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Abstract

One major socio-economic problem today is coping with increasing demand for water for domestic and other uses. In most cases, people depend on alternative means of supply such as rainwater harvesting, collection from rivers, streams and any available water body, channelling runoff to ponds and other storage facilities and purchase from water vendors. These methods often compromise water quality. This study evaluated the spatial variation of rainwater quality in Benin City using the core of the city (Forestry, Ring-Road), intermediate zone (Upper Mission Road, Airport Road) rural-urban fringe (Ikpoba-Hill, Ogba) and NIFOR (control) in Benin City in the months of March and July, 2016. The objectives of the study are to examine the spatial variation of the physical (Colour, Electrical Conductivity, Salinity, Total Suspended Solids), chemical (pH, Total Dissolved Solid, Chemical Oxygen Demand, Nitrate, Sulphate, Magnesium), biological (Total Coliform Count) and heavy metal (Iron, Copper, Zinc, Manganese) properties of rainwater, examine the seasonal variation of rainwater quality, compare rainwater quality with the World Health Organization (WHO) Quality Standard (2012) for Domestic Water and examine the implications of rainwater quality in the study area. Descriptive Statistics, Analysis of Variance and Student t-test were employed in the analysis of the data collected for this study. The results showed that rainwater quality in study locations was more acidic in the month of July which represents the typical wet or rainy season of the year compared to the month of March.

Index terms— rainwater quality, spatial variation, seasons, benin city, WHO STD.

1 Introduction

he most direct impact of urbanization on ecosystems is altering the hydrologic cycle that controls the ecosystem energy and matter flows (DeFries and Eshleman, 2004). Indeed, water resources in urban environments around the world are increasingly stressed due to population rise, rapid land use change (Foley et al., 2005;Piao et al., 2007), and climatic variability (McCray and Boving, 2007; **??**un et al., 2008). In many parts of the world, water availability has severely limited environmental, social, and economic development (Vorosmarty et al., 2000;Falkenmark et al., 2007; **??**cDonald et al., 2011). Water stress is especially problematic in fast-growing population centres in particular, where water demands are high and water quality is generally low. (Oki and Kanae, 2006).

Air pollution is one of the most visible environmental problems in urbanized areas (Babanyara and Saleh, 2010).Air pollution is defined as the presence of one or more contaminants (pollutants) in outdoor atmosphere and indoor in such quantities that they may tend to be injurious to humans, plant or animal life. Air pollutants are sometimes classified into primary air pollutants(mainly suspended particles, oxides of sulphur and nitrogen, hydrocarbons, carbon monoxide and toxic trace elements, halides, organic phosphates, chlorinated hydrocarbons, uranium and radioactive elements emitted by man) and secondary air pollutants(formed as a result of chemical reactions of primary gaseous pollutants within the atmosphere ??Harrison, 1986). During rainfall, these gases are washed out from the atmosphere by rainwater thereby causing land and surface water pollution (acid rain).

Right from the outset Benin City had always been a region of attraction because of its commercial and administrative roles. For example, the ancient Benin Empire was prominent and regarded as the centre for trade in ivory, pepper and slaves. The kingdom's artisans were noted for wood, ivory carving and bronze casting. These socio-economic roles are still functional (though gradually fading away) in this contemporary era (Nkeki, 2016).Presently, Benin City has experienced a transformation from agro-based socio-economic activities to a growth pole of commercial and administrative functionality, supported by numerous financial establishments, educational, health and other plethora of corporate activities.

These activities especially industrial are expected to impact on its air quality and hence on the rainwater quality. In view of the inadequacies of water supply witnessed in Nigeria and Benin City in particular, it has become absolutely necessary to examine the quality of rainwater. It is important because its T knowledge will help highlight its suitability or otherwise for specific uses. This should be an important aspect of planning for domestic water supply. According to National Bureau of Statistics (2009), at least 27% of Nigerians depend absolutely on streams, pond, river and rainwater for their drinking water source. Research has shown high prevalence of waterborne diseases such as cholera, diarrhoea, dysentery, hepatitis etc. among Nigerians ??Oguntokeet al., 2009;Raji and Ibrahim, 2011). The need for water quality monitoring is paramount to safeguard the public health and also to protect the water resource in Nigeria.

Bangiraet al., ??2007), conducted a study in Harare, Zimbabwe's largest city, to determine the concentration and flux of lead in rainwater, and to identify areas that experience acid rain. The study was carried out during the 2000/2001 to 2003/2004 rainy seasons. Rainwater was collected after each rain event from three meteorological stations located in Harare: Harare Agricultural Research and Extension (Arex), Harare International Airport (Airport) and Belvedere. The results showed that Harare experienced acid rain with Arex having the highest frequency of acidic rainwater than Belvedere and Airport throughout the four seasons. Very high Pb concentration in rainwater was recorded. The seasonal lead concentration in rainwater at all the sites was more than ten times higher than those reported in industrialised areas indicating high levels of pollution. Since Harare is not as industrialised as cities in the developed world, acidity and high levels of Pb in rainwater in Harare were attributed to the long range transport of pollutants and high levels of sulphur-dioxide and Pb emissions from the exhausts of motor vehicles that still use leaded petrol. It was concluded that Harare experienced acid rain and Pb problem.

