Evaluation of Water Quality Index of River Musa for Drinking Purpose in Bida, Nigeria

Abubakar, Y.¹ and Abdulrahman, N.²
¹National Cereals Research Institute Badeggi, Bida, Nigeria
²Department of Agricultural and Bioenvironmental Engineering, Federal Polytechnic, Bida, Nigeria

Abstract
River Musa in Bida, Nigeria is of great importance to the people of the town and its environs. Due to the indiscriminate disposal of domestic and industrial effluents into the river, there is a need to evaluate the river water quality for drinking purpose. The objective of this study was to evaluate some selected physicochemical parameters (Total dissolved solids (TDS), pH, ammonia (NH₄), Sodium, Calcium, Magnesium and four heavy metals (Fe, Pb, Cu and Mn)) of water from River Musa to reveal the detailed water quality of the river for its suitability for drinking purpose. To achieve this objective, the Canadian Council Water Quality index (CCWQI) was applied to the analytical results of the selected parameters to obtain a single value that was used to rank the river at each of the sampling locations. The annual average water quality indexes (for both rainy and dry season) at five locations are (40.9, 42, 40, 39.1 and 37.5). The results showed that the water quality of the entire river is poor (39.9) and the river water is not suitable for drinking purposes.

Keywords: Bida, Drinking water, Quality index, Physiochemical properties, River Musa

Introduction
The economic value of every water decreases due to the presence of pollutants which affects human health and other aquatic forms of life (James, 2008). Water pollution was investigated to be one of the major problems facing many countries of the world (Waruguru et al., 2011). It is caused by direct or indirect disposal of the different pollutants. Nasir et al. (2012) reported that surface water as an important integral part of the environment is the major recipient of the pollutants originating from various sources from manmade and from naturally occurring activities within our environment. The authors reported that the high susceptibility of surface water to pollution was due to its easy accessibility of natural and anthropogenic activities from its surrounding.

Sources of water pollution have been classified into point and non-point sources. According to John (2017), a point source is a single identifiable localized source of water pollution, an example of point source are sewage treatment plants, factory effluents etc while non-point sources are identified as diffuse sources of pollution which cannot be traced back to a particular location due to pollution originating from a wide variety of human activities on the land and natural processes, an example use of fertilizer and pesticide in food production. Research has shown that the majority of the common freshwater sources in Nigeria are polluted, leading to serious outbreak diseases and sudden deaths. Research conducted by Umeh et al. (2004) cited by Aboyeji (2013) showed that 48% of the people in Katsina-Ala local government of Benue State, Nigeria were affected by urinary schistosomiasis,
because of an increase in water pollution index discharging into water bodies. Aboyeji (2013) noted that the causes of water pollution in some Nigeria communities are industrial based water pollution, agricultural water pollution, oil spill based water pollution and domestic water pollution.

Research has also shown that the quality of River Landzun in Bida, which is a tributary to the River Musa was not good for drinking purposes. Research conducted by Mohammed and John (2012) showed that River Landzun water pollution was generated by Bida abattoir effluent. River Musa being an important river for economic, agricultural and environmental significance in the town, there are various pollution activities taking place along the river bank. In view of this, the objective of the study was to evaluate the seasonal variation of some selected physicochemical properties of River Musa and determine its water quality for drinking purposes using the Canadian Council of Ministers of Environment (CCME) water quality Index.

Materials and Methods

Study location
River Musa in Bida town, Niger state is the longest river that flows across the town and its environs. The river water source is from edokota station and empties at Bida Army Barrack Bridge. The river is geographically located between latitudes 9°2'40" and 9°8'0"N and longitudes 5°58'40" and 6°4'0" with a total length of (8.307) km. Bida has annual rainfall ranging from 1000mm to 1200mm with a marked rainy season from April to October. The average annual air temperature is 27°C. It is a major driver of economic, agricultural and environmental significance in the town. The river water is used by the people of Bida and its environs for different activities (irrigation, fishing and household usage).

Sampling and analytical technique
Water samples were taken from five locations (Edokota, Musa mini Bridge, Bida/Minna bridge, Cirriko and Army Barrack bridge) for pH, Magnesium, Calcium, Ammonia, total dissolved solids, Sodium and heavy metals (Iron, Lead, Manganese and Copper). The parameters were used to calculate water quality index. The pH was measured using a pH meter. Total dissolved solids, Ammonia, Calcium, Magnesium and Sodium were determined using standard methods recommended by the American Public Health Association (APHA, 1995). Heavy metals were determined using Atomic Absorption Spectrometer (AAS). The heavy metals of water samples were evaluated by digesting water samples using concentrated nitric acid HNO₃ and concentration of Iron (Fe), Copper (Cu), Lead (Pb) and Manganese (Mn) were measured with S series atomic absorption spectrophotometer.
Method of samples collection

Sample collection was carried out with the use of plastic bottle containers which were washed before use. Bottles were properly rinsed with the river water at location points and were properly labelled. Samples were filtered with Whatman paper to remove particles before the analysis. Samples were collected at five (5) different locations. The detention time of samples was 45 minutes between the sample collection sites and the laboratory.

