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SEASONAL VARIATION IN WATER QUALITY PARAMETERS OF RIVER MKOMON KWANDE LOCAL GOVERNMENT AREA, NIGERIA

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Abstract: **The indiscriminate dumping and release of wastes containing hazardous substances into Rivers might lead to environmental disturbance which could be considered as a potential source of stress to biotic community. River Mkomon which is one of the tributaries of River Benue serve as an excellent disposal agent by some of the communities at the river bank and farmers. The objective of the study was to investigate the seasonal variation in physico-chemical and bacteriological characteristics of River Mkomon water at four different sampling stations of the River. Analyses of river water quality containing 16 parameters were done during dry and rainy seasons in the year 2015. Results revealed deterioration in water quality with seasonal changes between the sites. The data have been compared with the norms for River water of World Health Organization (WHO), National Environmental Standards and Regulations Enforcement Agency (NESREA) and standard organization of Nigeria (SON). The results obtained revealed enhanced level of water temperature (28.8±0.08)^{o}C, turbidity (8.5±0.15) NTU, cadmium (0.087±0.00) mg/L, lead (0.299±0.00) mg/L, chromium (0.521±0.00) mg/L, total coliform (159.1±24.9) CFU and decrease or normal levels in phosphate (3.7±0.05) mg/L, chloride (55.2±1.35) mg/L, electrical conductivity (56.2±0.49) µS/cm, biological oxygen demand (3.3±0.08)mg/L, suspended solid(48.9±0.31) mg/L, pH(6.5±0.07), dissolved oxygen(4.0±0.09) mg/L, total dissolved solids(47.7±0.15) mg/L and total hardness (83.2±1.13) mg/L. Moreover, increase of pollution load during rainy season indicated the increase in organic matter in River water during the season due to increase in anthropogenic interferences of the surrounding areas.**

Keywords: **Anthropogenic, Mkomon, Seasonal, Variation, parameters, Water.**

1. INTRODUCTION

The increasing vulnerability of natural resources and the environment to pollution is one of the great challenges to humanity in recent times. Water, which is essential to all forms of life and makes about 50–97 percent of the weight of all plants and animals, is the most poorly managed resource in the world(Fakayode, 2005). About 20 percent of the world's population lack access to safe drinking water (UNEP, 2000). The quality of surface water which depends on the equilibrium between the physical, chemical, and biological characteristics of the surrounding environment is constantly changing in response to daily, seasonal, and climatic rhythms**.** The proportion of available but polluted water is continuously increasing as a result of changes in the modes of industrial activities, agricultural production, and increasing urbanization (Pestle, 2000). Although statistics vary, the World Health Organization, (WHO, 2006) reported that approximately 36 percent of urban and 65 percent of rural Nigerian's were without access to safe drinking water. Normally, water is often used for domestic purposes especially for drinking, and is the source of all biological lives and their sustenance too. For different purposes, water has its own requirements for the composition and purity and each body

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of water has to be analyzed on a regular basis to confirm the suitability. Drinking contaminated water can cause diarrhea, cholera, dysentery, and various other diseases like typhoid, amoebiasis, jaundice, *enterobacteriaceae*, etc. (Mishra, 2010). Many infectious diseases are transmitted by water through the feacal-oral route.

In Nigeria, many researchers constantly undertake work on assessment of physiochemical and microbiological quality of water bodies (Eneji, 2010; Fakayode, 2005) however, in Mkomon District in Kwande Local Government Area of Benue State; physico-chemical and bacteriological examination of water for drinking purposes has not been carried out. The probability of ingesting infective dose of disease causing microorganism is very high considering the fact that water borne pathogens generally have low infective dose. The bacterial growth is also regulated by physico-chemical quality of water.

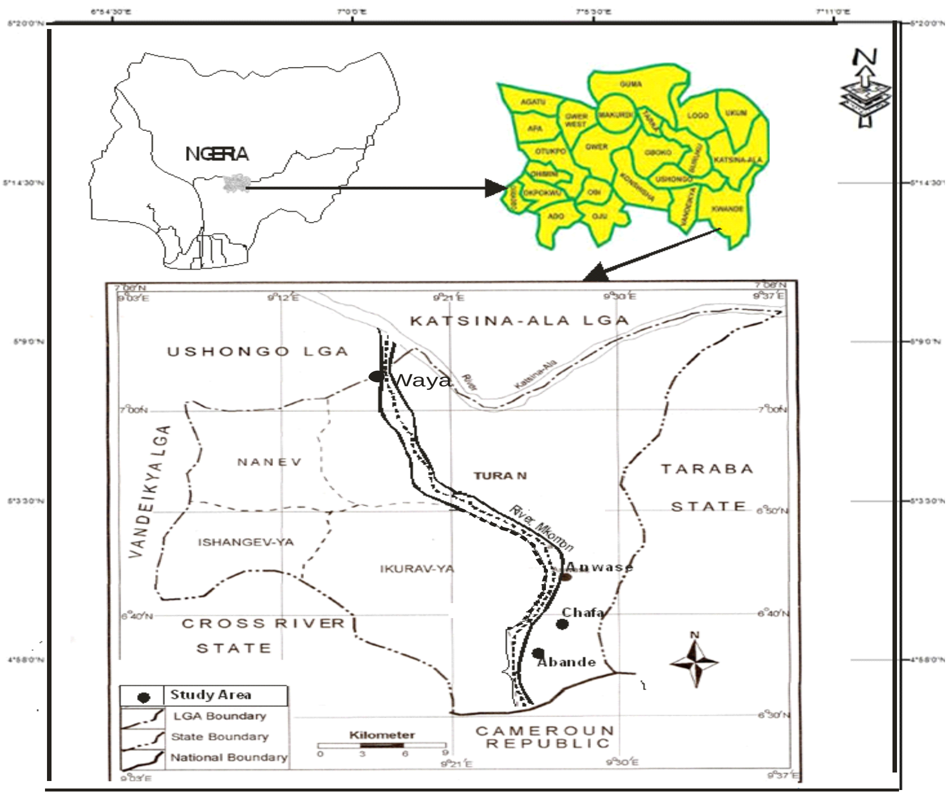
2. METHODS

River Mkomon:

River Mkomon, which rises from the highlands in the East of Mkomon district (Cameroun Mountains), is one of the largest upper tributaries of the river Benue. Some of the communities along the river are; Waya, Kendev, Anwase , Chafa, Abande and Ityuav (where water fall is located.) Activities carried out on the river include fishing (using nets, hook and line and chemicals), washing of cloths as well bathing and Tourist activities (swimming and photographing etc). Activities carried out on the river bank include farming (throughout the year), cattle grazing and burnt bricks laying, rice milling and groundnut processing (small scale industries). The river is a source of drinking water for all the communities situated along the river bank.

Sampling Stations:

Four sampling stations were established from which the water samples were collected from the River. The names of those communities are Abande, Chafa, Anwase and Waya (**Figure 1).** Selection of these stations was based on the intensive farming activities and the small scale processing of rice and groundnuts going on in the area with a lot of herbicides being used as alternative to weeding as well the colour of the water.



SOURCE: Ministry of land and Survey, Makurdi Benue State.

Figure 1: Map of Kwande Local Government, Showing the Four Sampling Stations

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Collection of Water Samples:

At each sampling station, three water samples were collected along a North-South transect across the river in the four sample sites (Abande, Chafa, Anwase and Waya).