Eruolaet al., ??2011), investigated the Qualitative Assessment of the Effect of Thunderstorm on Rainwater Harvesting from Rooftop Catchments at Oke-Lantoro Community in Abeokuta, Southwest Nigeria. Results showed strong dilution effects in the variation in harvested rainwater quality with thunderstorm and rainstorms. However, the rainwater harvested under thunder storm had less pollution as compared to water harvested from rain storm. The asbestos roofing sheet water sample gave higher calcium and magnesium content which reflects in the total hardness value. Sample from the aluminum roofing sheet gave the best result but it was also affected by the influence of atmospheric dust particles. Considering the results of the physico-chemical tests, irrespective of storm, the harvested water samples could be put to other domestic uses, as they cannot be consumed directly. Olayiwola and Igbavboa (2014), revealed that Benin City has actually experienced significant expansions at three different periods between 1987 and 2008.It follows therefore that bythe year 2050, if the population of Benin City stands at 5,805,573 as projected, it is expected that the city will be left with only 385,505.9 hectares of its total area. This is likely to have impact on human health. The natural bush cover is being removed without any consideration for replacement, thus there is the tendency for reduction in the amount of carbon-dioxide in circulation. Consequent upon this, there is likely to be a change in the environmental conditions in terms of rainfall and temperature.

Most of the residents in Benin City have resulted to different alternative source of water. in addition, the cost of drilling a water bore-hole to an accepted depth and its maintenance are high, coupled with the inadequacy of surface water and public supply scheme have resulted to use of rainwater harvested and stored for various domestic needs and consumption. It is obvious that from the existing literature that little or no research work has been carried out on the spatial variation of rainwater quality in Benin City.

2 II.

3 Materials and Methods

4 a) Study Area

Benin City is the administrative capital of Edo State. It is found at the southern margin of the state between latitudes 6° 16' to 6° 33' N and longitudes 5° 31' to 5° 45' E (Figure 1). To the west of the city is Ovia-North East Local Government Area, to the South is the fringe of Oredo Local Government Area while to the East is Ikpoba-Okha Local Government Area (Okafor, 1998). Initially, the urbanised part of the region spread over three local government areas (LGAs), these are Oredo, Egor and Ikpoba-Okha. Overall, it territorial coverage is roughly 1,318 km2 with 166 km in perimeter and average elevation of about 78 meters above sea level ??Nkeki, 2013). Due to its rapid urban growth, the metropolitan region has presently spread into two additional contiguous LGAs-Ovia northeast and Uhunmwode.

Benin City has a land mass of 10,956km 2 (Edo World, 2016).The population is heterogeneous owing to rural-urban migration within Edo State as well as migration from other parts of Nigeria as a result of the constant growth in the level of economic opportunities over the last years coupled with other factors such as extended family affinity system (Onokerhoraye, 1995). By 1952, the population of Benin was 53,753 and by 1963, the population almost doubled to a figure of 100,694 with annual growth rate of 5.5 percent. In 1972, it was estimated to have increased to 201,000 (Doxiadis Associates, 1972) and in 1976 a household survey presented an estimate of 314, 219 **??**Sada, 1976). This estimation indicates 8.5 percent growth rate between 1963 and 1976. In 1991 **??**NPC, 1991), the population of the city rose to 801,622. By 2006, the population for the region had risen to 1,085,676 **??**NPC, 2006). The population of Benin City as at 2017 is projected to be 1,456,716 using the national growth rate of 2.7%.This rise in population has initiated a steady increase in the spatial extent of the metropolitan region with its attendant effects on quality of water resources. 2 and Table 1. Two samples were collected in all the selected sites in the city as well as the control. In all four samples were collected per zone. Beavington (1988).The rainwater samples were collected and analyzed for physical, chemical, biological and selected heavy metal content following standard laboratory procedures. We tested for the following: Colour, turbidity, total suspended solids (TSS), total dissolved solids (TDS), chemical oxygen demand (COD), Ammonium-Nitrogen, total coli form count (Macconkey Agar), and determination of heavy metals (Fe, Zn, Cu, Pb, Cr, V& Ni)while the pH and electrical conductivity of rainwater samples were determined in situ electrometrically with a glass electrode (JENWAY 3540) pH/conductivity meter and a conductivity meter (Standard Methods for the Examination of Water and Wastewater, 2004).

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Generated data was tested statistically using Analysis of Variance (ANOVA) and the Student's t-test performed by the use of Statistical Packages for Social Sciences (SPSS 16.0) and results presented.

6 Discussion of Result

In figure 1 (a), the values of salinity of rainwater samples are presented. For the onset of the rainy season (March), the values from the core area of the city were; Forestry (0.061g/l) and Ring-Road (0.025g/l), intermediate-Upper Mission (0.036g/l) and Airport-Road (0.027g/l), rural-urban fringe -Ikpoba-Hill (0.035g/l) and Ogba (0.030g/l) and NIFOR (control site) was 0.015g/l. During the onset of rainy season (March), the values ranged from 0.015 to 0.061g/l with a mean of 0.032g/l. For the peak of the rainy season (July), the values from the core area of the city were; Forestry (0.026g/l) and Ring-Road (0.022g/l), intermediate-Upper Mission (0.034g/l) and Airport Road (0.032), rural-urban fringe -Ikpoba-Hill (0.040g/l) and Ogba (0.028g/l) and NIFOR (control site) was 0.010g/l. The values ranged from 0.010 to 0.040g/l with a mean of 0.27g/l at the peak of rainy season (July). The presence of a high salt content may render water unsuitable for domestic, agricultural or industrial use, or may affect its suitability for shellfish **??**WHO, 2001).

