Investigation of the Quality of Physicochemical Parameters in Water Samples From Qua Iboe River, Ikot Ekpene Stretch, Akwa Ibom State, Nigeria

Abstract

Water, whether used for the purpose of drinking, irrigation, domestic purposes, has an important impact on health. Although pollution can occur naturally, it is anthropogenic (man-induced) pollution that creates more problems. These activities include agriculture, fishing, sand mining, boating, industrial and automobile works, transportation of all forms and a host of other activities carried out by man to solve his social and economic problems. These activities are capable of causing severe damage to the aquatic environment. Standard methods were used to assess the physicochemical parameters in water samples from Qua Iboe River, Ikot Ekpene stretch, Akwa Ibom State. The levels of physicochemical parameters determined across the sampling locations were higher at the location (Afaha Ikot Ebak) with tremendous human activities and lowest at the location (Uwa) with the least human activities. Physicochemical parameters obtained across the sampling locations showed an increase with levels of human activities across the sampling locations. Although the levels of all the parameters determined were within UNICEF and WHO (2008) permissible limits, they were higher at locations with tremendous human activities. The sustainability of the studied river for use by the present and future generations demands routine monitoring to prevent escalation beyond tolerability limits given by regulatory bodies.

Keywords: Physicochemical, Analysis, water samples, Qua Iboe River

1. Introduction

Water pollution occurs when toxic substances enter water bodies such as lakes, rivers, oceans and so on, getting dissolve in them, suspended in the water as colloids or deposited on the bed. This degrades the quality of water and the pollutants also seep through and reach the ground water, which might end up in our household as contaminated water we use in our daily activities, including drinking (Ayanwu, 2012; Nsi, 2020).

Water pollution can result in a number of ways, one of the most polluting sources being city sewage and industrial waste discharge. Indirect sources of water pollution include contaminants that enter the water supply from soils or groundwater systems and from the atmosphere via rain (Abowei and George 2010). Water pollutants include contaminants due to domestic wastes, insecticides and herbicides, food processing wastes, pollutants from livestock operations, volatile organic compounds (VOCs), trace metals, chemical wastes and others (Adefemi *et al*., 2007; Ubong *et al*., 2023).

Humans are the main cause of water pollution, which is triggered in many ways. Dumping of industrial waste; due to temperature rise that causes the attractions of water by reaching the oxygen in its composition or due to deforestation, which causes sediment and bacteria to appears under the soil and therefore contaminate groundwater. Trace metals and other chemicals find their ways into water bodies through many sources. These include natural occurring biogeochemical cycles (Ajibade, 2004).

Qua Iboe River, Ikot Ekpene segment, Akwa Ibom state is an important source of water for various purposes to riverine communities. It flows through densely populated and farming regions. Predominant human activities within the section of the river under study with potential to pollute the river with trace metals and other kinds of pollutants include sand mining, farming, fishing, transportation including run off through automobile workshops, domestic waste discharge, washing, boasting etc (Ikpe *et al*., 2019). The presence of these pollutants at elevated levels in the river can affect levels of physicochemical parameters and consequently aquatic life.

Qua Iboe River, Ikot Ekpene stretch studied, passes through an urban area highly populated where several human activities such as farming, road construction, sand mining, fishing, transportation, boasting

including several automobile workshop activities are carried out. The studied river is located down gradient to residential areas around it. It is a truism that after rain the end products and after effects of these activities are usually washed into the river thereby polluting the river with all kinds of contaminants with the potential to affect the Riverine communities who depend on it for food, domestic and other purposes (Ubong *et al*., 2021; Etuk *et al*., 2020)

The research was carried out to Investigate the quality of physicochemical parameters in water samples from Qua Iboe River, Ikot Ekpene Stretch, Akwa Ibom State, Nigeria and comparison of the levels with standards set up by UNICEF and WHO (2008) for human consumption.