Water samples were collected in two different seasons: January, 2015 for dry season and October, 2015 for rainy season, during morning hours, between 8.30 a.m. to 11.30 a.m. A total number of eighteen water samples were collected, the samples were taken five centimeter below the water surface (to minimize the contamination of the water sample by surface films) five times with 500 mL white glass bottles and transferred into 2 litres brown borosilicate bottle. All the samples were collected with 2 L polyethylene cans which were leached with a 1:1 HCl and rinsed with distilled-de-ionized water. At the point of collection, the cans were rinsed with the water samples before collection. The water samples meant for metal analysis were treated with 3 mL of concentrated $HN0_3$ for 1 litre of water to bring the pH to 2-3 and stored (Ademoroti, 1996).

The pH metre was standardized with two standard buffer solutions of different pH values 4 and 9, the calibrated pH metre was used to measure the pH of the water by inserting the probe in the water sample and allow it to stabilized before the pH is taken to the nearest one decimal place unit with HANNA pH metre (model Hi 9610).

Digestion of Water Samples:

The water samples were digested by acidifying with 1mL conc.$HN0_3$ per 100 mL sample and autocleaved at 121 ^oC to solubilized particulate matter content. This was later made up to mark with distilled water in a 25 mL standard flask and later transferred into an acid-leached polyethylene bottle prior to analysis (okoye *et al*., 2010).

General Water Quality Parameters Determination:

Table 1: List of Physicochemical Parameters and their test methods

S/N	PARAMETER	UNIT	METHOD
1	pH		pH meter
2	Dissolve Oxygen	mg/L	Winkler method
3	Biochemical Oxygen Demand	mg/L	5 days incubation at 20^{o}C and titration of initial and final DO
4	Chemical oxygen demand	mg/L	Open Reflux method
5	Alkalinity	mg/L	Titration
6	Total dissolve solid	mg/L	Digital conductivity meter
7	Chloride	mg/L	Argentometric titration
8	Sulphate	mg/L	Gravimetric method
9	Turbidity	NTU	Nephelometric method
10	Ammonia-Nitrogen (NH_3-N)	mg/L	Spectrophotometric
11	Total hardness as $CaCO_3$	mg/L	EDTA Titration
12	Conductivity	µS/cm	Conductivity meter
13	Temperature	^{o}C	Thermometric method
14	Heavy metals	mg/L	Spectrophotometry
15	Phosphate	mg/L	Stannous chloride method

Source: Patel and Parikh (2013).

Water pH:

The pH, TDS and Temperature were determined by a portable digital pH, TDS Meter and thermometer, respectively, at the collection site immediately after sampling, since the biological and chemical reactions between the atmosphere and the sample could readily alter the pH.

Temperature (T):

The surface temperature of the river was determined by inserting the thermometer probe in the water samples below the water surface for about 5 minutes until it stabilized. The temperature was recorded in degree Celsius.

Electrical conductivity (EC):

This was done using a multipurpose HANNA digital model conductivity/TDS metre to determine the conductivity of the water samples on the field. About 250 mL water samples were taken using 500 mL white glass bottle, the electrical conductivity was recorded immediately by dipping the probe of the conductivity metre inside the water samples for about two minutes. The values obtained were expressed in micro-siemens per centimeter (µs/cm).

Total dissolved solids (TDS):

This was done using a multipurpose HANNA digital portable model conductivity metre /TDS to determine the TDS of water samples on the field. About 250 mL water samples were taken using 500 mL white glass and the TDS was recorded immediately by dipping the probe inside the water samples for about two minutes. The values obtained were expressed in milligram per litre (mg/L).

Dissolved oxygen (DO):

About 100 mL of five percent (5%) sodium sulphite solution was stired constantly with electric stirrer for about five minutes and the DO probe was dipped into it and the metre was set to zero mark; after the setting, the probe was dipped into 100 mL water sample, and the DO was recorded in mg/L using DO 150, model 50150.

Biochemical oxygen demand (BOD):

Diluted water was prepared by aerating the BOD free distilled water adequetly.In 1mL each of 0.01 M phosphate buffer solution, 0.02 M $MgSO_4$ solution, 0.03 M calcium chloride solution, and 0.03 M iron chloride solution was added. The pH of the sample was adjusted to 7.0. Two sets of BOD bottles were filled with the water sample, the dissolved oxygen content (DO) in one set was determined immediately and the remaining set of BOD bottles were incubated at 20 ^oC for five days in a BOD incubator. The bottles were taken out after five days to determine immediately their dissolved oxygen content (DO_5) Ademoroti (1996).

Calculation:

$$BOD_5 = \frac{(DO - DO_5)}{P} ------------- (1)$$

Where: D_0=dissolved oxygen (DO) of the diluted solution after preparation (mg/L)

$D0_5$ = dissolved oxygen of the diluted solution after five days incubation (mg/L)

P =decimal dilution factor = 1/f

f = dilution factor.

Total hardness ($Ca^{2+,}$ Mg^{2+})

Twenty milliliters (20 mL) of the water sample was diluted to about 50 mL with distilled water in an Erlenmeyer flask and one milliliter (1 mL) of ammonia buffer solution and about 5 drops of Erichrome Black-T indicator was added. The diluted water sample was titrated with 0.01 M ethylenediamine tetra acetic acid (EDTA) to wine red colour.

Calculation:

$$Total\ Hardness\ (mg/L) = \frac{T \times 1000}{V} --------------- (2)$$

Where T = Volume of EDTA used (mL)

V = Volume of sample (ML)

Chloride:

Ten milliliters (10 mL) of the water sample was taken into an Erlenmeyer flask. 5 to 6 drops of 1.0 mL potassium chromate indicator was added. The color of the sample became yellow and the sample was titrated against 0.03 M silver nitrate solution until the colour changed to brick red. Chloride was calculated as:

$$Chloride\ (mg/L) = \frac{V \times N \times 35.4 \times 1000}{S} ----------------(3)$$

where V= mL $AgNO_3$ used for titrating sample, N = Molarity of $AgNO_3$

S = Volume of water sample (mL)

Inorganic phosphate:

Twenty five milliliters (25 mL) of the sample was taken in a flask and 1 mL of 0.01 M ammonia molybdate solution was added. The flask was stoppered and vigorously shaken, then 3 drops of freshly prepared 0.01 M stannous chloride ($SnCl_2$) solution, was also added. After 10 minutes, the water samples were run on a spectrophotometer at a wavelength of 690 nm. All the measurements for water quality parameters were carried out in triplicate.

Bacteriological Analysis:

Microbial analysis was performed in terms of most probable number (MPN**)**

Most probable number analysis is a statistical method based on the random dispersion of microorganisms per volume in a given water sample.

Most probable number (MPN) was performed sequentially in three stages: presumptive, confirmed and completed test.

Presumptive coliform test:

MacConkey purple media of single and double strength were prepared in a test tube (lactose- 5.0 g, peptone- 5.0 g, beef extract- 3.0 g and one litre of distilled water) with Durham's tube and autoclaved for 15 minutes at 121 ^oC. Three sets of test tubes containing five tubes in each was used to prepared macConkey media of single and double strength. One set with 10 mL of double strength and the remaining two sets with 10 mL of single strength. 10 mL of the water sample was transferred to each of the double strength broth tubes using sterile pipettes. 1 mL of the water sample was also transferred to each of the 5 tubes of one set of single strength broth and 0.1mL of the water sample was as well transferred to the five tubes of the remaining last set of single strength broth tubes.

The tubes were incubated at 37 ^oC for 24 hours. After incubation, the tubes were observed for the production of gas in Durham's tubes and colour change (yellow) of the media.

The number of positive results from each set was recorded and compared with standard chart to give presumptive coliform count per 100 mL water samples.