In figure 1 (b), the electrical conductivity (EC)is presented. EC represents the amount of soluble salts (anions and cations) in the rainwater. The following values from the core area of the city were recorded; Forestry (135.1µS/cm) and Ring-Road (55.9µS/cm), intermediate -Upper Mission (80.4µS/cm) and Airport Road (58.8µS/cm), rural-urban fringe -Ikpoba-Hill (77.5µS/cm) and Ogba (66µS/cm) and NIFOR (control site) was 50.1µS/cm. The values ranged from 50.1 to 135.1uS/cm with a mean value of 74.91µS/cm at the onset of the rainy season (March). For the peak of the rainy season (July), the values from the core area of the city were; Forestry (57.2µS/cm) and Ring-Road (48.7µS/cm), intermediate -Upper Mission (50.0µS/cm) and Airport Road (71.1µS/cm), rural-urban fringe -Ikpoba-Hill (88.4µS/cm) and Ogba (62.6µS/cm) and NIFOR (control site) was 40.5µS/cm. The values ranged from 50.1 to 135.1µS/cm with reduced mean value of 57.50µS/cm. This also implies that more soluble salts associated with less dilation effect occurred at the onset of the rainy season (March) compared to the peak of the rainy season (July). Electric Conductivity for Forestry had the highest value (135.1?S/cm) due to urbanization while NIFOR location had the lowest of 50.1?S/cm for the onset of the rainy season (March) as seen in Figure **??**.4. This property is related to the ionic content of the sample which is in turn a function of the dissolved (ionisable) solids concentration. However, it has no direct significance concerning the health of humans **??**WHO, 2002). The EC values were within the WHO (2012) permissible limit.

In figure 1 (c), the Total Suspended Solids (TSS)is presented. The values for Total Suspended Solid (TSS) from the core area of the city were; Forestry (15.9mg/l) and Ring-Road (11.6mg/l), intermediate -Upper Mission (1.8mg/l) and Airport Road (19.4mg/l), rural-urban fringe -Ikpoba-Hill (13.1mg/l) and Ogba (7.2mg/l) and NIFOR (control site) was 1.2mg/l. It ranged from 1.2 to 19.4mg/l with a mean of 10.02mg/l. For the peak of the rainy season (July), the values from the core area of the city were; Forestry (2.8mg/l) and Ring-Road (1.3mg/l), intermediate -Upper Mission (1.4mg/l) and Airport Road (1.7mg/l), rural-urban fringe -Ikpoba-Hill (3.3mg/l) and Ogba (2.5mg/l) and NIFOR (control site) was 0.9mg/l. The values ranged from 0.9 to 3.3mg/l with a mean of 1.55mg/l as presented in Figure **??**.6. It is observed that rainwater samples collected at the onset of rainy season (March) had higher amount of suspended solids than those collected at the peak of rainy season (July) for all locations. This may be attributed to the accumulation of particles from the air during long dry spell (October to February) before the onset of the rain.

In figure 1 (d), the turbidity of the rainwater is presented. During the onset of the rainy season (March), the values from the core area of the city were; Forestry (8.1NTU) and Ring-Road (5.8NTU), intermediate -Upper Mission (ND) and Airport Road (10.6NTU), rural-urban fringe -Ikpoba-Hill (7.4NTU) and Ogba (4.3NTU) and NIFOR (control site) was 4.0NTU. The content of Turbidity during the onset of the rainy season (March) shows that Airport road location had the highest turbidity value (10.6NTU). This can be attributed to the commercial activities in the area. Rainwater samples from NIFOR location yielded the least turbidity (4.0NTU) value. Turbidity for the onset of the rainy season (March) ranged from 4.0 to 10.6NTU with a mean of 5.74NTU while for the peak of the rainy season (July), values were not detected (ND). Mean turbidity value for different locations was above the WHO upper and lower limits of 0.2 and 1.0NTU respectively. Turbidity in water arises from the presence of very finely divided solids (which are not filterable by routine methods). The existence of turbidity in water will affect its acceptability to consumers, utility in certain industries and interfere with the treatability of waters. Turbidity can be caused by sewage matter and there is a risk that pathogenic organisms could be shielded by the turbidity particles and hence escape the action of the disinfectant (USEPA, 2001).

In figure 2 (a), the p His presented. During the onset of the rainy season (March), the values from the core of the city were; Forestry (6.98) and Ring-Road (6.69), intermediate -Upper Mission (6.75) and Airport Road (7.01), rural-urban fringe -Ikpoba-Hill (7.03) and Ogba (6.88) and NIFOR (control site) was 6.01. The values for the peak of the rainy season (July) for the core area of the city were; Forestry (5.80) and Ring-Road (5.72); intermediate-Upper Mission (5.23) and Airport-Road (5.23); rural-urban fringe-Ikpoba-Hill (6.23) and Ogba (5.21) and NIFOR (control site) was 5.03. Ikpoba-Hill location had pH of 7.03 during the onset of rainy season (March) which represents a neutral condition while NIFOR had a pH of 6.01 (slightly acidic). The pH ranged from 6.01 to 7.03 in March indicating slight acidity to neutral condition. This can be attributed to lack of rainfall. In July (the peak of the rainy season), the pH ranged from 5.02 to 6.23 indicating moderate to slight acidic rainwater quality as shown in figure **??**.1 due to dilution by heavy rainfall. Hence, the rainwater was more acidic in the month of July which represents the typical wet or rainy season of the year compared to the month of March which represents peak month of the dry in agreement with the findings by Egwuogu et al., (2016) on rainwater quality assessment in Obio/Akpor Local Government Area of Rivers State, South-South Nigeria and Bangira et al., (2007) findings on the Spatial and Temporal Variation of pH and Lead in Rain Water in Harare City, Zimbabwe. The values were within the WHO (2012) permissible limit (Upper limit-8.0, lower limit-6.5). pH affects mucous membrane, causes bitter taste and corrosion.