2. Materials and Methods

2.1 Study Area

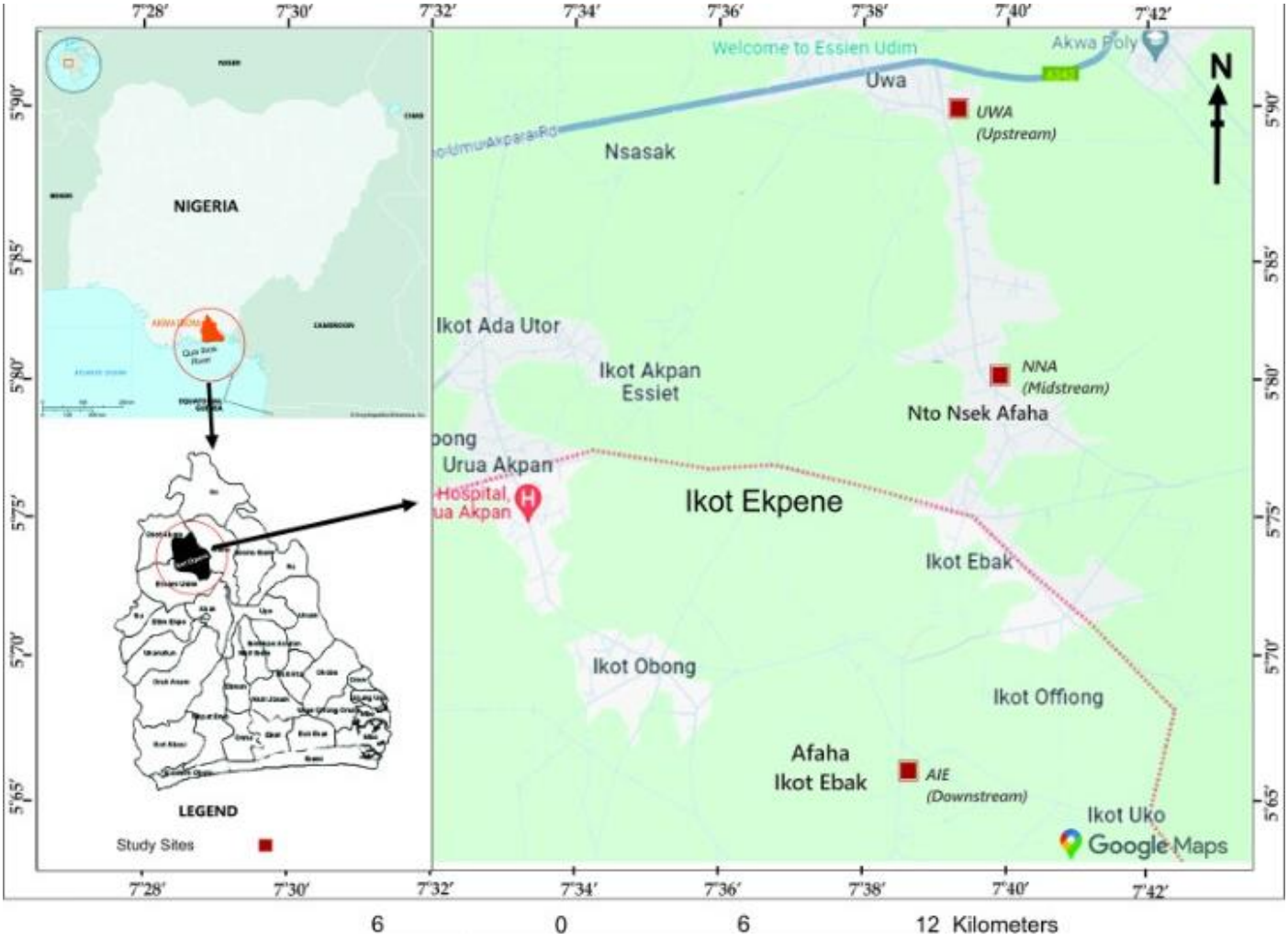

Figure 1: Map showing Qua Iboe River, Ikot Ekpene stretch, Akwa Ibom State, Nigeria.

The study area is Qua Iboe River, Ikot Ekpene stretch, Akwa Ibom State, Nigeria. It is one of major Rivers with tributaries streams that drains through Akwa Ibom State. It flows through agricultural farmlands and residential areas. The coast is densely populated with tremendous human activities such as agriculture, sand mining, fishing, transportation, roads construction among others. The river flows down gradient which makes it highly susceptible to pollution by agrochemicals through run-off from agricultural farmlands as well as domestic waste dump sites, automobile workshops and construction sites during rain. The riverine communities depend largely on the studied river for domestic, agricultural and industrial uses among other purposes.