Confirmed coliform test:

Here, all the positive presumptive test results were inoculated in a selective media; Eosine methylene blue (EMB) agar and was incubated at 37 ^oC. The presence of typical colonies at 37 ^oC confirmed positive coliform test. This test determined MPN.

$$MPN = \frac{Number\ of\ coliforms\ per\ colony\ count \times 1000}{volume\ of\ sample\ used} --------------(4)$$

Completed test:

At this stage,the colony in a tube of lactose broth with Durham's tube was inoculated . The broth cultures were then incubated at 37 oC with the Nutrient agar at same temperature. The production of gas and acid was examined in the Lactose broth.

Statistical Analysis:

Data collected were analyzed using One-way analysis of variance (ANOVA) and t-test. ANOVA was used to measure the variance between quality of water between sampling sites, and between seasons while t-test was used to test the formulated hypothesis. Descriptive statistics were also presented using charts and comparing the mean values with WHO,

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SON, and NESREA Drinking Water Guidelines. All analyses were performed on Statistical Package for Social Sciences (SPSS) 17.0

3. RESULTS

The mean and standard deviation values of all variables investigated in the three sampling stations for dry season and four sampling stations for rainy seasons were presented in Tables 4-6 and comparative charts from Figures 2-7.

Table 2: Means for Selected Physicochemical and Bacteriological Parameters of Water from Mkomon River for Dry Season at three Sampling Stations (January, 2015)

Variables	A (Mean±S.D)	B (Mean±S.D)	C (Mean±S.D)
Water temperature (^oC)	29.1±0.08	27.9±0.08	29.4±0.08
Turbidity (NTU)	3.9±0.12	4.2±0.01	4.3±0.03
pH	5.7±0.03	5.6±0.09	5.9±0.08
Conductivity (Ms/cm)	39.3±0.8	34.0±0.82	31.3±0.81
TDS (mg/L)	18.8±0.09	16.7±0.82	17.0±0.82
Suspended Solid (mg/L)	30.7±0.8	33.0±0.82	37.7±0.82
Total Hardness (mg/L)	66.7±0.8	46.7±0.82	113.6±12.53
Chloride (mg/L)	43.5±0.3	47.3±0.04	44.9±1.10
Dissolved Oxygen (mg/L)	3.0±0.07	2.9±0.07	2.8±0.07
BOD(mg/L)	2.7±0.07	2.7±0.08	2.4±0.11
Phosphate (mg/L)	2.9±0.08	2.7±0.02	2.7±0.04
Total coliform(CFU)	161±23.1	154.4±33.13	154.4±28.43
Zinc (mg/L)	ND	ND	ND
Cadmium (mg/L)	0.029±0.0	0.029±0.0	0.029±0.0
Lead (mg/L)	0.33±0.0	0.30±0.0	0.27±0.0
Chromium (mg/L)	0.047±0.0	0.073±0.0	0.049±0.0

ND= Not detected, S.D=standard deviation, A=Abande, B=Chafa, C=Anwase

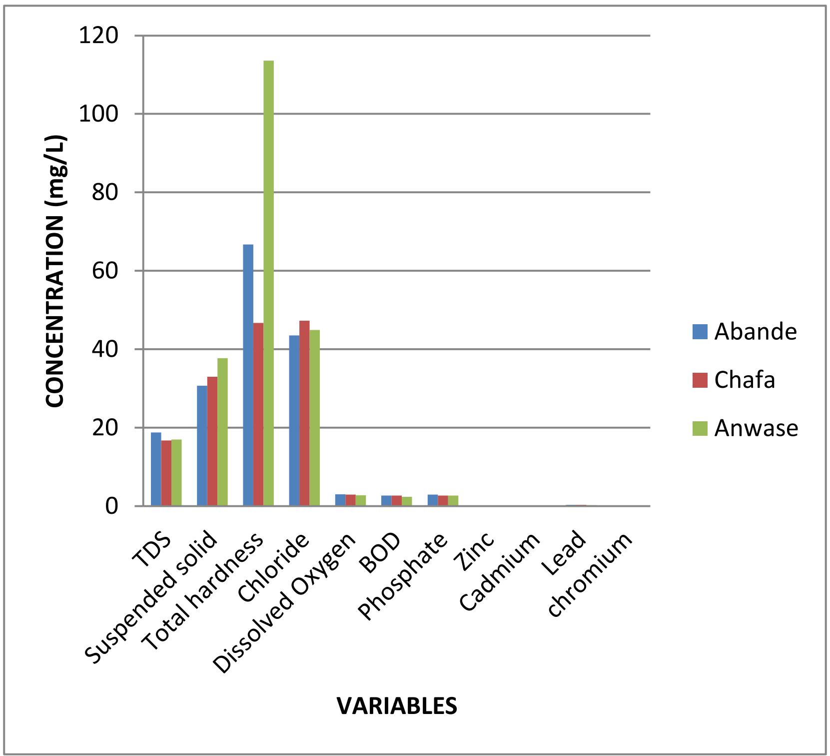

Figure 2: Comparation of some Water Parameters in River Mkomon During Dry Season at Abande,Chafa and Anwase

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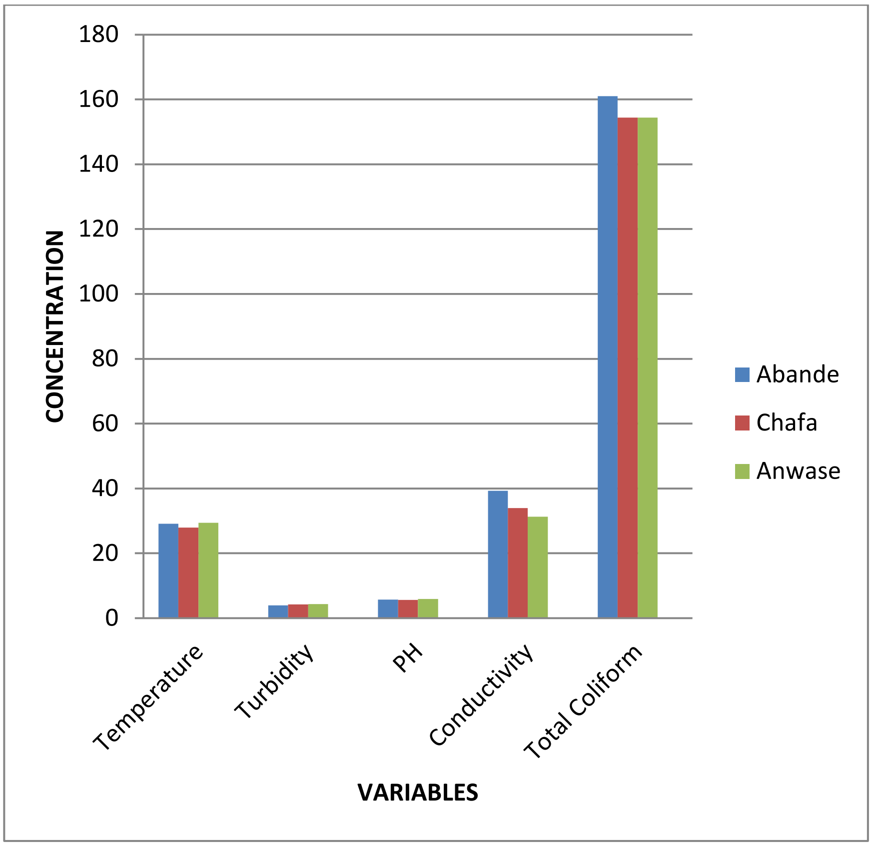

Units: Temperature (^{O}c), Turbidity (NTU), pH, Conductivity (Ms/cm), Total Coliform (CFU).

