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PHYSICOCHEMICAL PARAMETERS AND HEAVY METALS CONTENT OF SURFACE WATER IN DOWNSTREAM KADUNA RIVER, ZUNGERU, NIGER STATE, NIGERIA

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Abstract

Background and Aim: The quality of a given water body is controlled by its physical, chemical and biological factors. Physicochemical Parameters and Heavy Metals of Surface water in downstream Kaduna River, Zungeru, Niger State, Nigeria were evaluated to develop a baseline data on the pollution status of the water.
Method: Physicochemical Parameters and Heavy Metals of the water were determined monthly for a period of five months (April – August, 2015) using standard methods Three study sites were selected along the river course designated as Sites A, B, and C.
Results: The concentrations of the parameters ranged as follows: pH (5.90 – 6.80), air and water temperatures (25.00 – 31.00 ºC), electrical conductivity (32.00 – 72.00 µS cm^{-1}), dissolved oxygen (3.5 – 8.2 mg L^{-1}), biological oxygen demand (1.00 – 5.00 mg L^{-1}), phosphate (0.06 – 1.13 mg L^{-1}), nitrates (0.44 – 1.44 mg L^{-1}), alkalinity (8.00 – 16.00 mg L^{-1}), transparency (36.00 – 40. 00 m), manganese (0.03 - 0.70 mg L^{-1}), Iron (2.00 – 3.80 mg L^{-1}), zinc (0.04 – 0.35 mg L^{-1}), and copper (0.01 - -0.07 mg L^{-1}). There was no record of lead detected throughout the time of the study. Anaysis of Variance (ANOVA) calculated for the parameters showed that there was no significant difference ($P > 0.05$) in all the physicochemical parameters sampled among the sampling Sites, except for the air surface temperature. Linear correlation among temperature, conductivity, DO, and phosphates revealed that the water quality deteriorated increasingly as the water traveled from the upper reaches (Site A) down to the lower reaches (Site C). Most of the physicochemical parameters – pH, surface water temperatures, conductivity, BOD, phosphates, and nitrates were within the recommended limits for survival of aquatic organisms. However, the values of DO and transparency fell outside these limits. Data obtained for heavy metals showed that Manganese (Mn) and Iron (Fe) were above the maximum contaminant levels
Conclusion: Based on the extremely high values of Mn and Fe, the waters of Kaduna River is therefore, declared unfit for human consumption as this may lead to Fe and Mn related illnesses, therefore posing potential risk of bio-magnification for inhabitants that depend on the river. We therefore advocate proper surveillance as a tool for monitoring anthropogenic (human) activities in order to ensure minimized effects on these parameters of Kaduna River.

Keywords: Anthropogenic activities, Bio-magnification, Aquatic productivity, River pollution, Water quality.

INTRODUCTION

The physical and chemical properties of water immensely influences its uses, the distribution and richness of the biota (Courtney and Clement, 1998; Unanam and Akpan, 2006). Several of these physicochemical parameters have been studied on large man-made lakes in Northern Nigeria by Kolo and Oladimeji, 2004) and Ibrahim et al. (2009).