2.2 Materials

Apparatus employed for samples collection and analysis include mercury in glass thermometer, pH meter, conductivity scan meter, 1 litre (IL) white polyethylene bottles, BOD bottles, among others.

2.3. Sampling and Methods of Analysis

Sampling is an essential step in any analysis as it determines the validity of the results (Udosen, *et al.,* 2005). It is essential to carry out samples collection using suitable methods and apparatus. Samples were collected from three sampling locations namely; The samples were collected at Uwa upstream 5º.9' 16" N , 7º.39' 19" E, Nto Nsek Afaha 5º.8' 3"N, 7º.39' 28" E, Afaha Ikot Ebak 5º.6' 29"N, 7º.38' 38"E for four months covering both wet and dry seasons.

Water sampling was carried out at all sampling sites for a period of four months which include January and February for dry season and also in June and July 2023 for wet season. The bottles for sample collection were washed, sum dried prior to the day of collection. In the field, the bottles were pre-rinsed many times with water from the different sampling points. Water samples were collected with one litre (IL) polyethylene bottles with caps for analysis of physicochemical parameters. Water samples for biochemical oxygen demand (BOD_5) and dissolved oxygen (DO) were collected with amber glass stoppered bottles and fixed with 2 mL of Winkler solutions 1 and II using separate dropping pipettes for each respectively.

In this work, water quality parameters determined in the laboratory include temperature, hydrogen ion (pH), dissolved oxygen (DO), biochemical oxygen demand (BOD), suspended solids (SS), total dissolved solids (TDS), total solids (TS), alkalinity, acidity, total hardness (TH), chloride (Cl), sulphates (SO_4^{-2}), nitrates (NO^-_3), and phosphates (PO_4^{-3}), chemical oxygen demand (COD).

. The temperature of the different water samples was determined in-situ by dropping the mercury-in-glass celsuis thermometer (0ºC – 100ºC) for about five minutes until a steady level was observed.

Hydrogen ion (pH) of the water samples was determined in situ using pH meter Harch Sension 156 model 51935-10-11. The meter was standardized before use with a standard buffer solution of pH 4.0 (potassium hydrogen phthalate, 0.05 M) and pH 9.2 (Borax buffer, 0.01 M). The meter was gently being immersed into the water samples for about five minutes in each case. Measurements were made in triplicates and average recorded (Ademoroti, 1996a).

Salinity was determined by passing electric current between the two electrodes of a salinity meter in a sample of water.

Electrical conductivity (EC) was measured with conductivity scan Meter model 1560. The probe of the meter was calibrated by immersing it into a solution of known electrical conductivity and then rinsed with deionized water for each measurement. The probe was thereafter immersed in the sample obtained in a clean beaker and the instrument switched on for a stabilized digital display value expressed in µs/cm (APHA). This parameter was determined at sampling site.

Dissolve oxygen (DO) was determined using dissolve oxygen meter of model JYD-1A. The method for the determination of biochemical oxygen demand (BOD) was similar to that for DO, but in the BOD test, the water samples were kept in an incubator in the dark preset at 20ºC for 5 days. After incubation, the DO test was repeated (APHA, 1998).

Determination of chemical oxygen demand (COD) was carried out as thus. Each water sample (100 mL) was measured into different conical flasks. 5 mL of dilute H_2S0_4 was added and the solution quickly transferred to a steam bath to boil. Then 15 mL of 0.01 M $H_2C_20_4$ was added followed by drop wise addition of $KMn0_4$ (0.01M) from the burette until the solution turned pink (APHA, 1998). Total dissolved solid (TDS) was determined using conductivity meter with model HARCH SENSION 5.

Determination of acidity using phenolphthalein acidity (PA): 50 mL of each water sample was measured into 250 mL conical flasks. Three (3) drops of phenolphthalein indicator were added in each case and the solution titrated with NaOH solution (0.02 M) until the appearance of a faint pink colour (pH 8.3) was observed. This indicated the end point of the titration (APHA, 1998).