The five collection points are the main stations where various significant activities take place. These points are:

i. Edokota mini bridge where major domestic and farming activities take place. The distance between this station and Musa station is 0.563 km.
ii. Musa mini bridge where farming activities mostly occur. The distance between this station and Minna/Bida station is 2.940 km.
iii. Minna/Bida mini bridge where farming activities take place. The distance between this station and Ciriko station is 2.597 km.
iv. Ciriko mini bridge where gardening, irrigation farming, abattoir and municipal (waste dump) take place. The distance between this station and Army Barrack station is 2.207 km.
v. Army barrack mini bridge where farming activities occur.

Water quality index evaluation

Water Quality Indices make use of a ‘single value’ for the expression of the overall water quality of a particular source at a certain period of time on the basis of some water quality variables (Yogendra and Puttaiah, 2008). The Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) was used as a statistical technique for the work due to its simplicity and ability to simplify Drinking Water Quality (DWQ) data without compromising the technical integrity of the data (Haseen et al., 2005). The results of these parameters were compared with the World Health Organisation standard (Table 1). The WQI determination using CCME consist of three factors; Scope $F_1$, Frequency $F_2$ and Amplitude $F_3$. These factors were calculated for the five locations as follows.

Scope ($F_1$); This represents those water quality parameters with objectives that were tested during the time for the index calculation.

$$F_1 = \left( \frac{\text{Number of failed variables}}{\text{Total number of variables}} \right) \times 100 \quad (1.1)$$

Frequency ($F_2$); This represents the percentage of individual tests that do not meet the objectives (‘failed tests’):

$$F_2 = \left( \frac{\text{Number of failed tests}}{\text{Total number of tests}} \right) \times 100 \quad (1.2)$$

Amplitude ($F_3$); This is a measure of amplitude. This was calculated in three steps:

Step 1a: Calculation of excursion in which failed tests greater than objective involves the use of the formula below

$$\text{Excursions} = \left( \frac{\text{Failed Test Value}}{\text{Objective}} \right) - 1 \quad (1.3a)$$

Step 1b: Calculation of excursion in which failed tests less than objective was calculated as below

$$\text{Excursions} = \left( \frac{\text{Objective}}{\text{Failed Test Value}} \right) - 1 \quad (1.3b)$$

Step 2: Calculation of Normalized Sum of Excursions (nse)

$$\text{Nse} = \sum_{k=1}^{n} \left( \frac{\text{Excursions}}{\text{Total number of tests}} \right) \quad (1.4)$$
Step 3: Calculation of Amplitude (F3).

\[
F_3 = \left( \frac{nse}{0.01nre+0.01} \right) \tag{1.5}
\]

The CWQI was finally evaluated as:

\[
WQI = 100 - \left( 2 \left( \frac{F_1 + F_2 + F_3}{1.732} \right) \right) \tag{1.6}
\]

Statistical analysis was done using SPSS (21.0 software) package.

**Results and Discussion**

Water Quality Index for the five locations along the river was calculated for rainy and dry seasons in a year (2019) using selected physicochemical parameters listed in Table 3 and 4. The values of the various scopes (F1), frequencies (F2), and amplitudes (F3), with their water quality index are presented in Table 5. During the rainy season, the water quality index values of the river at all stations i.e. Edokota location, Musa bridge station, Bida/Minha station, Cirriko station and Army Barrack station were 43, 46.3, 46.1, 43.9 and 37.7 respectively. The values showed that the water was ranked poor at Edokota, Cirriko and Army barrack stations, but marginal at Musa and Bida/Minha stations. During the dry season, the water quality index values were relatively lower than in the rainy season, however, ranked poor for all the stations. The average annual index values (Table 6) of the River Musa (which range from 37.5 to 42.0) show that the water quality for drinking purposes at the all locations were ranked poor. The poor ranking of the river could be attributed to different types of pollutants entering the river due to various anthropogenic activities at those stations. Pollutants such as domestic sewage, runoff water from agricultural lands and abattoir wastes near the banks of the river may be responsible for the poor water quality of the river. In a similar study conducted on the Asa river in Ilorin Nigeria, it was reported that runoff water from agricultural land and domestic sewage were responsible for the poor water quality of river Asa in Ilorin (Ahaneku and Animanshaun, 2013). The poor water quality rating observed was determined by the analytical results of the physiochemical parameters (Table 3 and Table 4) chosen for WQI calculation. The pH average values of five stations during the rainy season range from 5.00-5.97. These values were below the WHO standard (6.5-8.4).