The distribution processes of the metals entering natural waters are controlled by a dynamic set of physicochemical interactions and their solubility are principally controlled by hydrogen ion concentration (pH), concentration, type of metal species, the oxidation state of mineral components and the redox environment of the aquatic system (Koffi *et al.,* 2014; Lalah *et al.,* 2008). After being introduced into the aquatic environment via various sources and paths, metals are adsorbed onto inorganic and organic particulates and are incorporated into sediment resulting in elevated levels of heavy metals in bottom sediment (Ochieng *et al.,* 2007; Liu *et al.,* 2009). Physicochemical parameters play an important role to determine the water quality. The accumulation of metals from the overlying water to the sediment is dependent on a number of external environmental factors such as pH, dissolved oxygen, electrical conductivity and the available surface area for adsorption caused by the variation in grain size distribution (Davies *et al.,* 2006). However, metals cannot always be fixed by sediments permanently. Some of the sediment-bound metals may remobilize and be released back to waters via the variation of environmental conditions such as acidification, redox potential conditions, and impose adverse effects on living organisms (Liu *et al.,* 2009). River Kaduna is an importance source of portable water for the riparian communities and also serves as a rich source for aquatic productivity, including fish productivity. It is against this backdrop that the present study was designed to evaluate the level of heavy metals and water quality parameters of lower River Kaduna, forming determinants of the pollution status of the water. Heavy metals pollution represents a serious problem for human health and for life in general. The disposal of heavy metals is a consequence of several activities like chemical manufacturing, painting and coating, mining, extractive metallurgy, nuclear and other industries. Those metals exert a deleterious effect on fauna and flora of lakes and stream (Sanayei *et al.,* 2009; Sayari *et al.,* 2005). Human activities such as industrial and municipal effluents, as well as atmospheric deposition and non-point source run-off have are the main sources of metals in rivers. They are one the most environmental pollutant which accumulates in living organisms. Its cumulative poisoning effects are serious hematological and brain damage, anemia and kidney malfunctioning (Sanayei *et al.,* 2009; Zheng *et al.,* 2008).

Materials and Methods

Description of the study area

Zungeru is a town in Niger state, Nigeria. It was the capital of British protectorate of northern Nigeria from 1902 until 1916. Lower River Kaduna is a lotic water body passing through Zungeru which originates from Kaduna, a tributary of the Niger River. It flows for 550 kilometers through Nigeria. The climate in Zungeru is tropical with annual temperature and relative humidity and rainfall of 30.2^0C, 61.2 % and 344 mm, respectively. The climate represents two distinct seasons, a rainy season between April and October, with the highest mean monthly rainfall in September and a dry season from November to March completely devoid of rainfall.

The vegetation reflects that of savannah zone, dominated by grass but with scattered trees. For the purpose of this study, the river was divided into 3 study sites. Site A is located at the upstream of the sampling site, site B at 3 meters from site A and site C is another 3 meters away from site B (Fig 1.1 &1.2).

Figure 1.1: Location of Wushishi Local Government Area in Niger State
Source: Remote Sensing/GIS Lab, Geography Department, FUTMINNA, (2015)