Determination of Alkalinity using Phenoltphalein alkalinity (PAK) method. Each water sample (50 mL) was measured into different (250 mL) conical flasks. Three (3) drops of the phenolphthalein indicator were added. The solution remained colorless indicating a zero PAK (APHA, 1998).

Determination of suspended solid was carried out as thus. The Whatman filter paper No. 42 was dried to constant weight, cooled to room temperature in a desiccator and the weight noted. 100 mL of thoroughly mixed water samples were measured and filtered. The filtered residue was dried at a temperature of 103^{o}C – 105^{o}C in an oven for 30 – 40 minutes. The filter paper and the residue was cooled and weighed (Iscen *et al.,* 2008). The sum of TDS and SS gave TS expressed in mg/L. Determination of chloride (Cl^-). To each water sample (100 mL), three (3) drops of

5% K_2CrO_4 indicator were added and titrated with a standard 0.02 M $AgNO_3$ until the colour changed from yellow to brick red.

Total hardness (TH) was determined as thus: 25 mL of each water sample was measured into 250 mL conical flask. 2 mL of buffer solution was added. This was followed by the addition of two (2) drops of Eriochrome black T indicator. The rose pink solution obtained was titrated with 0.01 M EDTA until the colour changed to blue indicating the end point and the EDTA complexed with Ca, Mg and Zn (APHA, 1998).

In the determination of nitrate (NO_3^-), each water sample (10 mL) was transferred into different 25 mL standard flasks and 2 mL of Brucine reagent was added; then 10 mL of conc. H_2SO_4 was also added rapidly. It was mixed for about 30
seconds and allowed to stand for 5 minutes. The flasks were set in cold water for about 5 minutes and then made up to volume with deionized water. The absorbance was read at 470 nm with Unicam 8626 UV/VIS spectrometer (Ekiye and Zejiao, 2010, Ademoroti, 1996).

In determining phosphate (PO_4^{3-}), 25 mL of each water sample was measured into 50 mL volumetric flasks. 10 mL of vanadate-molybdate reagent was added and diluted to volume with deionized water. A reagent blank was prepared by making up 20 mL of reagent to volume in a 50 mL volumetric flask. The solutions were mixed and allowed to stand for about 10 minutes for colour development.

Determination of sulphate (SO_4^{2-}) was carried out as thus: 10 mL of each water sample was measured into different 25 mL volumetric flask; 10 mL of deionized water was added. 1 mL of gelatin-$BaCl_2$ reagent was also added in each case and mixed thoroughly, made up to volume with deionized water. It was allowed to stand for about 30 minutes. The absorbance was read as stated above (Asonye, *et al.,* 2007).

3. Results and Discussion

The results of analysis of physicochemical parameters in water samples from three sampling locations of Qua Iboe River, Ikot Ekpene stretch, Akwa Ibom state, Nigeria are discussed in this section. Tables 1 - 2 show the levels of physicochemical parameters in water samples across the three sampling locations in dry season. Tables 3 - 4 show the levels of physicochemical parameters in water samples across the three sampling locations in wet season.

Table 1: PHYSICOCHEMICAL PARAMETERS IN SURFACE WATER OF QIR FOR JANUARY, 2023 (Dry season)

Location	Temp^{0}C	pH	Conductivity µs/cm^3	Salinity mg/L	Acidity mg/L	Alkalinity mg/L	DO mg/L	COD mg/L	BOD mg/L	Hardness mg/L	DS mg/L	SS mg/L
Uwa	28.4±0.00	6.5±0.01	25.0±0.00	0.00±0.00	24.00±0.05	16.00±0.03	11.43±0.02	45.15±0.11	5.60±0.03	52.40±0.20	37.62±0.04	68.10±0.03
Nto Nsek Afaha	28.7±0.01	7.5±0.00	28.80±0.03	0.00±0.00	26.00±0.03	20.00±0.02	14.61±0.01	45.65±0.06	6.00±0.02	53.25±0.15	4.11±0.03	72.30±0.02
Afaha Ikot Ebak	29.10±0.01	7.7±0.001	28.95±0.03	0.00±0.00	28.00±0.04	21.01±0.03	12.01±0.02	46.21±0.07	6.20±0.03	53.59±0.21	42.05±0.03	73.41±0.03