Similarly, research conducted in Owerri Nigeria Amadi et al. (2010b) reported a mean pH value of 5.02 for Otamiri river. This could be attributed to agricultural runoff from lands within the locations. During the dry season, average values ranged from (5.3-7.57) were observed in the five stations compared to rainy season data. The pH value of the river at the Edokota station has the highest average value of (7.57) and slightly alkaline compared to other stations.

Ahaneku and Animanshaun (2013) reported a(weak) alkaline pH mean value of 8.11 during dry season for river Asa, Ilorin. A higher value of pH obtained from River Musa during dry the season could be attributed to the hardness of water as a result of the concentration of calcium carbonates during dry season which are mostly CaCO3 from rocks, sulphate and nitrite of calcium and magnesium. The variations of pH between Edokota Bridge and other sampling stations during rainy and dry seasons were statistically insignificant at 5% (between upstream and downstream). During the rainy season, the TDS average values ranged from 9.35 to 148.74 mg/l with the highest value recorded at Ciriko station (148.74 mg/l) and are within the WHO standard (0-500 mg/l). In contrary to this study, Animanshaun et al. (2016) reported that during the rainy season, high TDS mean value (290mg/l) for Asa river in Ilorin. The observed value indicates that the river is been compromised by anthropogenic activities during the rainy season. During the dry season, the TDS average values of the river musa at the five stations ranges from 11.10 -104.34 mg/l. Ahaneku and Animanshaun (2013) reported that during the dry season the TDS mean value of 418 mg/l for river Asa. The variations of total dissolved solids between Edokota and other sampling stations during both seasons were statistically significant at a 5% level.

During the rainy season sodium (Na) average values from all locations range from 7.00-23.49 mg/l and all were within the WHO standard (0-200 mg/l)) with the highest value obtained at Edokota station. Amadi et al. (2010b) also reported a mean Na value of 54.3 mg/l for Otamiri
During the dry season, the recorded Na average values for the studied sites ranged from 1.13-15.83 mg/l, with the highest value recorded at Cirriko station. Similarly, in a research conducted in Anambra Nigeria, Chukwuma et al. (2016) reported a mean Na value of 7.72 mg/l in Ele River during the dry season. The high value of Na of River Musa during the rainy season could be attributed to agricultural runoff from farm lands within the locations. The variations of Sodium between Edokota and other sampling stations for both rainy and dry seasons were statistically significant at a 5% level. During the rainy season the average values of Ca at all sampling points ranged from 1.27-6.55 mg/l and are all within the permissible limit recommended by WHO (0-200 mg/l). In contrary to this study (Amadi et al. 2010b) reported that during the rainy season high Ca mean value of (84.2 mg/l) of Otamiri river in Owerri was observed. The hardness of water occurred as a result of the presence of dissolve calcium and magnesium (Amadi et al., 2010b).

During the dry season, the average calcium concentration at all sampling points ranged from 10.95-24.32 mg/l with the highest value recorded at Cirriko station (24.32 mg/l). Chukwuma et al. (2016) also reported a Ca value of 20.52 mg/l from Ele River. The variations of Calcium between Edokota and other sampling stations for both seasons were statistically significant at a 5% level. The average magnesium values at all sampling points during the rainy season range from 1.13-8.23 mg/l and are within the WHO threshold (0-150 mg/l). During the dry season, average magnesium values at all sampling points ranged from 14.92-30.82 mg/l which were within the threshold. Chukwuma et al. (2016) also reported that the mean Mg values of (17.85 mg/l) of Ele River was observed. During the dry season average values of Mg were higher than the rainy season values because of the high level of concentration of water hardness. The variations of magnesium between Edokota and other sampling stations for both seasons were statistically insignificant at a 5% level.

