on quantity of water supplied was collected from Kwara State Water Corporation which span from 2001-2011(11 years).

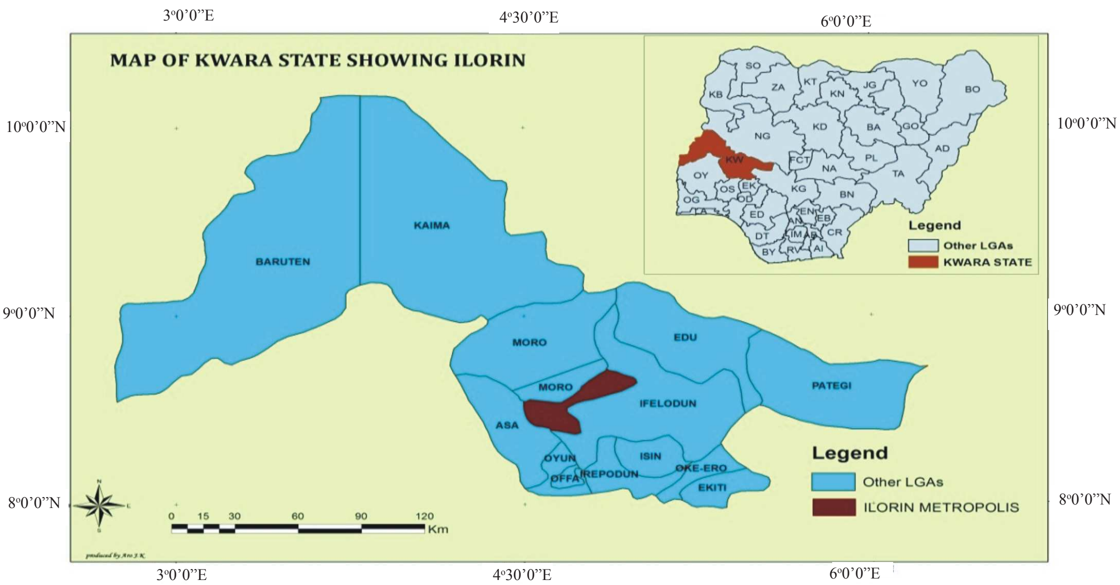

Fig. 1: Map of Nigeria Showing Ilorin

The following statistical measures were used in the study:

1. Mean median, minimum, maximum, standard deviation, skewness and bar graph for data presentation and summary.
2. Time Series analysis was used to determine the trend of rainfall and water quantity supplied. The formula is:

$$Y_t = a + bX_t \quad \text{(i)}$$

Where Y = the trend value

a———— intercept = $\frac{y - b\sum x}{n}$ …… (ii)

b————slope of the trend line =

$$\frac{n\sum xy - (\sum x)(\sum y)}{n\sum x^2 - (\sum x)^2} \quad \text{(iii)}$$

X_t———— Time point coded

3. Reduction analysis was also carried out to determine the fluctuation of rainfall and water supplied as well as the percentage change in rainfall received and quantity of water supplied over the period of study. Reduction analysis was used by Salami et al. (2010) and Makanjuola et al. (2010) to determine the fluctuation and percentage change in hydro-climatic variables.

The average annual variable (X_m) for the years of record is obtained as in the equation below:

$$X_m = \frac{\sum_i^n X}{n} \quad \text{(iv)}$$

Where X=the average annual value for each year
n=number of years of record
The deviation, (X-X_m) of each year's record from the average annual variable (X_m) was obtained.
A graph of the deviation (X-X_m) is then plotted against the years.

To get the percentage change in rainfall and water supply in Ilorin, the record years of rainfall and water supply are divided into groups of five years interval. The average annual variable (X_i) for the five years is calculated. The corresponding deviations from the average (X_m) for the groups and the corresponding percentage changes are obtained. The percentage change is obtained from the equation:

$$\frac{X - X_m}{X_m} \times 100\% \quad \text{(v)}$$

4. Pearson Product moment Correlation was used to determine the relationship between mean monthly rainfall and mean monthly water supplied. The method is of the form:

$$r = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sqrt{\sum (x - \bar{x})^2 \sum (y - \bar{y})^2}} \quad \text{(vi)}$$

Where r= product moment coefficient
Y= the mean monthly public water supplied, and;
X= the mean monthly rainfall

RESULTS AND DISCUSSION

Descriptive Pattern of Rainfall and Water Supply Data

The analysis was carried out on the rainfall data and water quantity supplied data to determine; mean, median, standard deviation, minimum, maximum, and skewness of the sets of data. The statistical monthly summary obtained for rainfall and water quantity supplied is presented in Tables 1 and 2 respectively.