Figure 3: Comparation of some Water Parameters at Abande, Chafa and Anwase in River Mkomon During Dry Season

Table 3: Means of Selected Physicochemical and Bacteriological Parameters of Water from Mkomon River for Rainy Season at Four Sampling Stations (October, 2015)

Variables	A **(Mean ±S.D)**	B **(Mean ±S.D)**	C **(Mean ±S.D)**	D **(Mean ±S.D)**
Water Temperature (^{0}C)	29.5±0.08	28.0±0.08	29.5±0.07	26.3±0.08
Turbidity (NTU)	5.6±0.08	5.6±0.08	5.4±0.08	17.2±0.34
pH	6.3±0.09	6.5±0.08	6.8±0.07	6.3±0.02
Conductivity (Ms/cm)	60.8±0.08	61.8±1.49	60.8±0.07	41.4±0.31
TDS (mg/L)	60.8±0.06	60.8±0.08	60.8±0.07	8.5±0.37
Suspended Solid (mg/L)	42.1±0.05	44.3±0.54	48.4±0.55	60.6±0.09
Total Hardness (mg/L)	70.7±0.35	71.0±0.82	133.7±3.01	57.4±0.32
Chloride (mg/L)	53.8±0.05	57.3±4.03	55.0±0.15	54.8±1.17
Dissolved Oxygen (mg/L)	4.0±0.05	4.0±0.14	3.8±0.08	4.3±0.07
(BOD) (mg/L)	3.4±0.06	3.9±0.13	3.6±0.08	2.4±0.04
Phosphate (mg/L)	3.9±0.07	3.7±0.04	3.6±0.05	3.5±0.04
Total coliform(CFU)	164.4±22.1	157.8±35.03	153.3±29.0	160.9±13.47
Zinc (mg/L)	ND	ND	ND	ND
Cadmium (mg/L)	0.145±0.0	0.065±0.0	0.052±0.0	ND
Lead (mg/L)	0.123±0.0	0.132±0.0	0.123±0.0	0.303±0.02
Chromium (mg/L)	0.87±0.0	0.54±0.0	0.153±0.0	ND

ND=Not detected, S.D=standard deviation, A=Abande,B=Chafa,C=Anwase, D=waya

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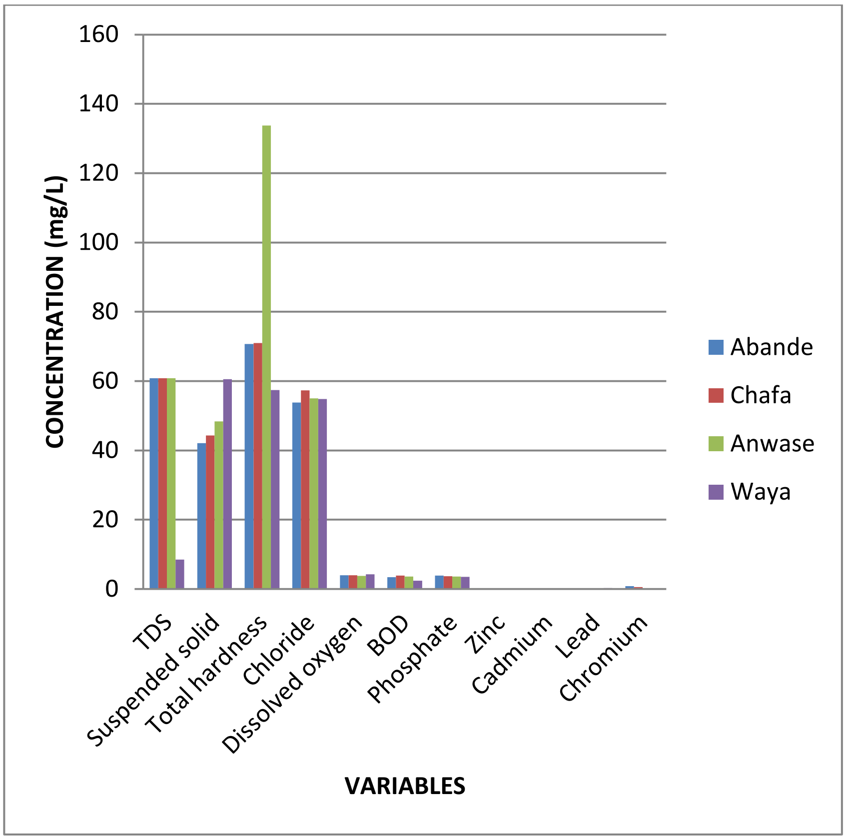
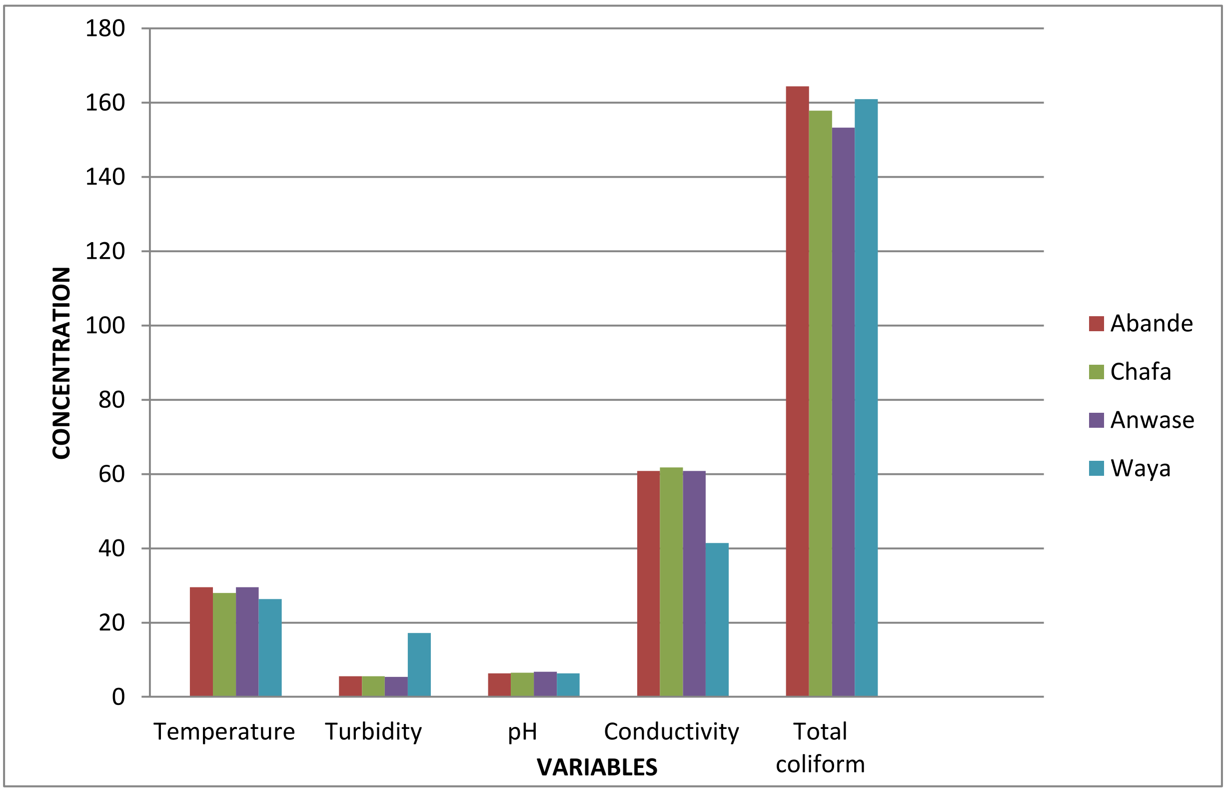


Figure 4: Comparation of some Water Parameters of River Mkomon at Abande,Chafa,Anwase and Waya During Rainy Season



Units: Temperature (^{0}C), Turbidity (NTU), pH, Conductivity (Ms/cm), Total Coliform (CFU).