During the rainy season, the average values of manganese at all sampling points ranged from 0.25-0.68 mg/l. The Mn average values of the River Musa at the five stations were above the permissible limit recommended by WHO (0-0.1). During the dry season, the average Manganese values at all sampling points ranged from 0.34-0.45 mg/l. Contrarily Cosmas et al. (2015) also reported the annual average value of (0.08 mg/l) of Mn of Bunza ground water in Kebbi, Nigeria. In a similar study (Amadi et al., 2010b) also reported an annual average value of (0.35 mg/l) of Mn for the Otamiri river in Owerri. The high values of manganese at all stations for both rainy and dry seasons could be attributed to the disposing of industrial waste into the river from mechanic villages near the stations. The variations of Mn within Edokota and other sampling stations were statistically insignificant at a 5% level for the two seasons. During the rainy season the average iron values at all sampling points ranged between 0.534-0.99 mg/l with the highest value recorded at Army barracks station (0.99) which was above the WHO standard (0-0.3 mg/l).

During the dry season, the iron average values of the River Musa at the five stations were above the permissible limit. The values ranged between 0.34-0.46 mg/l. The variations of Iron within Edokota and other sampling stations during the rainy season were statistically significant at a 5% level. During the dry season, the variations of iron within Edokota and other sampling stations were statistically insignificant at a 5% level. During the rainy season, the average values of lead at all sampling points ranged between 0.15-0.38 mg/l and all are above the permissible limit recommended by WHO (0-0.01mg/l). During the dry season, the average Pb concentration at all sampling points range between 0.42-0.51 mg/l. The high level of the lead during the both seasons at all stations could be attributed to disposing of industrial waste into the river from mechanic villages near the stations and as well as dissolved lead metal products in the river. The variations of lead between Edokota and other sampling stations during both seasons were statistically insignificant at a 5% level.

Ahaneku and Animanshaun (2013) reported that the concentration of the heavy metals of river Asa, Ilorin (lead and iron) exceed the permissible level recommended by WHO for drinking purpose at the two seasons (0.09 and 1.40 for the rainy
season, 0.11 and 1.90 mg/l for dry season respectively). During the rainy season the average values of ammonia at all sampling points ranged between 0.96-1.21 mg/l and all were above the permissible limit recommended by WHO (0-0.2 mg/l). contrarily, Ahaneku and Animanshaun (2013) reported low ammonia mean value (0.09 mg/l) forAsa river in Ilorin during rainy season. During the dry season, the average ammonia concentration at all sampling points ranged between4.40-6.97 mg/l with the highest value recorded at Army barracak station (6.97 mg/l). Ahaneku and Animanshaun (2013) also reported during the dry season low ammonia mean value (0.2 mg/l) for Asa river in Ilorin. The higher concentration of ammonia during both seasons could be attributed to the discharge of domestic and abattoir wastes into the river along the river banks. The variations of ammonia within Edokota and other sampling stations for both seasons were statistically insignificant at a 5% level. During the rainy season the average values of Cu at all sampling points ranged between0.30-0.58 mg/l and all were within the permissible limit recommended by WHO (0-1.0 mg/l). During the dry season, the average Cu concentration at all sampling points ranged between 0.33-0.78 mg/l. In a similar study, Animanshaun et al. (2016) reported during rainy and dry seasons low mean values of Cu (0.7 and 0.8 mg/l) were observed for Asa river in Ilorin. The variations of Cu between Edokota and other sampling stations during the rainy season was statistically insignificant at a 5% level and during the dry season the variation of Cu within all sampled points was statistically significant at all points.

**Conclusion**

The concentrations of selected physicochemical properties of River Musa were assessed and the annual river water quality index was determined using the CCME water quality Index. The result of the study showed that the river is not recommended for drinking purposes. More so, the study revealed that the application of Water Quality Index is a useful statistical technique in assessing the quality of river for drinking purposes in the study area. Periodic monitoring of the river and evaluation of water parameters should be adopted.

**References**

Aboyeji, O. O. (2013). Freshwater Pollution in Some Nigerian Local Communities, Causes, Consequences and Probable Solutions. *Academic Journal of Interdisciplinary Studies, 2*(13):111–117.

Ahaneku, I. E. and Animanshaun, I. M. (2013). Determination of Water Quality Index of River Asa, Ilorin Nigeria. *Advances in Applied Research, 4*(6): 277-284.

Amadi, A. N., Olaschinde, P. I. and Yisa, J. (2010a). Assessment of Water Quality Index of Otamiri and Oramiriukwa Rivers. *Physics international, 1*(2):116-123.

Amadi, A. N., Olaschinde, P. I. and Yisa, J. (2010b). Characterization of Groundwater chemistry in the Coastal Plain-sand Aquifer of Owerri using Factor Analysis. *International Journal Physical Sciences, 5*(8): 1306-1314.

Animanshaun, I. M., Busari, M. B. and Mohammed, T. B. (2016). Receptor Modelling Application on Surface Water Quality and Source Apportionment. *International Journal of Science Research in Agricultural Sciences, 3*(1):1-10.