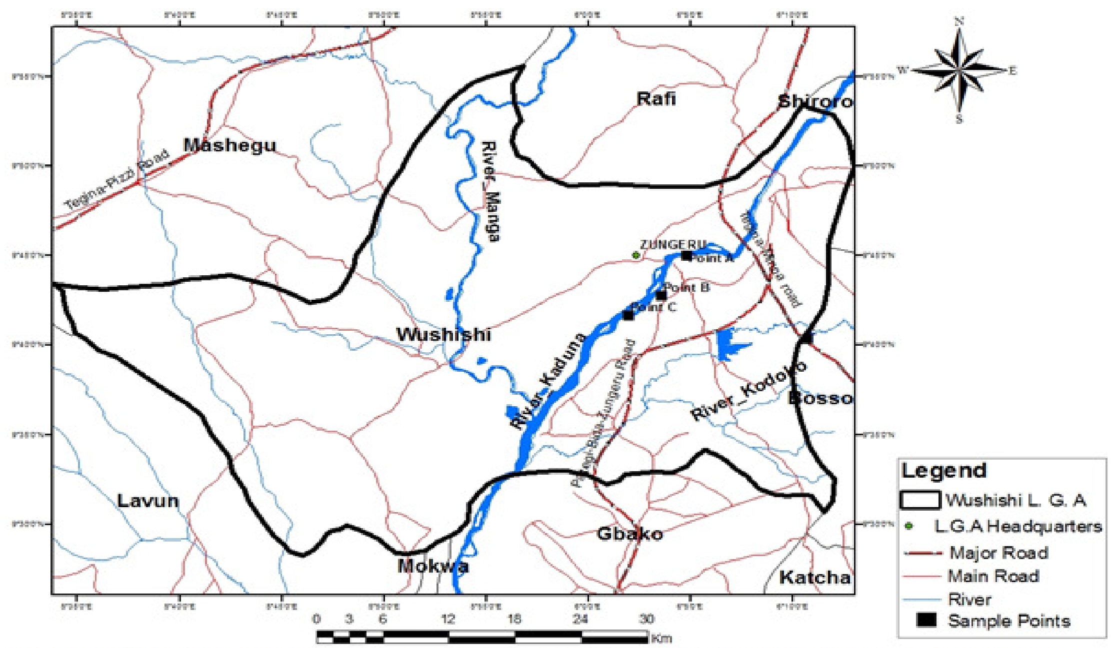

Figure 1.2: Sample Points Distribution Along River Kaduna in Wushishi L. G. A, Niger State
Source: Remote Sensing/GIS Lab, Geography Department, FUTMINNA (2015)

Sampling techniques

Water samples for physicochemical parameters were collected monthly between the period of March and September, within 8.00am and 12pm of the day from the three sites using 500 ml capacity specimen bottles. The water was fixed immediately using standard procedure of (APHA 2005), before getting to the laboratory for further analysis.

Physiochemical parameters determination

Hydrogen ion concentration (pH), temperature, and conductivity were determined *in situ* using Jenway (model type HANNAH 1910) multi-purpose tester. Total Alkalinity was determined using the titrimetric methods as clearly described by APHA (2005). Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD) were done using the titrimetric method (Wrinkler) as clearly described by Dubey and Maheshwari, (2004). Transparency, Nitrate, and Phosphates were determined as described by FAO (1997).

Processing and analyses of Sediments, and determination of Heavy metals

Heavy metals analyzed included, zinc, manganese, lead, copper, and iron. Analyses for heavy metals were conducted in accordance with standard procedures (APHA 2005). This involved the drying of sediments to constant weight in an oven at 65^0C, grinding of dry sediments to very fine particles and digesting it using strong hydrochloric acid. Absorbance of the specific metals in clear supernatants from digested materials was measured using an atomic absorption spectrophotometer (ALPHA Model). Concentration of the specific metals in sediments was calculated using regression equations of the standard.

Data Analysis

The range, mean and standard deviation for each parameter and Site were calculated. Analysis of Variance (ANOVA) was used to compare the means of the physico-chemical parameters and heavy metals obtained from the three sites. Prior to ANOVA, the assumptions of normality and homogeneity of variance were tested using the Shapiro–Wilk and Levene's tests, respectively. When it was found that these assumptions were violated, data were log (x+1) transformed, except for pH. Fixed effect ANOVAs were performed using dates as replicates. Significant differences between Sites indicated by ANOVA ($p<0.05$) were followed by Tukey's post hoc HSD test.

Results

Physicochemical parameters of Kaduna River

The summary of physicochemical parameters obtained for the three Sites of Kaduna River is shown in Table 1. These values are placed alongside WHO (2004), USEPA (2010) and NESREA (2011) standard values for guideline. ANOVA calculated for the parameters showed that there was no significant difference ($P > 0.05$) in all the parameters sampled among the sampling sites, except for the air surface temperature.

pH ranged from 5.9 to 6.80. The highest value (6.8) was recorded in Site A in August and the lowest value was recorded in Site C in July of the study of the period. The results obtained for air surface temperature showed a generally high temperature in all the Sites within the period of the study. There was significant difference between the three sites throughout the period of study with June having the highest value 31 ^{0}C recorded in Site C. The air and water temperatures fluctuated between 25.00 to 31.00 ^{0}C. Electrical conductivity fluctuated between the three months, with the highest value of 70 µS cm^{-1} recorded in Site A in April. The mean range was from 32.00 to 72.00 µS cm^{-1}. For dissolved oxygen, the result obtained showed that dissolved oxygen of the River decreased gradually from the month of April to August; hence the fluctuation between 3.50 to 8.2 mg L^{-1}. There was no difference between Sites A and B in the months of May and June. Low values were observed in Site C in all the months of this study. The lowest value of Biological oxygen demand (1.00 mg L^{-1}) was observed in Site C in August. Similar values were recorded in all the Sites in July (2.00 mg L^{-1}), whereas the highest value was recorded in Site A (5.00 mg L^{-1}) in April.