Figure 5: Comparation of some Water Parameters at Abande, Chafa, Anwase and Waya During Rainy Season

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Table 4: Means of Selected Physicochemical and Bacteriological Parameters of Water from Mkomon River for Dry and Rainy Seasons at Four Sampling Stations

Variable	Dry Season (Mean±S.D)	Rainy Season (Mean±S.D)
Water Temperature (^{0}C)	28.8±0.08	28.3±0.08
Turbidity (NTU)	4.1±0.05	8.5±0.15
pH	5.7±0.07	6.5±0.07
Conductivity (Ms/cm)	34.9±0.81	56.2±0.49
TDS (mg/L)	17.5±0.58	47.7±0.15
Suspended Solid (mg/L)	33.8±0.81	48.9±0.31
Total Hardness (mg/L)	75.7±4.72	83.2±1.13
Chloride (mg/L)	45.2±0.48	55.2±1.35
Dissolved Oxygen (mg/L)	2.9±0.07	4.0±0.09
(BOD) (mg/L)	2.6±0.09	3.3±0.08
Phosphate (mg/L)	2.8±0.05	3.7±0.05
Total coliform(CFU)	156.6±28.22	159.1±24.9
Zinc (mg/L)	ND	ND
Cadmium (mg/L)	0.029±0.0	0.087±0.0
Lead (mg/L)	0.299±0.0	0.170±0.01
Chromium (mg/L)	0.056±0.0	0.521±0.0

ND=Not detected, S.D= standard deviation

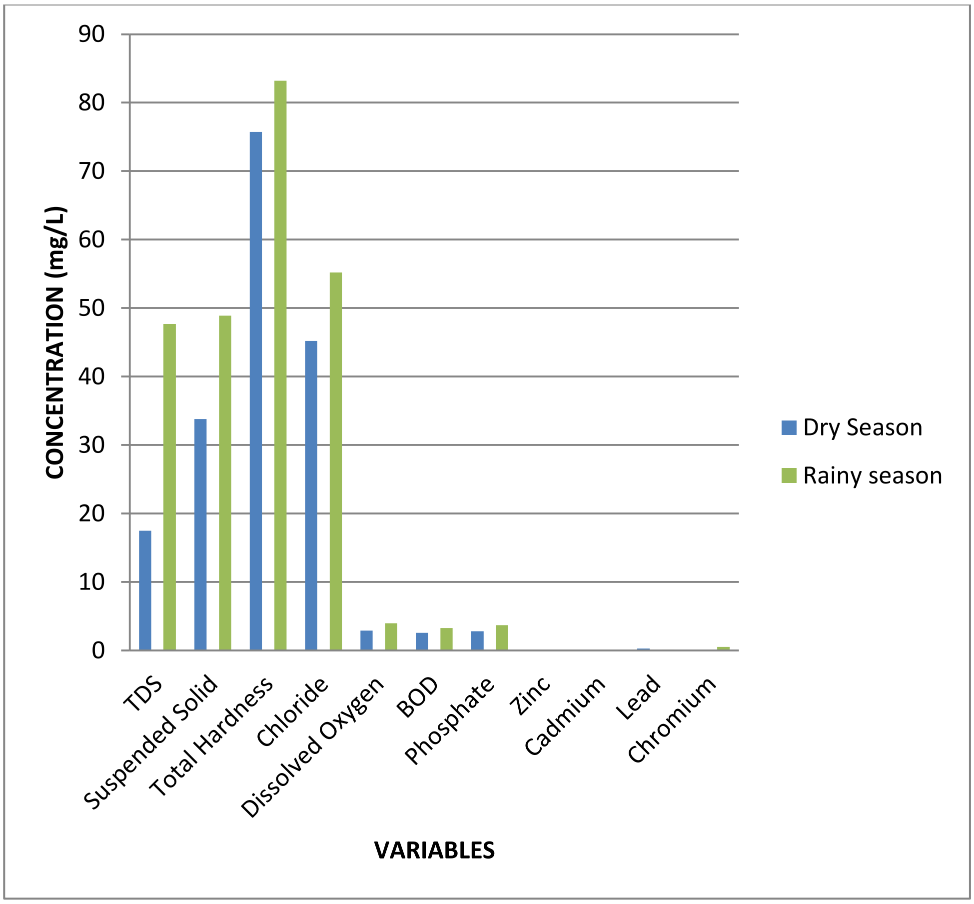

Figure 6: Comparation of some Water Parameters at River Mkomon during Dry and Rainy Season

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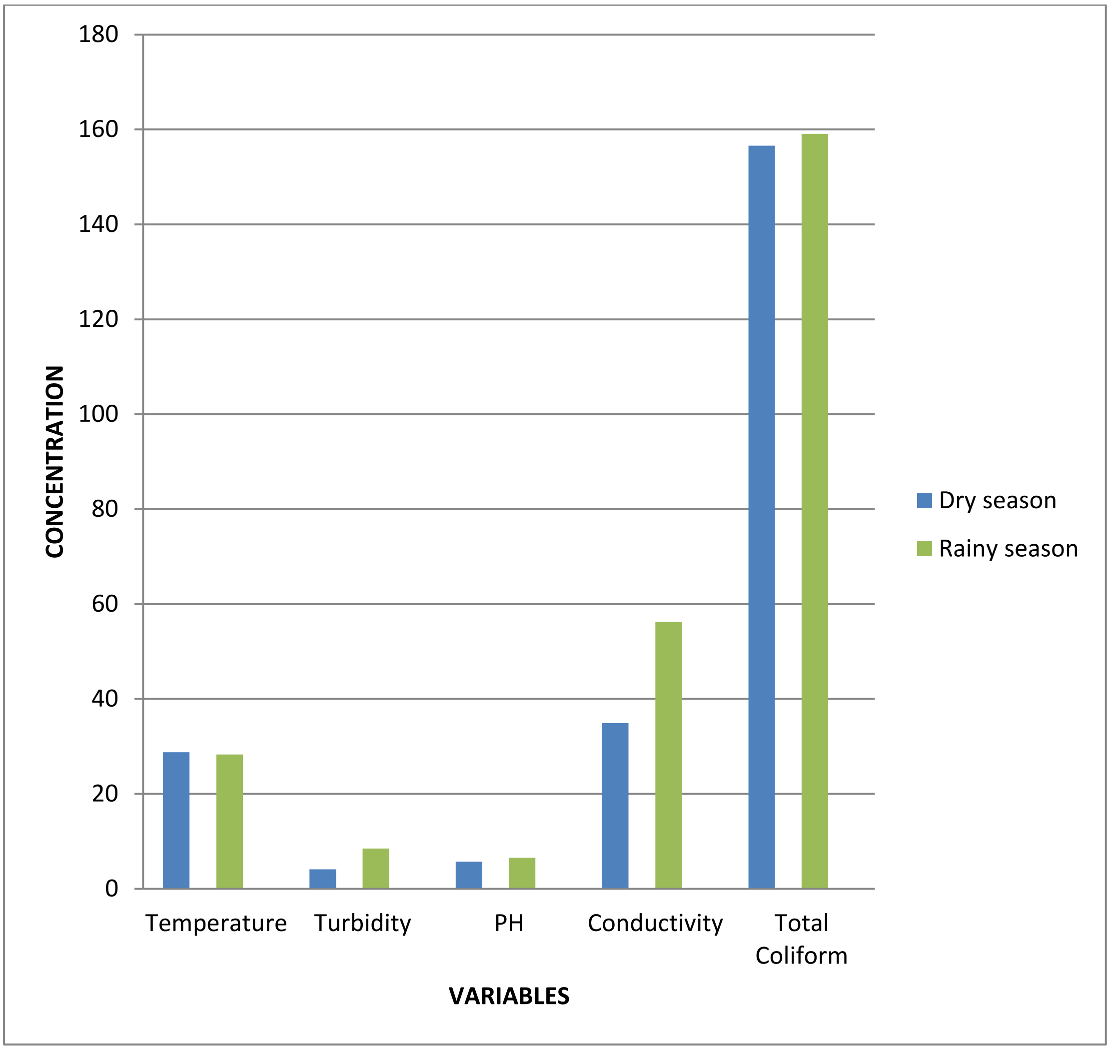

Units: Temperature (^{0}C), Turbidity (NTU), pH, Conductivity (Ms/cm), Total Coliform (CFU).