Mean concentration ± standard deviation

TABLE 2: PHYSICOCHEMICAL PARAMETERS OF SURFACE WATER OF QIR FOR FEBRUARY, 2023 (Dry season)

Location	Temp^{0}C	pH	Conductivity µs/cm^3	Salinity mg/L	Acidity mg/L	Alkalinity mg/L	DO mg/L	COD mg/L	BOD mg/L	Hardness mg/L	DS mg/Ls	SS
Uwa	28.95±0.00	6.6±0.001	25.35±0.00	0.00±0.00	24.68±0.05	16.34±0.03	11.48±0.02	46.01±0.01	5.81±0.03	54.01±0.20	37.91±0.04	68.51±0.03
Nto Nsek Ahaha	29.03±0.01	7.6±0.000	29.0±0.003	0.00±0.00	26.52±0.03	20.50±0.02	12.61±0.01	46.51±0.06	6.50±0.02	54.52±0.03	41.51±0.03	72.71±0.03
Afaha Ikot Ebak	29.56±0.00	7.8±0.001	29.05±0.004	0.00±0.00	28.72±0.003	22.01±0.03	12.93±0.02	47.02±0.07	6.62±0.03	55.21±0.21	43.00±0.03	73.46±0.03

Mean concentration ± standard deviation

TABLE 3: PHYSICOCHEMICAL PARAMETERS IN SURFACE WATER OF QIR IN JUNE, 2023 (Wet season)

Location	Temp^{o}C	pH	Conductivity µs/cm^3	Salinity mg/L	Acidity mg/L	Alkalinity mg/L	DO mg/L	COD mg/L	BOD mg/L	Hardness mg/L	DS mg/L	SS
Uwa	27.2±0.00	6.7±0.001	24.79±0.00	0.00±0.00	24.56±0.05	16.26±0.03	12.33±0.02	46.01±0.01	5.10±0.03	53.41±0.20	38.15±0.03	71.00±0.02
Nto Nsek Afaha	27.30±0.00	6.6±0.01	24.85±0.00	0.00±0.00	24.70±0.04	16.3±0.03	12.40±0.02	46.01±0.01	5.30±0.03	53.48±0.03	38.48±0.04	71.35±0.0
Afaha Ikot Ebak	27.50±0.00	6.9±0.01	24.5±0.00	0.00±0.00	24.80±0.04	17.15±0.04	13.01±0.02	47.22±0.01	5.80±0.04	54.01±0.03	39.20±0.04	73.01±0.0

Mean concentration ± standard deviation

TABLE 4: PHYSICOCHEMICAL PARAMETERS IN SURFACE WATER OF QIR IN JULY, 2023 (Wet season)

Location	Temp°C	pH	Conductivity µs/cm^3	Salinity mg/L	Acidity mg/L	Alkalinity mg/L	DO mg/L	COD mg/L	BOD mg/L	Hardness mg/L	DS mg/L	SS
Uwa	28.01±0.01	6.8±0.001	24.60±0.00	0.00±0.00	25.03±0.04	17.05±0.04	13.01±0.02	47.30±0.04	5.90±0.04	54.30±0.21	39.10±0.04	73.01±0.0
Nto Nsek Afaha	28.25±0.01	6.61±0.01	24.72±0.00	0.00±0.00	25.04±0.04	17.51±0.04	13.52±0.02	47.40±0.05	5.95±0.04	54.62±0.02	39.63±0.04	73.46±0.0
Afaha Ikot Ebak	27.01±0.02	6.71±0.01	24.83±0.01	0.00±0.00	26.05±0.04	17.85±0.04	13.95±0.02	48.03±0.05	6.01±0.04	55.02±0.02	40.11±0.04	73.57±0.0

Mean concentration ± standard deviation

3.1 Physicochemical parameters in water samples

The results of determination of physicochemical parameters in water samples in dry season presented in Tables 1 and 2 and wet season in Tables 3 and 4 are discussed in this section.

The levels of temperature in this study ranged from 28.4 to 29.1^{o}C and from 28.5 to 29.6^{o}C, Tables 1 and 3 respectively for dry season across the three sampling locations. The level gradually increased from Uwa sampling location (upstream) to Afaha Ikot Ebak (AIE) downstream. This could be attributed to increase in human activities from upstream to downstream in line with population distribution as well as downstream movement of pollutants among other factors. This temperature range is within permissible limits of 29.0 to 40.0^{o}C given by WHO for healthy aquatic life.