The Total Dissolved Solids (TDS) is presented in figure 2 (b). The Total Dissolved Solids (TDS) values of rainwater samples are presented in Figure **??**.7. During the onset of the rainy season (March), the values from the core area of the city were; Forestry (68.2mg/l) and Ring-Road (27.3mg/l), intermediate -Upper Mission (41.4mg/l) and Airport Road (28.9mg/l), rural-urban fringe -Ikpoba-Hill (38.3mg/l) and Ogba (33.7mg/l) and NIFOR (control site) was 1.2mg/l. The values ranged from 20.0 to 68.2mg/l with a mean of 36.8mg/l. For the peak of the rainy season (July), the values from the core area of the city were; Forestry (25.7mg/l) and Ring-Road (21.9mg/l), intermediate -Upper Mission (22.2mg/l) and Airport Road (32.0mg/l), rural-urban fringe -Ikpoba-Hill (39.8mg/l) and Ogba (28.2mg/l) and NIFOR (control site) was 19.5mg/l. peak of the rainy season (July) had values ranging from 19.5 to 39.8mg/l with a mean of 24.04mg/l. TDS is concerned with fishery waters where high deposition of solids can interfere with fish and with spawning grounds. It leads to undesirable taste, gastrointestinal irritation and corrosion or incrustation (Patil, Sawant, and Deshmukh, 2012). The values were within the WHO (2012) permissible limit.

The Chemical Oxygen Demand (COD) is presented in figure 2 (c). At the onset of the rainy season (March), the values from the core area of the city were; Forestry (33.2mg/l) and Ring-Road (2.4mg/l), intermediate -Upper Mission (5.7mg/l) and Airport Road (25.4mg/l), rural-urban fringe -Ikpoba Hill (19.0mg/l) and Ogba (16.9mg/l) and NIFOR (control site) was 4.9mg/l. The values ranged from 4.9 to 33.3mg/l with a mean of 16.78mg/l. For the peak of the rainy season (July), the values from the core area of the city were; Forestry (3.5mg/l) and Ring-Road (3.2mg/l), intermediate -Upper Mission (1.6mg/l) and Airport Road (1.8mg/l), rural-urban fringe -Ikpoba-Hill (1.5mg/l) and Ogba (2.2mg/l) and NIFOR (control site) was 1.0mg/l. The values ranged from 1.0 to 3.5mg/l with a mean of 2.11mg/l. During the onset of the rainy season (March), Forestry location had the highest value (33.2mg/l) followed by Airport road location (25.4mg/l) while NIFOR location had the least value (4.9mg/l). There was a great drop in the Chemical Oxygen Demand values for the peak of the rainy season (July) with Forestry location (3.5mg/l) and NIFOR location (1.0mg/l). COD values for the onset of the rainy season (March) were above the WHO (2012) limit (7.50mg/l) while at the peak of the rainy season (July) was lower.

The Magnesium content in rainwater is presented in figure 2(d). Magnesium ion (Mg2+) concentration in rainwater samples collected from different locations ranged from 0.35 to 3.36mg/l with a mean of 1.01mg/l for the onset of the rainy season (March). The values from the core area of the city were; Forestry (3.36mg/l) and Ring-Road (0.48mg/l), intermediate -Upper Mission (0.62mg/l) and Airport Road (0.67mg/l), rural-urban fringe -Ikpoba-Hill (1.11mg/l) and Ogba (0.52mg/l) and NIFOR (control site) was 0.35mg/l. For the peak of the rainy season (July), the values from the core area of the city were; Forestry (0.42mg/l) and Ring-Road (0.38mg/l), intermediate -Upper Mission (0.45mg/l) and Airport Road (0.56mg/l), rural-urban fringe -Ikpoba-Hill (0.84mg/l) and Ogba (0.48mg/l) and NIFOR (control site) was 0.22mg/l. The values ranged from 0.22 to 0.84mg/l with a mean of 0.47mg/l as shown in Figure ??.9. Forestry location had the highest value (3.36mg/l) during the onset of the rainy season (March) while NIFOR location had the least value (0.35mg/l). Magnesium ion (Mg^{2+}) values for onset and peak of the rainy season (March and July) of rain were below the WHO (2012) limit (30mg/l) for portable water.