Figure 7: Comparation of some Water Parameters at River Mkomon during Dry and Rainy Season

4. DISCUSSION

The mean of all physicochemical and bacteriological analyses at each station was presented in Tables 2-4. Variations of physicochemical and bacteriological parameters among stations were statistically analyzed using One-way ANOVA (Appendices II-VI).

Water Temperature:

The temperature values were relatively consistent along the water body. During the dry season, temperature ranged from 29.4 -27.9 °C among the sampling sites. During rainy season, temperatures ranged from 29.5-26.3 °C. The lowest levels were observed at Chafa and Waya with values of 27.9 and 26.3 °C during the dry and rainy seasons, respectively. The mean surface temperatures were nearly uniform in both seasons with values of 28.8 and 28.3 °C for dry and rainy seasons, respectively. Lower mean temperature values were recorded during the rainy season (28.30 ± 0.08 °C) and higher values during dry season (28.8± 0.08 °C)**.** The temperatures of the water body were believed to have been influenced by the intensity of sunlight as temperature rose from 27.9 °C to 29.4 °C particularly during the dry season and lower during the rainy season (28.3 °C). This lack of differences in trends between water temperatures is consistent with findings of Obire *et al.*, (2003) who observed a similar trend in Elechi Creek in Port Harcourt, Nigeria. The consistent trends in temperature values within the season (Figures 3 and 5) and between the seasons (Figure 7) can also be seen from the comparation charts.

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Akpan (2004) worked on tropical fresh water bodies in Uyo. He also noted the minima seasonal difference in temperature which he attributed to the effect of the prevailing air-masses. This is particularly so in the study area as it was greatly influenced by rainfall and cloud cover as noted especially during the rainy season. The high temperature values during the dry season indicate the high rate of metabolic processes or activities in the water. The result of temperature from the study for both dry and rainy seasons was above the recommended standard value by WHO, NESREA and SON. Considering the ANOVA values for dry and rainy seasons, there was no significant variation as can be seen from Appendices II-VI.

Turbidity:

Measurement of turbidity reflects the transparency in water. It is caused by the substances present in water in suspension. In natural waters it is caused by clay, silt, organic matter, phytoplankton and other microscopic organisms.

In the present study water turbidity values ranged from 4.3 to 3.9 NTU during the dry season to 17.2 to 5.4 NTU during rainy season. There were similarities between the values during the dry season from stations Chafa and Anwase (Table 4 and Figure 3). Similar trend was observed during the rainy season from all the stations except Waya station that had the highest value of 17.2 NTU. There was a variation between dry season and rainy season values. The relatively high mean turbidity in the rainy season can be adduced to run-offs that carried dissolved fertilizer, pesticides, herbicides and other particles from cultivated fields into the river. The high turbidity of the river samples from Waya (station D) may have been caused by higher flow rates during rainfalls that might have carried sediments and other materials into the river. The low mean turbidity of the river samples may be due to the absence of run-offs and the recession in flow level during the dry season (Table 4 and Figure 3). Results of experiment carried out on river Etsu by Garg *et al.*, (2010) also showed high turbidity during rainy season. During rainy season silt, clay and other suspended particles contribute to the turbidity values, while during dry season settlement of silt and clay results to low turbidity values. The turbidity value was high at Waya station (station D) as a result of the cumulative effect due to the distance of Waya (downstream location) from the river source. Turbidity was found above the WHO, NESREA and SON prescribed limit in all the water samples. This can also be seen from the various charts (Figures 3 and 6).

Phosphate (PO_4^{3-}):

Phosphate is considered to be the most significant among nutrients responsible for eutrophication of lakes as it is the primary initiating factor. In this study, the trend was similar in both dry and rainy seasons with close values in all the sampling sites, that is from Abande, Chafa and Anwase during the dry season and Abande,Chafa, Anwase and Waya during the rainy season, respectively. The phosphate concentration was high during the rainy season (3.9 mg/L) at Abande compared to the highest value recorded during the dry season (2.9 mg/L) at Abande. This could be attributed to domestic waste waters, particularly those containing detergents and fertilizer runoff from various sources to the river during the rainy season, while the mean values recorded in the dry season could be due to evaporation. The value of phosphate decreases from Abande to Waya (Table 5) during the rainy season as a result of dilution factor or as a result of increase in distance away from the phosphate sources. The farther away from the source the lesser the concentration of phosphate at that point. The mean values (2.8 and 3.7 mg/L) for dry and rainy seasons were within the WHO, SON and NESREA recommended limit for drinking water (Appendices I).

To the contrary, findings in Cross River, Eastern Nigeria by Akpan (2004) showed phosphate concentration in the water was above the 5.0 mg/L of World Health Organization (WHO) standard. Excess phosphate concentration in water give rise to algal bloom and causes risk to human beings as algae produce toxins, which damage neurological system and as well causes oxygen depletion in the water (Akpan, 2004). From the ANOVA (Appendix III) result there was no variation between the sampling points as well as between the seasons. The recommended maximum level of phosphate for rivers and streams had been reported as 5.0 mg/L, while 0.025 mg/L is found to accelerate eutrophication process in rivers and lakes (Chapman, 1996).

Chloride:

Chloride occurs naturally in all types of water with a very low concentration.

Chlorides are important in detecting the contamination of water. In this study, the chloride ion concentration fluctuated at the various sampling stations (A, B and C) during the dry season (43.5, 47.3 and 44.9 mg/L) with mean value of 45.2 mg/L and there was a consistent value during the rainy season with a mean value of 55.2 mg/L. The mean value of chloride was higher during the rainy season (55.2 mg/L) than the dry season(45.2 mg/L).This may be as a result of water runoff during the rainy season from chloride sources (domestic sewage which contains a good amount of chloride.) into the river. The result of the study is within the WHO, SON and NESREA permissible limit of 200 and 250 mg/L. Rajkumar (2004) showed that higher concentration of chloride was associated with high domestic sewage disposal in the river which increased the level of pollution especially during the rainy season.

Conductivity:

Result of conductivity (Table 5) was found to be 60.8, 61.8, 60.8, and 41.4 (μScm^{-1}) for Abande, Chafa, Anwase, and Waya stations, respectively, during rainy season. During dry season, the values of conductivity (Table 4) obtained at Abande, Chafa, and Anwase were: 39.3, 34.0 and 31.3 (μScm^{-1}), respectively. There was no significant difference among locations and seasons in conductivity as shown by the ANOVA analysis (Appendices II-VI).

Results of the analysis indicated decrease in conductivity values during the dry season and increase during the rainy season. Reasons for the increase during rainy season were due to increase in concentration of salts, organic and inorganic materials in the river as a result of discharged by the feeder streams and runoff from domestic and other human activities into the river during rainy season. The lower conductivity values during dry season may be due to the utilization of these organic and inorganic materials by phytoplankton and other aquatic organisms. High conductivity reflects the pollution load as well as tropic levels of aquatic body. Conductivity values below 50 (μScm^{-1}) are regarded as low, while those between 50 – 600 (μScm^{-1}) are said to be medium and values above 600 (μScm^{-1}) are considered to be high (Abida and Harikrishna, 2008).For the study the conductivity was low because the values for both dry and rainy seasons were below 50 μScm^{-1} .