In this study, pH levels ranged from 6.5 to 7.7 and from 6.6 to 7.8 across the sampling locations, Tables 1 and 2 respectively for dry season. Highest level was recorded in Afaha Ikot Ebak sampling location being downstream while lowest level was recorded in Uwa sampling location (upstream).

Electrical conductivity is the ability of water sample to conduct electricity. In this research, the level of EC obtained as presented in Tables 1 and 2 ranged from 25.00 $\pm$0.00 to 28.95$\pm$0.03 µs/cm^3 and from 25.00$\pm$0.00 - 29.65$\pm$0.03 µs/cm^3 respectively for dry season. The level of EC also gradually increased from Uwa (upstream) to Afaha Ikot Ebak (downstream). Variations in levels of EC across all the sampling locations were attributed to variation in human activities. Anthropogenic activities are the principal sources of elevated levels of pollutants in aquatic ecosystem. Thus, in dry season, the levels of electrical conductivity obtained in water samples were below maximum permissible limits of 300 µs/cm given by WHO for drinking water.

Results of Salinity determination obtained in dry season, shown in Tables 1 and 2 were below detection limit. The levels recorded were 0.00$\pm$0.00 mg/L across the sampling locations. The levels were below maximum permissible limits given by regulatory bodies.

Levels of acidity obtained in dry season presented in Tables 1 and 2 ranged from 24.00 $\pm$0.05 to 28.00$\pm$0.04 mg/L and between 24.60$\pm$0.05 to 28.72$\pm$0.03 mg/L respectively. The levels gradually increased across the three sampling locations from Uwa sampling location (upstream) to Afaha Ikot Ebak location (downstream) in line with levels of human activities among other factors. The results were similar to result reported by Uwah *et al.,* (2013) and were below maximum permissible limits given by regulatory bodies.

Levels of alkalinity recorded in dry season (Tables 1 and 2) ranged from 16.00$\pm$0.03 to 21.01$\pm$0.3 mg/L and from 16.34$\pm$0.03 to 22.01$\pm$0.03 mg/L respectively. The levels obtained also followed same trend obtained in other parameters. The increase in levels alkalinity obtained downstream could also be attributed to increase in levels of anthropogenic activities downstream. The levels recorded were similar to levels reported by Udosen and Benson (2006) and were below maximum permissible limits given by WHO (2006).

Dissolved oxygen is the amount of oxygen in water sample obtained by determination as at the time of water collection. It is an important parameter for water quality. Levels of DO obtained in dry season presented in Tables 1 and 2 ranged from 11.43$\pm$0.03 to 12.01$\pm$0.02 mg/L and from 11.43$\pm$0.02 to 12.93$\pm$0.02 mg/L respectively. Levels of DO recorded across the sampling locations also gradually increased from Uwa (upstream) to Afaha Ikot Ebak sampling location (downstream) in line with variation in levels of anthropogenic activities around the coast of the study area. Levels of DO obtained were similar to levels reported Udosen and Benson (2006) and were below maximum permissible limits set by WHO (2011) for human consumption.

Results of COD levels obtained in this study in dry season ranged from 45.13$\pm$0.11 to 46.21$\pm$0.07 mg/L and from 46.01$\pm$0.01 to47.02$\pm$0.07 mg/L (Tables 1 and 2) for January and February respectively. Variations in levels of COD across sampling locations were observed with lowest and highest levels recorded in Uwa and Afaha Ikot Ebak sampling locations respectively. This is a reflection of gradual increase in human activities downstream. COD is an important parameter that determines the level of pollution in a water body. COD levels recorded across the sampling locations were in line with standards given WHO.

Levels of BOD obtained in dry season presented in Tables 1 and 2 ranged from 5.60±0.03 to 6.20±0.03 mg/L and from 5.81±0.03 to 6.61±0.03 mg/L respectively. Levels obtained varied across all the locations. Unlike the trend obtained in other parameters, highest level of BOD was obtained in Uwa sampling location while lowest level was recorded in Afaha Ikot Ebak location. This was also attributed to variation in levels of human activities. Th results obtained were similar to levels reported by Uwah *et al.,* (2013). BOD levels obtained in this study were within permissible limits for portable water.