Phosphate values ranged from 0.06 to 1.13 mg L^{-1}. There was steady decrease in all sites between May and June, followed by a rapid increase in the month of July. Nitrate value of 1.44 mg L^{-1} was the highest recorded at Site C in April. Lowest value was (0.44 mg L^{-1}) at Site C in the month of August. Generally there was a gradual decrease in values between the five months. Transparency was high generally during the study, shortly afterwards, there was a drastic reduction towards the end. The value ranged from 36.00 to 40.00 cm. Alkalinity was observed in the range of 8.00 to 16.00 mg L^{-1}. Alkalinity values were same (14.00 mg L^{-1}) for three sites in April and June. Generally, values were higher in the beginning of the study, but suddenly became low towards end. Lowest value was 8 mg L^{-1} at Site A in the month of August, while highest value was 16 mg L^{-1} at Site C in the month of May.

Heavy metals of Kaduna River

The summary of the values of the heavy metals obtained for the three Sites is shown in Table 2. These values are placed alongside WHO (2004), USEPA (2010) and NESREA (2011) standard values for guideline. Data showed that manganese ion was low in all Sites. It fluctuated between 0.03 to 0.7 mg L^{-1}. The lowest value of 0.03 mg L^{-1} was observed in Site C in the month of June, while the highest value of 0.7 mg L^{-1} was recorded in Site B in the month of August. Concentration of iron showed some variations in all three Sites throughout the period of the study. It ranged from 2.0 to 3.8 mg L^{-1}. Generally, the results of iron were higher than the other metals sampled in all Sites. The result obtained for zinc showed a gradual increase in the concentration of zinc ions within the Sites having ranged from 0.04 to 0.35 mg L^{-1}. Copper was detected in the sediments from the three Sites. The range was from 0.01 to 0.07 mg L^{-1}. There was no record of lead detected throughout the time the study.

Table 1: Physicochemical parameters of water samples collected from Kaduna River, Zungeru from April to August, 2015.

	Sampled Sites[1]					
Parameters[2]	Site A	Site B	Site B	P value	WHO (2004)	NESREA (2011)
pH	6.31 ± 0.15 (5.90-6.80)	6.29±0.96 (6.10-6.60)	6.15±0.19 (5.40-6.40)	0.72	6.5-9.5	6.5-8.5
Surface Temp (°C)	27.00 ± 0.71 (25.00-29.00)	28.00±0.58 (27.00-30.00)	30.00±0.45 (29.00-31.00)	0.01	27	-
Water Temp (°C)	28.20±0.74 (26.00-30.00)	27.80±0.91 (26.00-30.00)	29.00±0.80 (27.00-31.00)	0.6[a]	35	-
Conductivity (µS cm^{-1})	48.40±8.40 (32.00-70.00)	60.80±4.25 (51.00-72.00)	62.00±.84.00 (59.00-67.00)	0.2	200	
DO (mg L^{-1})	6.30±0.60 (4.50-8.20)	5.50±0.60 (3.50-7.00)	4.90±0.50 (3.50-6.00)	0.22	6.0	-
BOD (mg L^{-1})	3.60±0.51 (2.00-5.00)	2.80±0.5.00 (1.00-4.00)	2.60±0.51 (1.00-4.00)	0.4	6	-
Phosphate (mg L^{-1})	0.30±0.20 (0.06-1.13)	0.45±0.23 (0.06-1.11)	0.46±0.22 (0.06-1.10)	0.84		3.5
Nitrate (mg L^{-1})	0.98±0.14 (0.62-1.31)	0.87±0.14 (0.44-1.09)	0.94±0.19 (0.45-1.44)	0.87	50	9.1
Transparency (m)	76±16.13 (40.00-113.00)	83.8±21.04 (36.00-138.00)	87.6±21.53 (39.00-140.00)	0.9	5	-
Alkalinity (mg L^{-1})	11.60±1.17 (8.00-14.00)	13.80±0.49 (12.00-15.00)	13.60±0.98 (10.00-16.00)	0.22	-	-

[1]Data are the means ± SE of triplicate determinations with minimum and maximum values in parenthesis. [a] indicates significantly calculated P value detected by ANOVA . [2]Temp = Temperature; DO = Dissolved Oxygen; BOD =Biological Oxygen Demand.