The Chloride values of the rainwater is presented in figure 2(e).The concentration of chloride ion (Cl^-) of rainwater samples for the onset of the rainy season (March) from the core area of the city were; Forestry (37.4mg/l) and Ring-Road (17.7mg/l), intermediate -Upper Mission (29.1mg/l) and Airport Road (24.2mg/l), rural-urban fringe -Ikpoba-Hill (28.8mg/l) and Ogba (29.0mg/l) and NIFOR (control site) was 15.5mg/l. The values ranged from 15.5 to 37.40mg/l with a mean of 25.95mg/l. For the peak of the rainy season (July), the values from the core area of the city were; Forestry (20.6mg/l) and Ring-Road (17.7mg/l), intermediate -Upper Mission (19.5mg/l) and Airport Road (24.3mg/l), rural-urban fringe -Ikpoba-Hill (25.8mg/l) and Ogba (21.5mg/l) and NIFOR (control site) was 15.5mg/l. The values which ranged from 15.5 to 25.8mg/l with a mean of 20.70mg/l were lower. The least value (15.5mg/l) for Chloride ion (Cl^-) during the onset of the rainy (March) was recorded in NIFOR location while the highest value (37.4mg/l) was in Forestry location. The values dropped slightly during the peak of the rainy season (July) with Ikpoba-Hill location having the highest value (25.8mg/l) and the least was in NIFOR location (15.5mg/l). All values were below the WHO (200mg/l) limit (WHO, 2012). Sewage contains large amounts of chloride, as do some industrial effluents. If a daily water consumption of 2 litres and an average chloride level in drinking-water of 10 mg/litre are assumed, the average daily intake of chloride from drinking-water would be approximately 20 mg per person (Department of National Health and Welfare, 2000), but a figure of approximately 100 mg/day has also been suggested ??WHO, 2002). Drinking water intake accounts for about 0.33-1.6% of the total intake. Chloride concentrations in excess of about 250 mg/litre can give rise to detectable taste, eye/nose irritation, stomach discomfort and Increase corrosive character of water. Consumers can, however, become accustomed to concentrations in excess of 250 mg/litre (WHO, 2010). The Nitrate values of the rainwater is presented in figure 2(f).During the onset of the rainy season (March), the Nitrate (NO_3^-) concentration of rainwater samples collected from the core area of the city were; Forestry (5.92mg/l) and Ring-Road (2.36mg/l), intermediate -Upper Mission (0.92mg/l) and Airport Road (5.11mg/l), rural-urban fringe -Ikpoba-Hill (3.86mg/l) and Ogba (1.48mg/l) and NIFOR (control site) was 0.55mg/l. The values ranged from 0.55 to 5.95mg/l with a mean of 2.88mg/l. For the peak of the rainy season (July), the values from the core area of the city were; Forestry (0.219mg/l) and Ring-Road (0.192mg/l), intermediate -Upper Mission (0.166mg/l) and Airport Road (0.256mg/l), rural-urban fringe -Ikpoba-Hill (0.373mg/l) and Ogba (0.157mg/l) and NIFOR (control site) was 0.120mg/l. The values ranged from 0.120-0.373mg/l with a mean of 0.21mg/l as shown in Figure 2 (c). Nitrate found in natural waters is of mineral origin, most coming from organic (waste discharges) and inorganic (artificial fertilisers) sources. However, bacterial oxidation and fixing of nitrogen by plants can both produce nitrates. High nitrate levels in water ($>$ 11mg/l) will render them hazardous to infants below the age of six months inducing them with shortness of breath and the "blue baby" syndrome (methaemoglobinaemia) (Patil et al., 2012).Sewage is rich in nitrogenous matter which through bacterial action may ultimately appear in the aquatic environment as nitrate. Nitrate values were within the WHO (2012) permissible limit.

Figure 3 shows the Total Coliform Count (TCC) which gives a general indication of the sanitary condition of a water supply. During the onset of the rainy season (March), the values from the core area of the city were; Forestry (2.6mg/l) and Ring-Road (2.1mg/l), intermediate -Upper Mission (3.4mg/l) and Airport Road (1.6mg/l), rural-urban fringe -Ikpoba-Hill (4.0mg/l) and Ogba (2.7mg/l) and NIFOR (control site) was 1.9mg/l. The TCC during the onset of the rainy season (March) had values ranging from 4.6 to 1.6cfu/ml while at the peak of the rainy season (July), TCC had non-detectable (ND) Coliform count per 100ml as a result of dilution or natural flushing from the rains. This is in line with the WHO (2012) standard which states that Total Coliform bacteria must not be detectable in any 100ml sample of water (0MPN/100ml). Total Coliforms include bacteria that are found in the soil, in water that has been influenced by surface water, and in human or animal waste. The absence of Coliform bacteria in the rainwater samples collected from different locations during the peak of the rainy season (July) is an indication that the harvested rainwater are in good sanitary state.

V.