APHA (1995). *Standard Methods for the Examination of Water and Waste Water* 19th edn. American Public Health Association (APHA), Washington DC.

CCME (2005). Canadian Water Quality Index 1.0. User’s Manual. Canadian Water Quality Guideline for the Protection of Aquatic Life. Available at [http://www.ccme.ca/asset/pdf/wqi-user_manual_fctsht-e.pdf](http://www.ccme.ca/asset/pdf/wqi-user_manual_fctsht-e.pdf)

Cosmas, E., Hassan, A. M. and Israel O. (2015). Physio-Chemical and Heavy Metals Analysis of Some Ground Water in Bunza, North Western Nigeria. *American Journal of Applied Chemistry, 3*(4):153-157

Chukwuma, E. C., Chukwuma, G. C., Uba, I. J., Orakwe, C. L. and Ogbu, N. K. (2016). Irrigation Water Quality Index Assessment of Ele River in Parts of Anambra State Of Nigeria. *Archives of*
Current Research International, 4(3): 1-6.

Haseen, K., Amir, A. K., and Sarah, H. (2005). The Canadian Water Quality Index: A Tool for Water Resources Management; MTERM International Conference, AIT, Thailand.

James, P. N. (2008). Water Quality for Ecosystem and Human Health. 2nd Edition. United Nations Environmental Programme Monitoring System. GEMS.

John, M. D. (2006). Application and Tests of the Canadian Water Quality Index for Assessing Changes in Water Quality in Lakes and Rivers of Central North America. Lake and Reservoir Management, 22(4): 308-320, DOI: 10.1080/07438140609354365.

John, O. A. (2017). Suitability of Athi River Water For Irrigation Within Athi River Town and its Environs in Kenya. M. Sc. Thesis Environmental Management. University of Eastern Kenya. Available at: http://repository.seku.ac.ke/handle/123456789/3550

Mohammed, S. and John, J. M. (2012). Impact of Abattoir Effluent on River Landzuun, Bida, Nigeria. Journal of Chemical Sciences, 2(1.21):132-136.

Maina, M. M. and Yunusa, A. (2020). Assessment of Water Quality and Identification of Pollutants Flowing into River Musa Using Principal Component Analysis. IOP Conference Series: Earth and Environmental Science, 445: 012 - 014. DOI: 10.1088/1755-1315/445/1/012014

Nasir, M. F., Abdul, Z. M., Juahir, H., Hussain, H., Zain, S. M. and Ramli, N. (2012). Application of Receptor Models on Water Quality Data in Source Apportionment in Kuantan River Basin. Iranian Journal of Environmental Health Science and Engineering, 9(18): 1–12

Umeh, J. C., Amali, O. and Umeh, E. U. (2004). The Socio-Economic Effects of Tropical Diseases in Nigeria. Journal of Economics and Human Biology, 2:245-263.

Waruguru, A. K., Kotut, K. and Gitonga, N. M. (2011). Impact of Waste Water Discharge on the Bacteriological Quality and Physico-Chemical Properties of Thome River, Nairobi. Available at: http://ir-library.ku.ac.ke/handle/123456789/1665.

WHO (2019). World Health Organisation. Water Drinking Standard. Available at www.fao.org/3/x562AE/5624e05.htm

Yogendra, K. and Puttaiah, E. T. (2008). Determination of Water Quality Index and Suitability of Urban Water Body in Shimoga Town, Karnataka. The 12th World Lake Conference, Pp:342-346.

| Parameters       | WHO set of established Standard |
|------------------|---------------------------------|
| Ph               | 6.5-8.5                          |
| Lead             | 0.01                            |
| Manganese        | 0.1                             |
| Sodium           | 200                             |
| Copper           | 1.0                             |
| Iron             | 0.3                             |
| Ammonia          | 0.2                             |
| Magnesium        | 150                             |
| Total Dissolve solid | 500                           |
| Calcium          | 200                             |

Source: WHO water drinking standard (2019)
Table 2: Canadian water quality index ranking, values and description

| Ranking    | CWQI Values | Description of the Ranks                                                                 |
|------------|-------------|----------------------------------------------------------------------------------------|
| Excellent  | 95-100      | Water quality satisfies with all criteria for drinking purpose                           |
| Good       | 80-94.4     | Water quality rarely disagree with all criteria for drinking purpose                   |
| Fair       | 65-79.9     | Water quality sometimes disagree with all criteria for drinking purpose                |
| Marginal   | 45-64.9     | Water quality often violates with all criteria for drinking purpose                    |
| Poor       | 0-44        | Water quality does not satisfy any criteria for drinking purpose                       |

Source: CCME (2005)