Table 2: Heavy metals of water samples collected from Kaduna River, Zungeru from April to August, 2015.

	Sampled Sites					
Parameters	Site A	Site B	Site C	P value	WHO (2004)	USEPA (2010)
Manganese (mg L-1)	0.15±0.03 (0.11-0.20)	0.19±0.50 (0.03-0.50)	0.26±0.22 (0.04-0.70)	0.88	0.4	0.05
Iron (mg L-1)	2.25±0.22 (2.0-2.70)	3.66±0.08 (3.54-3.80)	2.33±0.19 (2.10-2.70)	0.001	0.03	0.3
Zinc (mg L-1)	0.06±0.015 (0.04-0.09)	0.12±0.02 (0.10-0.16)	0.29±0.06 (0.18-0.35)	0.01	3	5
Copper (mg L-1)	0.02±0.01 (0.01-0.03)	0.04±0.01 (0.02-0.06)	0.04±0.01 (0.03-0.07)	0.43		1.3
Lead (mg L-1)	0.00±0.00 (0.00-0.00)	0.00±0.00 (0.00-0.00)	0.00±0.00 (0.00-0.00)		0.01	0.015

[1]Data are the means ± SE of triplicate determinations with minimum and maximum values in parenthesis. [a] indicates significantly calculated P value detected by ANOVA.

Discussion

The quality of a given water body is controlled by its physical, chemical and biological factors, all of which interact with one another to influence its productivity (Akponine and Ugwumba, 2014). Results obtained from Kaduna River showed that the physicochemical parameters of the water body are only stressed minimally. The pH range of 5.9-6.8 obtained from this study conferred slight acidity levels on River Kaduna. However, this range was within the range reported for rivers flowing through areas with thick vegetation (Uwadiae *et al.,* 2009; Akponine and Ugwumba, 2014).

Thus, the pH range obtained in this study is within the acceptable level of 6.0 to 8.5 for culturing tropical fish species and, for the recommended levels for drinking water (WHO, 2004; USEPA, 2010). Federal Environmental protection Agency (FEPA) recommended pH 6.5- 8.0 for drinking and 6.0-9.0 for aquatic life. High pH levels of water forces the dissolved ammonia to its toxic and unionized form which gravely affects aquatic organisms (USEPA, 2008). The water surface temperature is the most significant parameter which controls in-born physical qualities of water. The temperature of Kaduna River varied from 25 ^{0}C to 31 ^{0}C. The highest temperature was in August at Site C while the lowest was recorded in April at Sites A and B. This is because of the shallowness of the sites and the volume of water in contact with air. The mean air and surface water temperatures obtained are typical of African tropical rivers (Masese *et al.,* 2009). Both air and water temperatures range were observed to be within the recommended range for aquaculture as reported by Zheng *et al.* (2008), who observed that fish grow best at 25 to and 32 ^{0}C. Dissolved Oxygen (DO) in water affects the oxidation-reduction state of many of the chemical compounds such as nitrate and ammonia, sulphate and sulphite, ferrous and ferric ions. DO levels of 3.50 to 8.2 mg L^{-1} in this study were similar to 1.20 to 9.40 reported by Edokpayi and Osimen (2001) in Ibiekuma River in Ekpoma; Akponine and Ugwumba (2014) in Ibuya River in Old national park, Sepeteri. The results showed that, the dissolved oxygen recorded were within the permissible limits of the standard drinking water for WHO (2004) and NESREA (2011). The amount of dissolved oxygen in water has been reported not constant but fluctuates, depending on temperature, depth, wind and amount of biological activities such as degradation (Ibrahim *et al.,* 2009). The decrease in DO value observed at some points may be due to discharge of organic wastes at such periods, which led to biological respiration and decomposition processes, which in turn reduced the concentration of DO in water bodies. This agreed with the findings of Michael (2006), who reported that water with high organic or inorganic pollution may have very little oxygen in them. Biochemical Oxygen Demand (BOD) is a measure of the amount of dissolved oxygen removed from water by aerobic bacteria for their metabolic requirements during the breakdown of organic matter (Chapman, 1996).