7 Conclusion

The study examined the spatial variation of rainwater quality in Benin City at the onset (March) and peak (July) period of rainy season. Specific attention was on the physical, chemical and biological properties of the rainwater and how it varies from the core of the city (Forestry, Ring-Road), intermediate zone (Upper Mission Road, Airport Road) rural-urban fringe (Ikpoba-Hill, Ogba) and NIFOR (control) in Benin City. Based on the research findings, we conclude that there is spatial variation in rainwater quality in Benin City because there is a distant decay effect as one move from the core of the city to the periphery. There is seasonal variation of rainwater quality in Benin City because there was a significant reduction in the concentrations of parameters. Values were generally higher at the onset of the rainy season (March) compared to the peak of the rainy season (July).The following suggestions are recommended based on this study; Rainwater during the onset of the rainy season

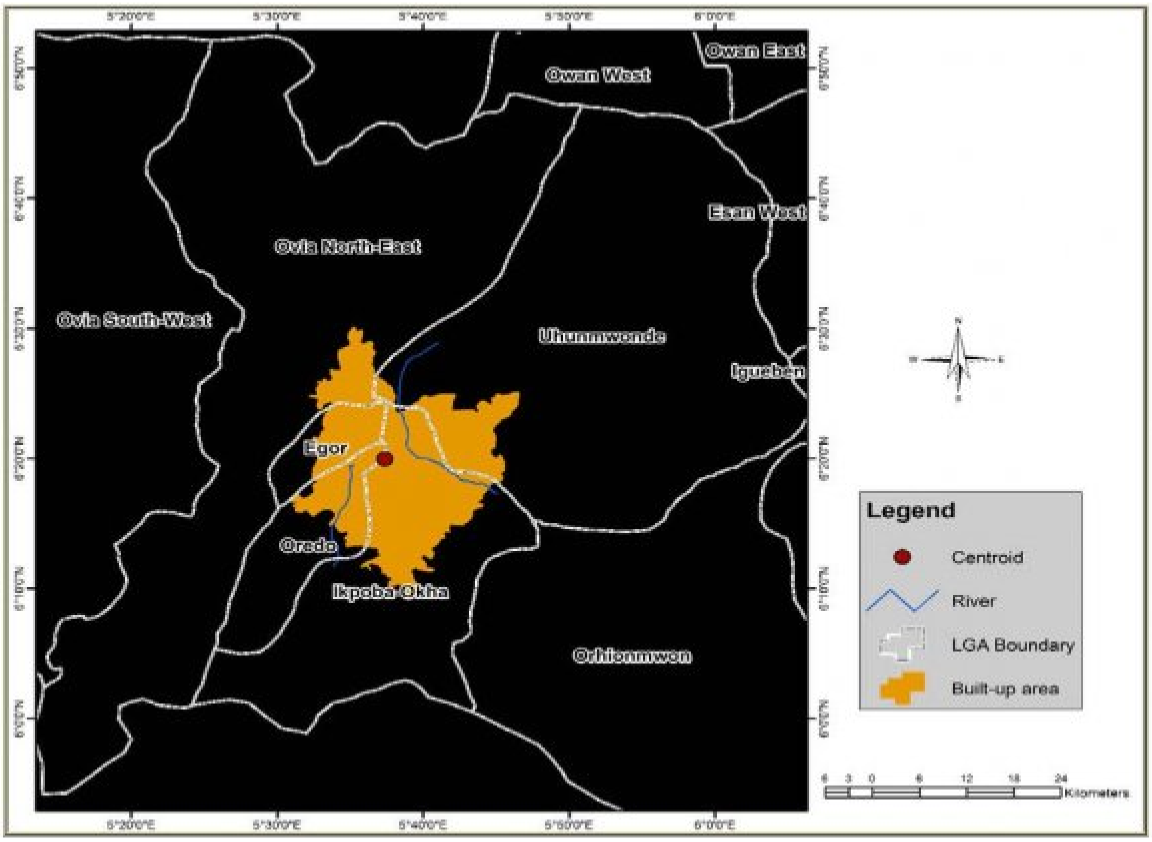
1 

Figure 1: Figure 1 :