For most Nigerian inland water bodies, conductivity values have been found to be below 500 (μScm^{-1}) at the peak of dry season and less than 100 (μScm^{-1}) during the rainy season. All the sampling stations are purely rural agricultural communities and the high conductivity could be due to fertilizer and herbicide applications in the farmlands. High conductivity values have been reported to be indicative of pollution load of a river (Abida and Harikrishna, 2008).

Biochemical oxygen demand (BOD):

Biochemical Oxygen Demand is a measure of the oxygen in the water that is required by the aerobic organisms. The biodegradation of organic materials exerts oxygen tension in the water and increases the biochemical oxygen demand (Abida and Harikrishna, 2008). Rivers with low BOD have low nutrient levels; therefore, much of the oxygen remains in the water. Unpolluted, natural waters will have a BOD of 5 mg/L or less. BOD directly affects the amount of dissolved oxygen in rivers and streams. The greater the BOD, the more rapidly oxygen is depleted in the stream. This means less oxygen is available to higher forms of aquatic life.

The consequences of high BOD are the same as those for low dissolved oxygen: aquatic Organisms become stressed, suffocate, and die. Sources of BOD include leaves and woody debris; dead plants and animals; animal manure; effluents from pulp and paper mills,Wastewater treatment plants, feedlots, and food-processing plants; failing septic systems; and urban storm water runoff (USEPA, 1997).The average concentration of BOD in the study was 2.6 mg/L in dry season. During rainy season, BOD level increased to 3.9 mg/L which was below the permissible limit of NESREA (Appendix I). It varied from 2.4 to 2.7mg/L during the dry season and 2.4 to 3.9 mg/L during the rainy season where as the permissible limit for BOD is 5 mg/L prescribed by WHO and NESREA (Appendix I).

Biochemical oxygen demand indicated low values in the downstream waters (Anwase and Waya) during dry and rainy season with values of 2.4 and 2.4 mg/L, respectively. This is expected because only the downstream water receives high organic pollutants through the effluents. The low BOD value in all the sample stations (Abande, Chafa, Anwase and Waya) showed good sanitary condition of the water. Seasonal analysis reveals that BOD values are more during rainy season (3.9 mg/L than dry season (2.6 mg/L). The trend of seasonality in BOD followed that of dissolved oxygen concentration with higher values during the rainy season than in the dry season. Similar trend was also reported by Ahipathi and puttaiah (2006). Open defecation nearby the river and discharging of Sewage waste water generated by the sampling towns during rainy season results to higher BOD value of 3.9 mg/L as well the presence of major organic pollution sources in the study area. BOD shows no variation within the seasons and between the seasons as shown from the ANOVA values (Appendices I1-VI).

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Suspended Solid:

The seasonality profile of total suspended solids in Mkomon River indicated that rainy season levels were higher than dry season values. Higher rainy season values were due to the influx of allochthonous materials into the river through surface run-of. The greater rainy season values of coefficient of variations for the four stations than the dry season values indicate a strong influence of rainfall on total suspended solids. During the dry season it increased from 30.7 mg/L to 37.7 mg/L while during the rainy season it was from 42.1 to 60.6 mg/L. This is consistent with the work carried out by Akpan (2004) for Qua Iboe River.

The dry season decrease in the level of total suspended solids was probably due to sedimentation when the current velocity and water level was reduced, and low tributary inputs.

Comparatively, higher values were considerably observed for all the stations in the rainy than dry season. However, the seasonal variation was not significant.

pH:

Aquatic organisms are affected by pH because most of their metabolic activities are pH dependent. Optimal pH range for sustainable aquatic life is pH 6.5-8.2. pH of an aquatic system is an important indicator of the water quality and the extent of pollution in the watershed areas (Kumar *et al*.,2000). The pH values were within the permissible level set by WHO and SON that is 6.5 to 8.5, varying between 6.3 to 6.8 during rainy season. The lowering of pH in dry season was due to less input of waste from different types of sources. Higher pH values during rainy season revealed the aerobic conditions and lesser anthropogenic sources as compared to the dry season. The pH of water affects the solubility of many toxic and nutritive chemicals; therefore, the availability of these substances to aquatic organisms is affected. As acidity increases, most metals become more water soluble and more toxic. Toxicity of cyanides and sulfides also increases with a decrease in pH (increase in acidity). Ammonia, however, becomes more toxic with only a slight increase in pH. The lower pH recorded in all the stations during dry season, is probably due to the concentration of dissolved substances as a result of evapotranspiration. Likewise, the pH increased during the rains as a result of dilution effect. This was consistent with the report of Akpan (2004) for Qua Iboe River. pH range of 5.6 – 6.8 reported for Mkomon River could be considered to be within the range considered as normal for unpolluted fresh water (Fakayode, 2005). The slight acidity values of the sampling stations especially during the dry season could be attributed to the fact that Mkomon River drains a catchment area with thick tropical rain forest. The seasonality pattern in the pH of Mkomon River is similar to that reported by Akpan (2004) for Qua Iboe River.

Dissolved oxygen (DO):

Dissolved oxygen is one of the most important factors in stream health. Its deficiency directly affects the ecosystem of a river due to bioaccumulation and biomagnifications. The oxygen content in water samples depends on a number of physical, chemical, biological and microbiological processes. DO values also show lateral, spatial and seasonal changes depending on industrial, human and thermal activity. Oxygen is the single most important gas for most aquatic organisms; free oxygen (O_2) or DO is needed for respiration. DO levels below 1 ppm will not support fish; levels of 5 to 6 ppm are usually required for most of the fish population. The mean value of DO levels (6.5 mg/L) indicates the mean quality of river water (APHA 2005).

Dissolved oxygen levels were higher in the rainy season than in the dry season due to the increased current flow that enables the diffusion and mixing of atmospheric oxygen into the water (Table 3). Higher levels of dissolved oxygen observed in the rainy season in all the stations in Mkomon River is consistent with the work of Izonfuo and Bariweni (2001), in Niger Delta, while working in Epie Creek. Their observed average DO levels of 4.45 mg/L in the rainy season was higher than 3.35 mg/L obtained in the dry season. They attributed this seasonal fluctuation to the effect of temperature on the solubility of oxygen in water. At high temperatures, the solubility of oxygen decreases while at lower temperatures, it increases. The dry season decline in dissolved oxygen concentration was due to increased input of organic load into the water (mainly as leaf litter), whose decomposition increases oxygen depletion and stream stagnation (Izonfuo and Bariweni, 2001).

Total dissolved solids (TDS):

In water, total dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, magnesium, sodium, potassium and manganese; as well as organic matter, salt and other particles (Mahananda, 2010). At high flows, the TDS values tend to be diluted by surface runoff and for most rivers there are an inverse correlation between discharge rate and TDS (Charkhabi and Sakizadeh, 2006). As expected, the maximum total dissolved solids were observed during the rainy season (60.8 mg/L) at stations Abande, Chafa and Anwase than the dry season (18.8 mg/L) at stations Abande,Chafa and Anwase, as a large amount of sediment load was transported from the watershed during the rainy season. Higher level of TDS during rainy season is more likely due to the influence of small industrial activities such as rice mill, groundnut processing and burnt bricks effluent addition to the river. ANOVA analysis (Appendices II-VII) showed no seasonal variation. Some but not the entire dissolved solids act as conductors and contribute to conductance. Waters with high total dissolved solids (TDS) are unpalatable and potentially unhealthy. The results of analysis on the River showed that the total dissolved solids value was below the maximum recommended limit by the WHO, SON and NESREA (Appendix I).Similar findings have been reported by Garg *et al., (*2010), Kirubavathy *et al.,* (2005).