Table 3: Descriptive statistics of water quality parameters of the river during rainy season

| LOCATION          | Ca (mg/l) | Mg (mg/l) | Na (mg/l) | N\textsubscript{NH}_3 (mg/l) | Fe (mg/l) | Mn (mg/l) | Cu (mg/L) | pH  | Pb (mg/L) | TDS (Mg/l) |
|-------------------|-----------|-----------|-----------|--------------------------------|-----------|-----------|-----------|-----|-----------|-------------|
| EDOKOTA Mean      | 1.38      | 2.47      | 23.49     | 0.98                          | 0.54      | 0.26      | 0.30      | 5.97| 0.23      | 16.92       |
| Minimum           | 0.64      | 2.30      | 22.90     | 0.88                          | 0.48      | 0.04      | 0.20      | 4.90| 0.15      | 13.32       |
| Max               | 2.08      | 2.70      | 23.86     | 1.11                          | 0.59      | 0.47      | 0.35      | 8.00| 0.40      | 19.98       |
| SD                | 0.72      | 0.21      | 0.51      | 0.12                          | 0.08      | 0.30      | 0.09      | 1.76| 0.14      | 3.36        |
| MUSA BRIDGE Mean  | 6.55      | 1.13      | 20.95     | 1.15                          | 0.59      | 0.41      | 0.32      | 5.63| 0.15      | 9.35        |
| Minimum           | 1.76      | 0.30      | 18.76     | 0.90                          | 0.59      | 0.33      | 0.05      | 5.10| 0.15      | 6.66        |
| Max               | 16.03     | 1.70      | 23.30     | 1.65                          | 0.59      | 0.49      | 0.45      | 6.60| 0.16      | 13.32       |
| SD                | 8.21      | 0.74      | 2.27      | 0.43                          | 0.01      | 0.12      | 0.23      | 0.84| 0.00      | 3.51        |
| BIDA/MINNA Mean   | 1.27      | 3.43      | 20.20     | 1.21                          | 0.65      | 0.48      | 0.43      | 5.50| 0.15      | 12.99       |
| Minimum           | 0.96      | 2.50      | 17.80     | 0.95                          | 0.59      | 0.47      | 0.40      | 5.00| 0.15      | 6.66        |
| Max               | 1.64      | 4.40      | 24.10     | 1.69                          | 0.70      | 0.49      | 0.45      | 6.60| 0.16      | 18.98       |
| SD                | 0.35      | 0.95      | 3.41      | 0.42                          | 0.08      | 0.02      | 0.03      | 0.87| 0.00      | 6.17        |
| CIRIKO Mean       | 1.92      | 8.23      | 18.77     | 1.06                          | 0.70      | 0.69      | 0.58      | 5.07| 0.15      | 148.74      |
| Minimum           | 1.68      | 6.90      | 9.90      | 1.00                          | 0.70      | 0.471     | 0.50      | 4.80| 0.15      | 113.22      |
| Max               | 2.31      | 10.20     | 22.90     | 1.16                          | 0.70      | 0.90      | 0.75      | 5.50| 0.15      | 179.82      |
| SD                | 0.33      | 1.74      | 6.98      | 0.09                          | 0.00      | 0.30      | 0.14      | 0.38| 0.00      | 33.52       |
| ARMY BARRACK Mean | 1.72      | 4.23      | 7.00      | 0.96                          | 0.99      | 0.45      | 0.41      | 5.00| 0.38      | 42.18       |
| Minimum           | 0.80      | 2.90      | 2.20      | 0.91                          | 0.59      | 0.43      | 0.35      | 4.70| 0.15      | 13.32       |
| Max               | 2.20      | 6.20      | 9.90      | 1.04                          | 1.40      | 0.47      | 0.44      | 5.20| 0.50      | 59.94       |
| SD                | 0.80      | 1.74      | 4.19      | 0.07                          | 0.57      | 0.03      | 0.05      | 0.26| 0.20      | 25.21       |