Table 1: Monthly Summary of the Statistical Analysis for Rainfall (mm) 1981-2010

Months (mm)	Mean	Median	Std. Dev.	Min.	Max.	Skewness
January	6.19	0.00	15.82	0.00	73.30	3.33
February	6.21	0.01	17.19	0.00	90.70	4.43
March	43.43	39.20	28.61	0.00	109.20	0.56
April	93.34	90.30	50.55	19.60	223.90	1.07
May	163.32	147.85	90.21	42.30	457.80	1.42
June	190.05	184.20	64.67	89.30	370.80	0.85
July	159.12	140.15	76.76	69.20	323.00	0.84
August	159.26	148.85	76.76	16.50	334.60	0.19
September	219.47	238.25	81.56	61.40	400.10	-0.19
October	136.22	140.50	71.54	16.40	250.70	-0.12
November	10.50	2.35	16.09	0.00	55.60	1.72
December	6.97	0.00	27.43	0.00	148.5	5.08

Source: Authors' computation, 2012

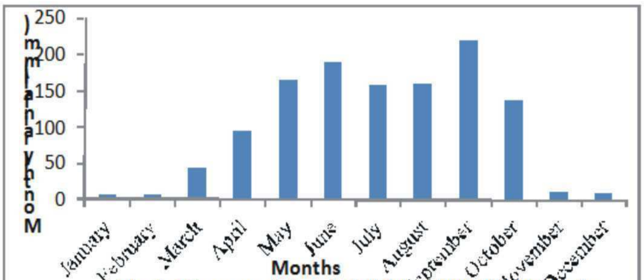

Fig. 2: Mean monthly rainfall from 1981-2010 in Ilorin

Table 1, shows that the maximum monthly rainfall received was 457.80mm and the minimum was 0.00mm over the 30 years period. Figure 2, shows the mean monthly rainfall, it revealed that the months of September and June recorded the highest rainfall over the 30 years period of study. The month of September recorded a mean of 219.47mm and June recorded a mean of 190.05mm, it can be said that rainfall is at its' peak between these months. The months of November to March recorded the lowest amount of rainfall over the period of study which is the period of low flow. Range of value for standard deviation was 15.82-90.21mm.

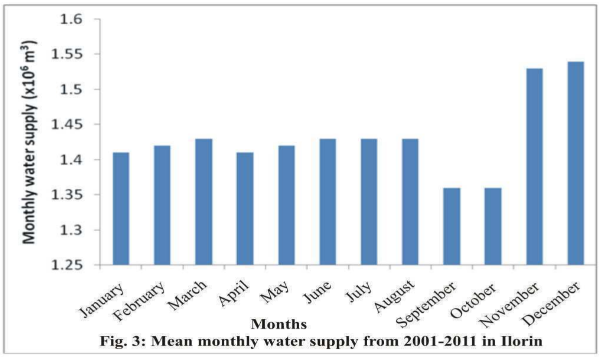

Fig. 3: Mean monthly water supply from 2001-2011 in Ilorin

to other months over the 11 years period of study. The high water production in the months of November and December is due to the high water in storage and lower cost of water treatments in the dry season months of November and December. However the quantity supplied decreases as we enter the months of January through March because the reservoir level also drops in accordance since inflow also drops as there is little or no rainfall to replenish the storage. The monthly mean water supply recorded in November and December are 1.53 million (m^3) and 1.54 million (m^3) respectively. The

Table 2: Monthly Summary of the Statistical Analysis for Water Quantity Supply ($x10^6m^3$) 2001-2011

Months	Mean ($x10^6m^3$)	Median	Std. Dev.	Min.	Max.	Skewness
January	1.41	1.22	0.59	0.95	2.89	1.72
February	1.42	1.40	0.57	0.95	2.83	1.54
March	1.43	1.43	0.59	0.96	2.93	1.68
April	1.41	1.44	0.57	0.94	2.81	1.45
May	1.42	1.42	0.57	0.95	2.80	1.45
June	1.43	1.45	0.59	0.95	2.89	1.55
July	1.43	1.44	0.57	0.96	2.84	1.53
August	1.43	1.45	0.60	0.95	2.93	1.62
September	1.36	1.46	0.41	0.95	2.07	0.27
October	1.36	1.45	0.43	0.94	2.16	0.40
November	1.53	1.46	0.71	0.95	2.84	1.14
December	1.54	1.51	0.73	0.95	2.93	1.16

Source: Authors' computation, 2012

Table 2, shows that the maximum monthly water supply recorded was 2.93 million (m^3) and the minimum was 0.94 million (m^3) for the 11 years period. Table 2 and figure 3, shows that the mean monthly quantity of water supplied for the months of November and December were higher compared month of June to August has uniform quantity of water supply, while September and October recorded the lowest water supply over the period of study. Values of standard deviation for monthly water production ranges between 0.41-0.73m^3.