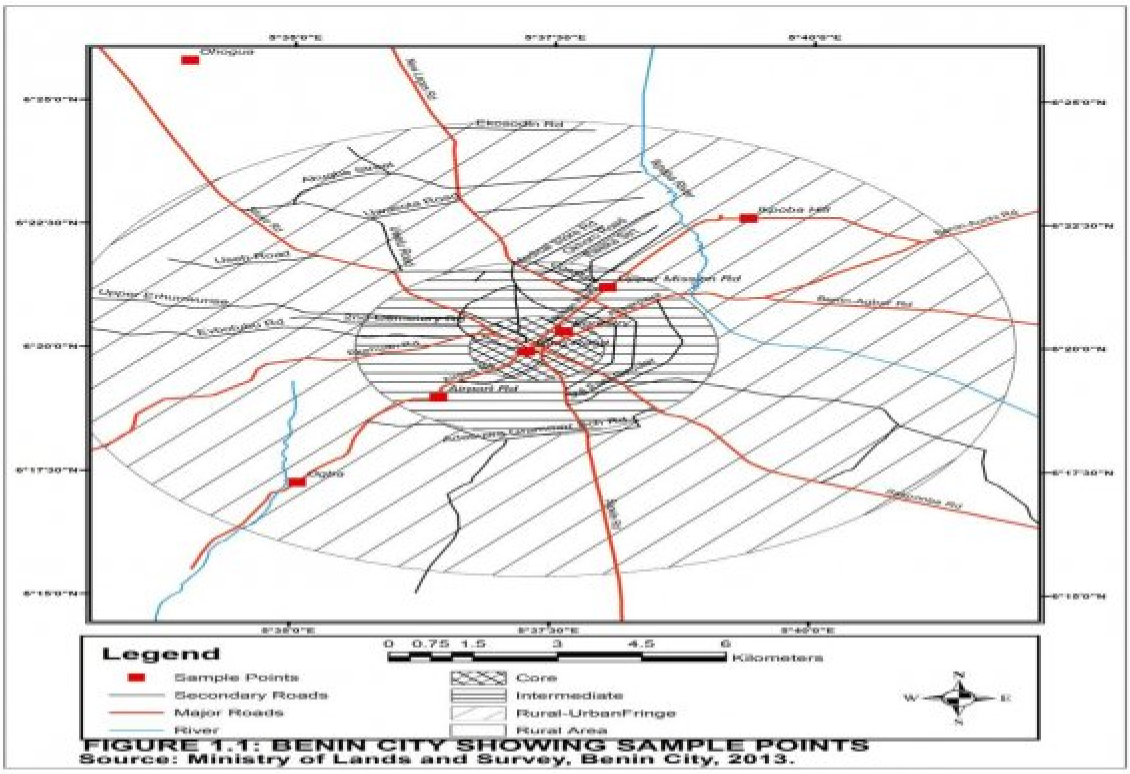
2 

Figure 2: Figure 2 :

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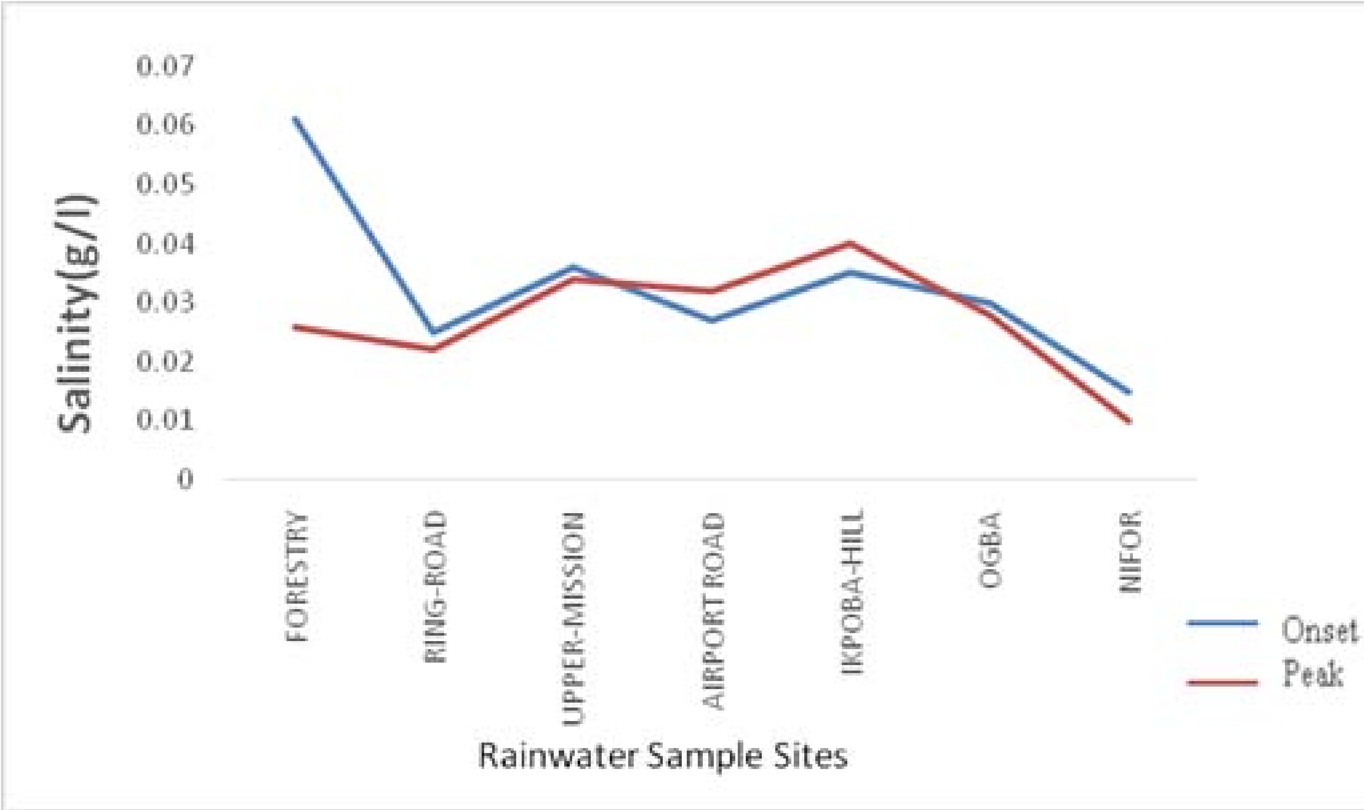

Figure 3: Figure 1 :Figure 2 :