Results of levels of hardness obtained in dry season presented in Tables 1 and 2 ranged from 52.40±0.20 to 53.59±0.21 mg/L and from 54.01±0.20 to 55.21±0.21 mg/L respectively. Levels of total hardness recorded followed the same trend obtained in other parameters. The levels of hardness were within permissible limits set up by regulatory agencies.

Results of levels of dissolved solid (DS) obtained in dry season across the sampling locations ranged from 37.62±0.04 to 42.05±0.33 mg/L and from 37.91±0.04 to 43.00±0.03 mg/L, Tables 1 and 2 respectively. Variations in levels of DS obtained in all sampling locations were all below maximum permissible limit of 500 mg/L set by WHO (2011).

Levels of suspended solids (SS) obtained in dry season across all sampling locations presented in Tables 1 and 2 ranged from 68.10±0.03 to 73.41±0.03 mg/L and from 68.51±0.03 to 73.46±0.03 mg/L respectively. Suspended solid levels gradually increased from Uwa sampling location (upstream) to Afaha Ikot Ebak (downstream). Similar to the trends of other physicochemical parameters determined, the gradual increase in level of suspended solids downstream could also be ascribed to variations in levels of anthropogenic activities by coastal dwellers, downstream movement of suspended matter as well as run-off. Levels of SS obtained were similar to results reported by Udosen and Benson (2006) and were within maximum permissible limits of 500 mg/L given by WHO for drinking water

Physicochemical parameters levels in water samples of Qua Iboe River, Ikot Ekpene stretch, Akwa Ibom State in wet season were also determined to assess variation across sampling locations. Results presented in Tables 3 - 4 show levels of physicochemical parameters in water samples in wet season.

Results of temperature measurement in water samples across the sampling locations in wet season presented in Tables 3 and 4 ranged from 27.2 to 27.5^{o}C and from 28.01 to 29.0^{o}C respectively. Though not significantly, levels obtained gradually increased from Uwa sampling location (upstream) to Afaha Ikot Ebak (downstream). This could be attributed to variation in levels of anthropogenic activities across the sampling locations. This temperature range is within permissible limits of 29.0 to 40.0^{o}C recommended by regulatory bodies.

Results of levels of pH obtained in water samples across sampling locations in wet season presented in Tables 3 and 4 ranged from 6.7 to 6.9 and from 6.8 to 6.7 respectively. Variation in pH levels across the sampling locations in wet season followed the same trend of levels recorded in dry season which increased from Uwa sampling location (upstream) to Afaha Ikot Ebak (downstream). Levels obtained were similar to levels reported by Udosen *et al.,* (2005) and were below maximum permissible limit of 8.5 recommended by WHO. Level of pH beyond permissible limit given by regulatory bodies cause adverse effect on aquatic life.

Electrical conductivity (EC) measurement in water samples across sampling locations in wet season presented in Tables 3 and 4 ranged from 24.79±0.00 - 24.56±0.00 µs/cm and from 24.60±0.00 to 24.83±0.01 µs/cm respectively. Similar to the EC trend obtained in dry season, the levels recorded in dry also increased from Uwa sampling location (upstream) to Afaha Ikot Ebak (downstream). This is also attributed to variations in levels of human activities across the sampling locations. The levels were within permissible limits recommended by World Health Organisation.

Salinity levels determination in water samples from the study area in both seasons were not different. The level recorded in all locations was 0.00±0.00 mg/L across all the sampling locations and seasons. Salinity levels obtained were below detection limit and within permissible limits given by regulatory bodies.

Results of levels of acidity measurement in water samples during wet season ranged from 24.56 ±0.05 to 24.80 ± 0.05 mg/L and 25.03 ± 0.04 to 26.05 ± 0.04 mg/L, Tables 3 and 4 respectively. Lowest level was

recorded in Uwa sampling location (upstream) while highest level was recorded in Afaha Ikot Ebak (downstream) similar to the trend obtained in dry season. Comparatively, there was no significant difference in levels between the two seasons. Levels recorded in both seasons were within the guideline given by WHO.