Time Series Analysis of Rainfall and water supplied in Ilorin

The trend (variation) in rainfall received over Ilorin and trend (variation) in quantity of water supplied were obtained by plotting each variable against year. Time series analysis of rainfall over Ilorin and trend in quantity of water supplied are presented in figures 2 and 3 respectively.

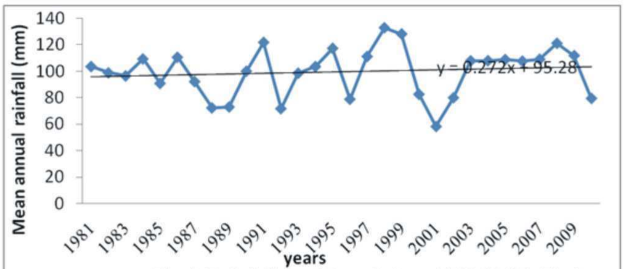

Fig. 4: Rainfall trend (trend) from 1981-2010 in Ilorin

By plotting the rainfall values against year in figure 2, a graph with a positive trend line with gentle slope was obtained, showing that rainfall increased over time although at a very low rate. From the trend line equation, it can be inferred that rainfall increased at the rate of 0.27mm every year over the 30 years period under study.

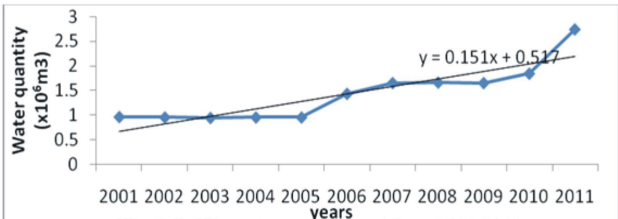

Fig. 5: Public water supply trend from 2001-2011

With the plot of water quantity supplied values against year, a graph with a positive trend line was also obtained, showing that water supply increased with time. From the trend line equation, it can be inferred that water supply increases at 0.20 million (m^3) every year over the period of study.

Reduction analysis

Reduction analysis was carried out in order to study the deviation of the data for five year periods from the overall mean (average) of the whole data. This analysis was done on rainfall and water supply; the results are as shown in Tables 3 and 4 respectively. Also, reduction pattern analysis was done on the complete data for rainfall and water supply to show the fluctuation of the rainfall and water supply with time. The results are presented in Figures 6 and 7.

3.1 Fluctuation of Rainfall and Water Supply over Time in Ilorin

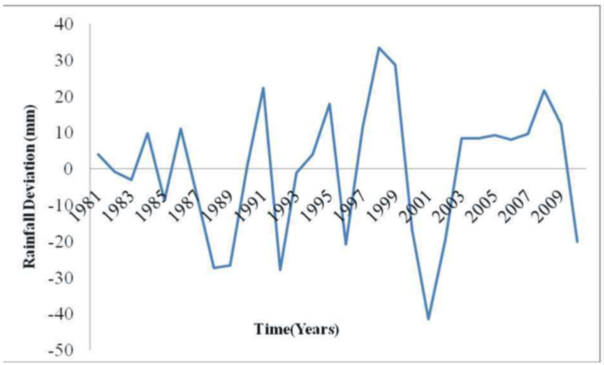

Fig. 6: Fluctuation of rainfall over time

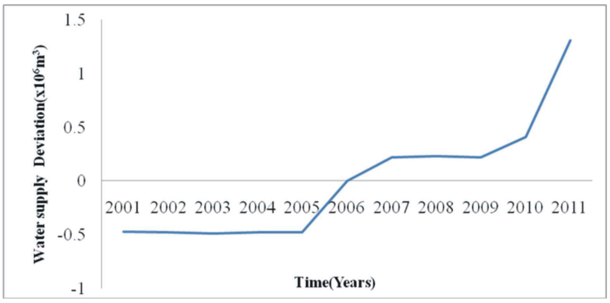

Fig. 7: Water supply fluctuation over time

Percentage Change in Rainfall and Water Supply over Time in Ilorin

The record years of rainfall and water supply are divided into groups of five years intervals. Hence, a decadal analysis will not be possible in view of the 11 years length of water production record that made available by Kwara State Water Corporation (KWWC). This was used to get the percentage change in rainfall and water supply over time in Ilorin.