Zinc, Cadmium, Lead and Chromium:

The metal analysis gave values (mg/L) with ranged as follows during the dry season: Cd (0.029-0.029); Pb (0.33-0.27); Cr (0.073.0.047) and Zinc was not detected in all sampling stations while the range for rainy season was : Cd (0.145-0.052); Pb (0.303-0.123); Cr (0.87-.0.153); Zinc was also not detected in all the sampling stations. WHO limits are 0.01 mg/L Pb , 0.07 mg/L Cr and 0.003 mg/L,Cd. The concentration values of the heavy metals were higher during the rainy season than the dry season. The values were above the recommended limits in both seasons by the WHO, NESREA and SON (Appendix I).

Sources of these toxic metals in the water bodies are attributed to waste dumps in the river and agricultural lands. Cadmium is a common impurity in phosphate fertilizer and with increasing use of fertilizers in agriculture, cadmium dispersion from this source would increase. Other probable sources include leachates from nickel-cadmium based batteries which are so carelessly discarded by battery chargers, and cadmium plated items that are disposed at the refuse dumps both in urban and rural communities. Also, these water bodies are very soft (<50 mg/L) and very soft waters are known to have plumbo-solvency (liability to take lead into solution) (Porteous, 2000).

The most significant zinc ores include sphalerite (ZnS) and smithsonite ($ZnCO_3$). These compounds end up in water on locations where zinc ores are found. About three-quarters of the total zinc supply is used in metal form. The remainder is applied as various zinc compounds in various industries. Industrial wastewaters containing zinc stem from galvanic industries, battery production, etc. (Porteous, 2000).

The absence of zinc in both dry and rainy seasons in River Mkomon is a clear indication that there was no zinc ores, galvanic industries and battery production sites near the river bank where they can be transported during rain into the river.

Total Coliforms:

The Total coliforms numbers increased uniformly at the upstream water (at station A, both in dry and rainy seasons). The Total coliform numbers per 100 milliliters of water varied from 154 to 161 CFU during the dry season and 153.3 to 164.4 CFU during rainy season. The total coliform values decreased linearly uniformly during rainy season (Table 4 and Figure 5) and for rainy season the values fluctuated. The difference in total coliform densities between the dry and rainy season's waters was not significant as can be seen from ANOVA analysis.

The total coliform count (TCC) for all samples were exceedingly higher than the WHO, NESREA and SON standard for coliform bacteria in water which is zero total coliform per 100 milliliters of water (Appendice 1). Tables 4 and 5 showed the total coliform counts (TCC) for the various points of sampling. The least TCC was observed during dry season and it was 154.4 MPN per 100 mililitres while the highest TCC was recorded during the rainy season with a value of 164.4 MPN per 100 milliliters of water samples. This is contrary to Olayemi (1994), who work on River Osun where higher total coliform count was recorded during the dry season. The high total coliform count during the rainy season (than the dry season) was in lined with Venkatesharaju *et al.*, (2010) who investigated the physico-chemical and bacteriological parameters of River Cauvery kollegal stretch in Karnataka. Their results revealed that rainy season exhibited more counts than the dry season. This high coliform count during rainy season was attributed to discharging of domestic wastes containing faecal matters to the river body and open defecation along the sides of river bank. None of the sampling points of the water sources complied with WHO, NESREA and SON standard for coliform in water (Appendice I). According to WHO standard, every water sample that has coliform must be analyzed for total/feacal coliforms with a view to ascertaining contamination with human or animal waste and possibly pathogenic bacteria (Venkatesharaju *et al.*, 2010).

Total Hardness:

Total hardness is due to the presence of bicarbonate, sulphate, chlorides and nitrates of calcium and magnesium. Hard water requires more soap and synthetic detergents for home laundry and washing, and contributes to scaling in boilers and industrial equipments (ASAE and WQA, 2016). The WHO maximum permissible limit of total hardness for drinking water is 600 mg/L (Appendix I).

Mean value of total hardness was found to be 70.7, 71.0, 133.7, 57.4 (mg/L) for Abande, Chafa, Anwase and Waya stations, respectively, during the rainy season (Table 5) and 66.7, 46.7 and 113.6, (mg/L) as mean values for stations Abande, Chafa and Anwase, respectively, during the dry season (Table 4). There was significant difference among sampling sites, but no significant difference was observed in seasons (ANOVA, Appendices II-VI).

The result of hardness indicated low hardness values during dry season (75.7 mg/L) and high values during rainy season (83.2 mg/L) which may probably be due to high rate of inflow during rainy season and low value during dry season due to reduced inflow rate.

Results of One-way ANOVA and T-test:

There was no significant difference between physicochemical and bacteriological variables of water from the three sampling points (stations A, B and C) during the dry season .This can be justified from the ANOVA results.

The ANOVA table for dry season sampled at stations A, B and C has an F (2, 132) = 0.133 and a significant value of 0.875 which was greater than 0.05 the critical alpha value. Therefore the null hypotheses that; there was no significant difference between physicochemical and bacteriological variables of water from stations A, B and C, Kwande LGA during dry season was accepted (Appendices II-VII).

Similar trend was observed during the rainy season with stations A,B,C and D sampling points having F (3, 170) = 0.074 and a significant value of 0.974 which was greater than 0.05 the critical alpha value. Therefore the null hypothesis that: there was no significant difference between physicochemical and bacteriological parameters of water from Mkomon River sampled at stations A, B, C, and D, Kwande LGA during the rainy season was accepted.

The t- test was used to test for the significant difference between physicochemical and bacteriological variables of water from Mkomon river sampled at stations A, B, C and D, Kwande LGA during the dry and rainy seasons. A mean value of 9.132 for dry season and 8.744 for rainy season, standard deviation of 13.937 and 11.134 for dry and rainy seasons, respectively, were derived. At a value of 0.272, degree of freedom (df) of 307, and a significant value of 0.785 which is greater than 0.05, the critical alpha value, therefore the null hypotheses was accepted: that there was no significance difference between the dry and rainy season physicochemical and bacteriological variables of water from Mkomon River sampled at stations; A, B, C and D, Kwande LGA during both seasons (Appendices II-VI).

5. CONCLUSION AND RECOMMENDATIONS

Conclusion:

The bacteriological quality of the water of River Mkomon sampled at Abande,Chafa Anwase and Waya was unacceptable, and would pose serious health risks to consumers who use them without treatment.

The bacterial counts detected were above the permissible limits for drinking water in all the sampled stations. Data suggested the importance of greater attention for household contamination, environmental sanitation control and awareness about water contamination. Improvement in water quality and availability will aid hygienic practices and interrupt the transmission of enteric pathogens through contaminated water in the studied areas. Provision of sewerage systems and public health education aimed at improving personal, household and community hygiene is imperative.

6. RECOMMENDATIONS

River Mkomon is a source of drinking and domestic water to its host communities and the study carried out on the river revealed some level of pollution of the water. Therefore recommend that;

(i) The use of chemicals such as herbicides and pesticides by farmers around the bank of river Mkomon should be monitored and applied appropriately.

(ii) More studies should be conducted on the river to know the level of pollution and to check people's activities on the river.

(iii) River Mkomon should be frequently monitored to ascertain the seasonal variation in the chemical, physical and bacteriological parameters of the river, since we are faced with the problem of flooding in Benue state in which river mkomon is not an exception. In the process increase in level of pollution of the river could be detected early and mitigation measures could be put in place early enough to prevent an epidemic.

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