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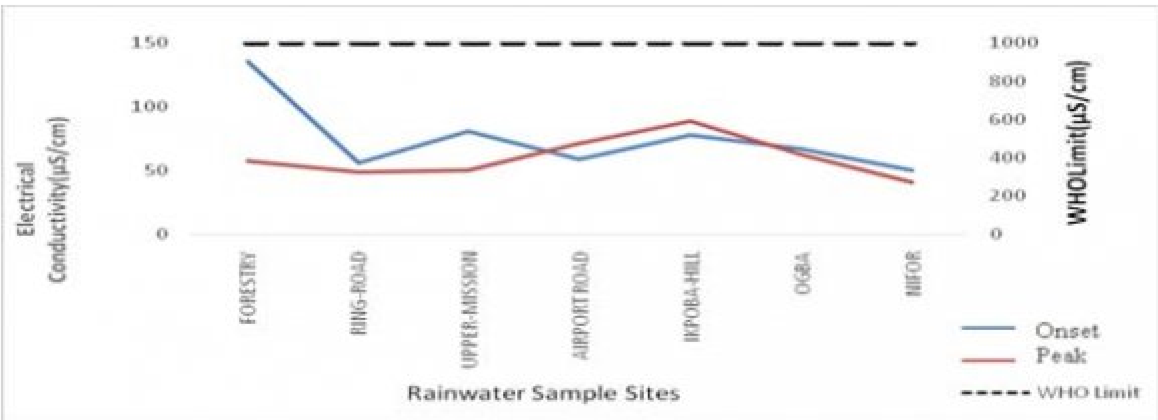

Figure 4: Figure 3 :

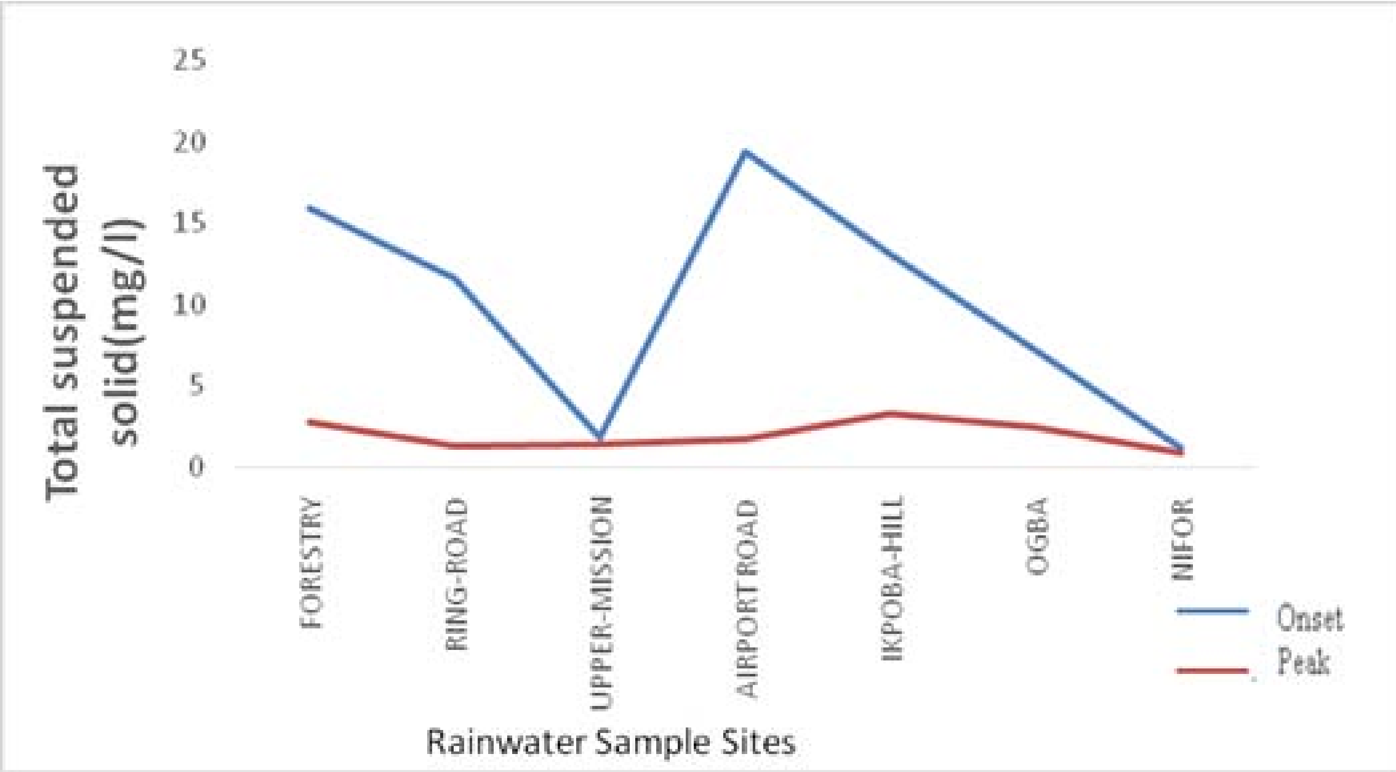

Figure 5:

1

S/N	ZONE	SAMPLING LOCATIONS
1	Core	Forestry and Ring-Road
2	Intermediate	Upper-Mission and Airport Road
3	Rural-Urban Fringe (Periphery)	Ikpoba-Hill and Ogba Road
4	Control Site	NIFOR
	Source: Author's computation from field work (2016)	

c) Laboratory Analysis

Rainwater samples were collected by placing an open container (20.5cm diameter) in an open space free from direct human activities and 1.5m away from ground level (of for, et al., 2014). At the end of each rainfall event, the samples were immediately transferred into clean high density polyethylene (HDPE) bottles and transported to the laboratory following

Figure 6: Table 1 :

(March) should be subjected to treatment before domestic use since analysis shows that it is more impaired.
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[2] Seasonal and Spatial Variation in Physico-Chemical & Biological Quality of Rainwater in Benin City, Edo State

[_04 and Pdf] , _04 , Pdf .

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