Levels of alkalinity obtained in water samples across sampling locations in wet season ranged from 16.26±0.00 to 17.15±0.04 mg/L and from 17.05±0.04 to 17.85±0.04 mg/L as presented Tables 3 and 4 respectively. There were no significant differences in levels across all locations. In both seasons, levels were all below maximum permissible limit of 250 mg/L.

Levels of dissolved Oxygen (DO) obtained in water samples across all sampling locations in wet season presented in wet season ranged from 12.33±0.02 to 13.01±0.02 mg/L and from 13.01±0.02 to 13.95±0.02 mg/L respectively. DO level in wet season followed the same trend obtained in dry season in which highest level was obtained at Afaha Ikot Ebak sampling location (downstream) and lowest level recorded at Uwa sampling location (upstream). The increase in level of DO downstream could also be ascribed to variations in levels of human activities across sampling locations. DO levels in this research were higher than levels reported Udosen *et al.*, (2005) but were within WHO (2011) guideline for portable water. DO above permissible limit cause air bubbles disease in fish and corrosion of water pipes.

Levels of BOD obtained in water samples across the sampling locations in wet season presented in Tables 3 and 4 ranged from 5.10±0.03 to 5.80±0.04 mg/L and from 5.9±0.4 to 6.01±0.04 mg/L respectively. Comparatively, there were no significant differences in levels across both seasons and the sampling locations. Levels obtained were higher in location with tremendous human activities and were below maximum permissible limit recommended by WHO (2011).

Levels of chemical oxygen demand (COD) obtained in water samples across sampling locations in wet season presented in Tables 3 and 4 ranged from 46.01±0.01 to 47.22±0.01 mg/L and from 47.30±0.04 to 48.03±0.05 mg/L respectively. COD levels varied from one sampling location to another. Trend obtained in wet season followed the same trend recorded in dry season in line with varying degrees of human activities among other factors along the coast of the study area. There were no significant differences in COD levels obtained across the sampling locations and seasons and were all below maximum permissible limit given by regulatory bodies.

The levels of hardness determined in water samples during wet season ranged from 53.41±0.20 to 54.01±0.03 mg/L and from 54.30±0.21 to 55.02±0.02 mg/L, Tables 3 and respectively. Comparatively, levels increased from Uwa sampling location (upstream) to Afaha Ikot Ebak location (downstream) in both seasons. Levels recorded in this study were similar to levels reported by Uwa *et al.*, (2013) and were all within allowable range given by WHO (2011) for healthy growth of aquatic biota and plants.

In wet season, the levels of dissolved solids determined in water samples ranged from 38.15±0.03 to 39.20±0.04 mg/L and from 39.10±0.04 to 40.11±0.04 mg/L presented in Tables 3 and 4 respectively. Levels recorded in wet season were not significantly higher than levels dry season. In both seasons, DS levels gradually increased from Uwa sampling location to Afaha Ikot Ebak location (downstream) which is a reflection of the corresponding increase in human activities across all the locations. In both seasons, dissolved solids levels were all within a permissible limit of 500 mg/L according to WHO (2011) guideline

Suspended solids (SS) levels obtained in water samples across the sampling locations in wet season presented in Tables 3 and 4 ranged from 71.00±0.03 to 93.01±0.03 mg/L and between 73.01±0.01 and 73.50±0.01 mg/L respectively. There were no significant differences in levels across sampling locations and seasons. In both seasons, levels obtained were below maximum permissible limit of 500 mg/L given by World Health Organisation.

4. Conclusion

The levels physicochemical parameters obtained in water samples varied across sampling locations and seasons. Higher levels of some physicochemical parameters were obtained in location with tremendous human activities while lowest levels were recorded in location with less human activities. The level of physicochemical parameters in water samples is affected by the levels of human activities across the sampling locations in the study area. Moreover, although the levels of physicochemical parameters obtained

in water samples across the sampling locations were below maximum permissible limits set by regulatory bodies, they were higher in location with tremendous human activities reflecting the effects of the tremendous anthropogenic activities. However, the levels of some physicochemical parameters across the sampling locations were higher in dry season than wet season. Government should educate riverine community on the danger associated with indiscriminate dumping of wastes into the river. Industries should treat their industrial effluents before discharging into the river. These will enhance environmental sustainability of the studied river.

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