Note: TDS = Total Dissolved Solids
Table 4. Descriptive statistics of water quality parameters of the river during dry season

| Location      | pH  | TDS (mg/L) | NH4 (mg/l) | Ca (mg/L) | Mg (mg/L) | Na (mg/L) | CU (mg/l) | Pb (mg/l) | Mn (mg/l) | Fe (mg/l) |
|---------------|-----|------------|------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Edokota       |     |            |            |           |           |           |           |           |           |           |
| Mean          | 7.57| 11.10      | 4.43       | 10.95     | 24.16     | 1.45      | 0.33      | 0.44      | 0.34      | 0.42      |
| Minimum       | 6.1 | 6.66       | 4.17       | 8.02      | 8.76      | 0.96      | 0.11      | 0.35      | 0.26      | 0.33      |
| Max           | 8.8 | 13.32      | 4.89       | 13.22     | 34.29     | 2.00      | 0.61      | 0.49      | 0.39      | 0.52      |
| SD            | 1.37| 3.85       | 0.41       | 2.66      | 13.56     | 0.52      | 0.26      | 0.07      | 0.06      | 0.09      |
| Musa          |     |            |            |           |           |           |           |           |           |           |
| Mean          | 6.9 | 11.1       | 4.41       | 14.16     | 14.92     | 1.12      | 0.63      | 0.42      | 0.37      | 0.35      |
| Minimum       | 5.5 | 6.66       | 4.32       | 6.41      | 7.05      | 0.79      | 0.33      | 0.28      | 0.28      | 0.28      |
| Max           | 8   | 19.98      | 4.51       | 26.05     | 28.69     | 1.3       | 1.11      | 0.55      | 0.46      | 0.42      |
| SD            | 1.28| 7.69       | 0.09       | 10.45     | 11.97     | 0.29      | 0.42      | 0.13      | 0.08      | 0.07      |
| Minna         |     |            |            |           |           |           |           |           |           |           |
| Mean          | 5.6 | 17.69      | 4.40       | 14.16     | 20.11     | 2.09      | 0.78      | 0.46      | 0.41      | 0.42      |
| Minimum       | 5.5 | 13.32      | 4.16       | 5.61      | 4.86      | 1.29      | 0.28      | 0.35      | 0.30      | 0.33      |
| Max           | 5.7 | 19.98      | 4.71       | 20.84     | 37.45     | 3.5       | 1.17      | 0.55      | 0.50      | 0.52      |
| SD            | 0.1 | 3.79       | 0.28       | 7.79      | 16.39     | 1.23      | 0.46      | 0.10      | 0.09      | 0.09      |
| Ciriko        |     |            |            |           |           |           |           |           |           |           |
| Mean          | 5.53| 104.34     | 5.76       | 24.32     | 17.92     | 15.83     | 0.76      | 0.51      | 0.45      | 0.46      |
| Minimum       | 5.5 | 86.58      | 5.34       | 23.25     | 16.54     | 11.2      | 0.5       | 0.35      | 0.33      | 0.32      |
| Max           | 5.6 | 119.88     | 6.59       | 25.65     | 19.94     | 21.90     | 1.00      | 0.62      | 0.56      | 0.52      |
| SD            | 0.06| 16.76      | 0.71       | 1.23      | 1.79      | 5.49      | 0.25      | 0.14      | 0.12      | 0.11      |
| Army Barrack  |     |            |            |           |           |           |           |           |           |           |
| Mean          | 6.63| 46.62      | 6.97       | 15.09     | 30.08     | 6.50      | 0.65      | 0.49      | 0.45      | 0.44      |
| Minimum       | 5.6 | 39.96      | 5.37       | 6.41      | 11.19     | 6.20      | 0.27      | 0.35      | 0.37      | 0.33      |
| Max           | 8.3 | 53.28      | 8.05       | 21.24     | 47.67     | 6.90      | 0.83      | 0.62      | 0.54      | 0.57      |
| SD            | 1.46| 6.66       | 1.42       | 7.73      | 18.28     | 0.36      | 0.32      | 0.13      | 0.09      | 0.12      |
| WHO Standard  | 6.5-| 0-500      | 0-0.2      | 0-200     | 0-150     | 0-200     | 0-1.0     | 0-0.1     | 0-0.1     | 0-0.3     |

Table 5. Quality index for wet and dry season

| Station      | Scope (F₁) | Frequency (F₂) | Amplitude (F₃) | Water Quality Index (WQI) | Scope (F₁) | Frequency (F₂) | Amplitude (F₃) | Water Quality Index (WQI) |
|--------------|------------|----------------|---------------|--------------------------|------------|----------------|---------------|--------------------------|
| Edokota      | 50         | 40             | 74.1          | 43.4                     | 50         | 42.5           | 84.1          | 38.4                     |
| Musa         | 50         | 40             | 67.3          | 46.3                     | 60         | 37.5           | 81.0          | 37.8                     |
| Bida/Minna   | 50         | 40             | 67.8          | 46.1                     | 60         | 47.5           | 85.0          | 33.9                     |
| Ciriko       | 50         | 42.5           | 71.5          | 43.9                     | 50         | 47.5           | 90.0          | 34.3                     |
| Army Barrack | 50         | 45             | 84.3          | 37.7                     | 50         | 40             | 87.4          | 37.4                     |
### Table 6: Average annual WQI and the ranking

| Station          | Average Annual WQI | Ranking |
|------------------|--------------------|---------|
| Edokota          | 40.9               | Poor    |
| Musa             | 42                 | Poor    |
| Bida/Minna       | 40                 | Poor    |
| Cirriko          | 39.1               | Poor    |
| Army Barrack     | 37.5               | Poor    |