According to Stevens Institute of Technology (SIT), (2008), BOD classification of 1-2 mg L^{-1} as very good, with less organic matter present; 3-5 mg L^{-1} as moderately clean; 6-9 mg L^{-1} as poor, somewhat polluted (indicates organic matter is present and bacteria are decomposing this waste); etc, the water samples were moderately clean and safe for drinking. The level of BOD recorded in this study revealed that River Kaduna was moderately clean. The higher value of BOD in Site A may be due to higher rate of decomposition of organic matter at higher temperatures. This also corroborated with Umeham (1992), who observed that organic matter from increased weed decomposition within lake water and domestic sewage increased the biological oxygen demand. The present values were within acceptable limits prescribed by the World Health Organization, (WHO, 2004).

Electrical conductivity is the normalized measure of the water's ability to conduct electric current. This is mostly influenced by dissolved salts such as sodium chloride and potassium chloride (SIT, 2008). The sources of conductivity may be an abundance of dissolved salts due to poor irrigation, minerals from rain water run-offs, or other discharges. Generally, the conductivity levels measured in this study were far below the maximum contamination levels (MCL) of WHO (2004). The generally low conductivity levels indicated low dissolved salts in the study Sites. Higher mean conductivity values of 60.00 and 62.00 µS cm^{-1} were observed for Sites A and B, respectively. This could be as a result of dissolved solutes from decaying organic materials deposited at these sites form surface run-offs. Conductivity levels below 50 µS cm^{-1} are regarded as low; those between 50 µS cm^{-1} to 600 µS cm^{-1} are medium, while those above 600 µS cm^{-1} are high conductivity levels (Umeham and Elekwa, 2005). The mean conductivity level of 57.07 µS cm^{-1} for the three sites might have placed this River Kaduna as portable water. The mean conductivity level of 57.07 µS cm^{-1} also fell within the range of inland waters. Transparency values recorded during the research were within the range reported by Kemdirim (1990) who stated that the recommended range for transparency is between 11.0cm-108.5cm for productive waters.

Nitrate and phosphates can reach both surface water and groundwater as a consequence of agricultural activities (including excess application of inorganic nitrogenous fertilizers and manures), wastewater disposal and from oxidation of nitrogenous waste products in human and animal excreta, including septic tanks (Where latrines and septic tanks are poorly sited, these can lead to contamination of drinking-water sources with nitrate) (Umeham and Elekwa, 2005). The concentrations of nitrates recorded in this study were very low for primary productivity, since the concentrations did not fall within the range recommended by Beadle (1981), who observed that nitrate-nitrogen range of 9.8- 49 mg L^{-1} is required for more production in lakes of Africa. This low nitrate level of River Kaduna might be linked to dearth of significant farming activities around the sites. This corroborated the study of Yakubu *et al.* (2014) on the assessment of the water quality parameters of Agaie/Lapai dam in Niger State, Nigeria. The low nitrates level might as well be attributed to high photosynthetic activities by aquatic plants since the vegetation of the study sites vegetation reflected that of savannah zone, dominated by grass but with scattered trees. This is similar to the findings of Akponine and Ugwumba (2014) on the physico-chemical parameters and heavy metal contents of Ibuya River in old National Park, Sepeteri, Oyo State, Nigeria. The overall mean values of phosphates recorded (0.40 mg L^{-1}) were generally low when compared to the standard of 3.2 to 630 mg L^{-1} recommended by Beadle (1981), and this could also be attributed to same dearth of significant farming activities around the study sites. It could also be due to dilution and movement of water which could not allow aquatic sedimentation and decay of organic matter. The studies of Yakubu *et al.* (2014) and Ojutiku and Kolo (2011) in

Nigerian water bodies corroborated this present study. Meanwhile, phosphates concentrations decreased as from the water moves from Site A through Site C, and this could be attributed to the impact of anthropogenic activities that were more evident and increased from Site A through Site C.