From the rainfall record of 1981-2010 in Ilorin, the average rainfall was 99.51mm. From 1981-1985rainfall increased slightly to 99.78mm, showing a percentage change of0.27%. From 1986-1990, rainfall reduced to 89.56mm, showing a negative change and a percentage reduction of -9.99%. From 1991-1995, rainfall at Ilorin increased to 102mm, with a percentage difference of 3.08%. Rainfall continues to increase till 2000 with a percentage change of 7.27%. It however shows a negative change again from 2001-2005. From 2006-2010, rainfall rose again to 105.85mm with a positive change of 6.37%. From the results, the year 1986-1990 and 2001-2005 were the period where the percentage changes were negative.

Table 3: Percentage Change in Rainfall over Ilorin from 1981-2010

Period	Average annual for five years (X_i)	Deviation from the average (X_m)	X_i- X_m	% Change
1981-1985	99.78mm	99.51	0.27	0.27
1986-1990	89.56mm	99.51	-9.95	-9.99
1991-1995	102.57mm	99.51	3.06	3.08
1996-2000	106.74mm	99.51	7.23	7.27
2001-2005	92.54mm	99.51	-6.97	-7.00
2006-2010	105.85mm	99.51	6.34	6.37

Source: Authors' Computation, 2013

Table 4: Percentage change in water supply from 2002-2011

Period	Average annual for five years (X_i)	Deviation from the average (X_m)	X_i- X_m	% Change
2002-2006	1.04	1.43	-0.39	-27.27
2007-2011	1.91	1.43	0.48	33.57

Source: Authors' Computation, 2013

From 2001-2011, the annual mean (average) quantity of water supplied in Ilorin was 1.43million (m^3). Quantity of water supply however reduced to 1.04 million (m^3) from 2002-2006 with a percentage change of -27.27%. From 2007-2011, quantity of water supplied increased to 1.91 million (m^3) with a percentage increase of 33.57%. This shows that, public water supply in the Kwara State Water Corporation dam, Ilorin is increasing in the last five years. This is expected in view of the various Government intervention programmes such as expansion in treatment plant, etc.

Relationship Between Monthly Rainfall And Monthly Water Supplied

Pearson Moment Correlation analysis was carried out between mean monthly rainfall and mean monthly water supplied in Ilorin to determine the relationship.

The result of the correlation analysis carried out between monthly rainfall and monthly water supplied shows a negative relationship, r= -0.60 which is significant at 95% confidence level. The implication of this is, during period of high rainfall the quantity of treated water supplied from Kwara State Water Corporation reduces and vice versa. It can be concluded that increase in rainfall increases water turbidity, pathogens and sediment loads which causes treatment challenges for the water provider. This decrease can be as a result of various problems such as:

Table 5: Correlations between rainfall and water supplied

variables		Rainfall	Water supply
Rainfall	Pearson Correlation	1	-.570*
	Sig. (1-tailed)		.027
	N	12	12
Watersupply	Pearson Correlation	-.570*	1
	Sig. (1-tailed)	.027	
	N	12	12

*. Correlation is significant at the 0.05 level (1-tailed).

1. Increase in sediment loads of streams in rainy season, which has made water treatment expensive,

2. Power outages as a result of destruction to power lines by rainstorms,

3. Problem of pipe burst due to erosion exposing water lines, and

4. Availability of alternative sources for people, and hence demands is less.

CONCLUSION

This study has investigated the rainfall variability impacts on public water supply in Ilorin. The trend in rainfall received in Ilorin shows that rainfall is on the increase but exhibited some degree of variability during the period of study. Water supply on the other hand is also increasing but the relationship between monthly rainfall and monthly water supply was negative which suggested that if rainfall is on the increase in a particular month, water supply is on the decrease and vice versa.

It therefore can be concluded that increase in rainfall may increase water turbidity which may pose treatment challenges to the water provider. In view of this, the problem of water supply in Ilorin is beyond that of rainfall variability. Other factors such as water treatment challenges, logistics and proper management of the available water resources etc. can be attributed to the problem of water supply in Ilorin. It is therefore recommended that the number of treatment plants should be increase and micro dams built. This would enable the proper management of the abundant surface water and in turn increase water supply Ilorin.

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