### Table 7: Rainy season ANOVA between parameters and locations

| Parameter      | Sum of Squares Between Groups | df | Mean Square | F     | Sig.  |
|----------------|-------------------------------|----|-------------|-------|-------|
| pH             | 1.953                         | 4  | 0.488       | 0.512 | 0.729 |
| Cu             | 0.133                         | 4  | 0.033       | 1.697 | 0.227 |
| TDS mg/L       | 41547.111                    | 4  | 10386.778   | 28.518| 0.000 |
| Ca mg/l        | 60.176                       | 4  | 15.044      | 1.092 | 0.412 |
| Mg mg/L        | 86.447                       | 4  | 21.612      | 14.338| 0.000 |
| Na mg/L        | 493.904                      | 4  | 123.476     | 7.413 | 0.005 |
| Pb mg/L        | 0.064                        | 4  | 0.016       | 1.358 | 0.315 |
| Fe mg/L        | 0.662                        | 4  | 0.166       | 3.639 | 0.044 |
| Mn mg/L        | 0.307                        | 4  | 0.077       | 2.903 | 0.078 |
| N-NH₃Mg/l      | 0.134                        | 4  | 0.034       | 0.431 | 0.784 |
Table 8: Dry season ANOVA between parameters and locations

| Parameter | Sum of Squares | Df | Mean Square | F    | Sig. |
|-----------|----------------|----|-------------|------|------|
| pH        |                |    |             |      |      |
|           | Between Groups | 9.137 | 4 | 2.284 | 2.029 | 0.166 |
|           | Within Groups  | 11.260 | 10 | 1.126 |      |      |
|           | Total          | 20.397 | 14 |       |      |      |
| Cu        |                |    |             |      |      |
|           | Between Groups | .120 | 4 | 0.030 | 11.396 | 0.001 |
|           | Within Groups  | .026 | 10 | 0.003 |      |      |
|           | Total          | .146 | 14 |       |      |      |
| TDSmg/L   |                |    |             |      |      |
|           | Between Groups | 19004.205 | 4 | 4751.051 | 57.442 | 0.000 |
|           | Within Groups  | 827.110 | 10 | 82.711 |      |      |
|           | Total          | 19831.315 | 14 |       |      |      |
| Ca mg/l   |                |    |             |      |      |
|           | Between Groups | 305.498 | 4 | 76.374 | 1.602 | 0.248 |
|           | Within Groups  | 476.655 | 10 | 47.666 |      |      |
|           | Total          | 782.153 | 14 |       |      |      |
| Mg mg/L   |                |    |             |      |      |
|           | Between Groups | 416.181 | 4 | 104.045 | 0.557 | 0.699 |
|           | Within Groups  | 1866.531 | 10 | 186.653 |      |      |
|           | Total          | 2282.711 | 14 |       |      |      |
| Na mg/L   |                |    |             |      |      |
|           | Between Groups | 464.799 | 4 | 116.200 | 18.067 | 0.000 |
|           | Within Groups  | 64.317 | 10 | 6.432 |      |      |
|           | Total          | 529.115 | 14 |       |      |      |
| Pb mg/L   |                |    |             |      |      |
|           | Between Groups | 0.616 | 4 | 0.154 | 1.551 | 0.261 |
|           | Within Groups  | 0.994 | 10 | 0.099 |      |      |
|           | Total          | 1.610 | 14 |       |      |      |
| Fe mg/L   |                |    |             |      |      |
|           | Between Groups | 0.022 | 4 | 0.006 | 0.554 | 0.701 |
|           | Within Groups  | 0.099 | 10 | 0.010 |      |      |
|           | Total          | 0.122 | 14 |       |      |      |
| Mn mg/L   |                |    |             |      |      |
|           | Between Groups | 0.026 | 4 | 0.006 | 0.751 | 0.580 |
|           | Within Groups  | 0.085 | 10 | 0.009 |      |      |
|           | Total          | 0.111 | 14 |       |      |      |
| N-NH\(^3\) Mg/l | Between Groups | 2.739 | 4 | 0.685 | 0.365 | 0.828 |
|           | Within Groups  | 18.766 | 10 | 1.877 |      |      |
|           | Total          | 21.505 | 14 |       |      |      |