Metal levels in the three sites existed in the order Fe >Mn>Zn >Cu >Pb. Lead (Pb) was not detected at all. Similar result was also observed by Khan, *et al*. (1998) in Ganga-Brahamputra-Meghna Estuary. The mean concentration of Mn in this study was 2.0 mg L^{-1}. In all the sampled sites, Mn was found to be higher than 0.01 mg L^{-1} recommended limit for Mn in drinking water (USEPA, 2010). The waters of River Kaduna is therefore, declared unfit for human consumption as this would lead to Mn related illnesses. Adoption of adequate measures to remove this Mn load is necessary to avoid further deterioration of the river water quality. River Kaduna is contaminated by Fe. The mean value of 2.73 mg L^{-1} recorded in this study exceeded the maximum contamination level (MCL) of < 0.03 and <0.3 recommended by WHO (2004) and USEPA (2010), respectively. The high concentrations of Fe in the sediment had no identifiable point source discharge rather than lithological or crustal origin. This may also be linked to the fact that River Kaduna and its tributaries is surrounded by high concentration of industries and factories such as petrochemical plants, battery factory, fertilizer and pesticides factory as well as Defense Industrial Corporation (DIC) base in Kaduna town. These factories including household and sewage waste constitute potential sources of Iron (Fe^{+}) and other heavy metals which might be transported in large volumes that could reach fish and other aquatic organisms either through direct drainage or atmospheric deposition.

Copper (Cu) is an essential substance to human life, but chronic exposure to contaminant drinking water with Cu can result in the development of anemia, liver and kidney damage (Madsen, *et al*., 1990; Bent and Bohm, 1995). On the other hand, lack of copper intake causes anemia, growth inhibition, and blood circulation problems (Jennings, *et. al*., 1996). Zn is present in large amounts in natural water (USEPA, 2010). The mean concentrations of 0.03 mg L^{-1} and 0.16 mg L^{-1} for Cu and Zn, respectively, were far below the MCL of WHO (2004) and USEPA (2010). Pb was not detected at all in all the sampled sites. Exposure to lead is cumulative over time. High concentrations of lead in the body can cause death or permanent damage to the central nervous system, the brain, and kidneys (Jennings *et. al*., 1996). This damage commonly results in behavior and learning problems (such as hyperactivity), memory and concentration problems, high blood pressure, hearing problems, headaches, slowed growth, reproductive problems in men and women, digestive problems, muscle and joint pain. Studies on lead are numerous because of its hazardous effects (Salem *et al.,* 2000). Lead is considered the number one health threat to children, and the effects of lead poisoning can last a lifetime. Not only does lead poisoning stunt a child's growth, damage the nervous system, and cause learning disabilities, but also it is now linked to crime and anti-social behavior in children (Salem *et al.,* 2000).

Conclusion and Recommendations

There was linear correlation among temperature, conductivity, DO, and phosphates, and this correlation revealed that, due to anthropogenic activities, the water quality deteriorated increasingly as the water traveled from Site A to Site B. The physicochemical parameters – pH, surface and water temperatures, conductivity, BOD, phosphates, and nitrates were within the limits recommended by USEPA (2010) and FEPA (1991) for survival of aquatic organisms, as well as WHO (2004) for drinking purposes. However, the values of DO and transparency fell outside these limits. Data obtained for heavy metals showed that Mn and Fe were above the maximum contaminant levels (MCLs) of USEPA (2010) and WHO (2004). The waters of River Kaduna is therefore, declared unfit for human consumption as this would lead to Fe and Mn related illnesses, therefore posing potential risk of bio-magnification for inhabitants that depend on the river. Therefore, there is an urgent need to properly manage wastes in the cities and monitor anthropogenic (human) activities in order to ensure minimized effects on these parameters of River Kaduna. The need for constant monitoring of the levels of contamination to assess the impact of the heavy metals cannot be underestimated. This is necessary since the river serves as a source of drinking water, irrigation and fisheries for the local inhabitants.

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Author's Contributions:

UNK and FOA designed the study, performed the statistical analysis and wrote the draft of the manuscript. SMA did the sample collection and analysis while AVA managed the literature searches and heavy metal analysis. All authors read and approved the final manuscript.

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