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Assessment of physicochemical and elemental quality of water from River Lavun, Bida, Niger State, Nigeria

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Abstract
Bida axis of Niger State, Nigeria depends on River Lavun for its domestic and commercial activities especially for fishing, drinking, washing, transportation, irrigation and waste disposal, with potential impact on physicochemical and elemental qualities of the river water. The physicochemical parameters of the river water, namely: temperature, pH, alkalinity, conductivity, phosphate, nitrate, biochemical oxygen demand (BOD) and chemical oxygen demand (COD) evaluated were found to be within acceptable limit set by World Health Organization (WHO) and/or Nigeria Industrial Standard (NIS) while dissolved oxygen (DO) was above the limit. Elemental composition of the river water was also studied using atomic absorption spectrophotometer (AAS). Results of the elemental analysis showed that silver, cobalt, and lead were not detected, while the levels of iron, manganese, nickel, and cadmium, were above acceptable limit of drinking water set by WHO and/or NIS.

Keywords: Physicochemical; Elemental, Water quality, River Lavun

INTRODUCTION

Water is available in abundance in the earth crust, but accessibility and availability of good quality water to the populace at the right time is still a mirage [1]. The main source of water to the rural people in developing countries is surface water (rivers, streams and lakes) whose quality is often altered due to anthropogenic activities that happen around the river. Rivers are also used as medium for disposal of wastes that are mostly derived from industrial, agricultural and domestic activities. These water bodies, which often receive treated, untreated or partially treated industrial wastes, are often highly polluted [2]. The undesirable changes in the water quality negatively affect the ecosystem and eventually the populace of the locality who often depend on the water for survival [3,4]. Such pollutions resulted in disease causing in the presence of organisms which if consumed without proper treatment would impact negatively on the health of the populace [5]. Also, Shalom *et al.* [6] revealed that surface water of Cananland, Ota (Southwest Nigeria) is contaminated and of poor quality. This growing problem of river water pollution has necessitated the monitoring of water quality [7,8]. In majority of local settlements of developing countries, there is often paucity of infrastructure for proper treatment and distribution of water, which its

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eventual consumption could result in waterborne diseases.

The modern agricultural practices, which encourages the use of metal-based fertilizers, could alter the quality of fresh river water through agricultural land run-off [9]. Dimowo [10] reported that River Ogun (South-western Nigerian) is highly polluted and unsafe for both domestic uses and aquacultural purposes. In the same line, it was reported [11] that disposal of industrial effluent as well as human activities negatively impacted on the quality of Ikpoba River Benin (South-South Nigeria) such pollution have caused the death of all aerobic species, including, fish [12].

Chemicals (organic and inorganic), from industrial waste, mining and agricultural activities often found their way into lakes, rivers and streams through open drains and gutters. Human activities could also deteriorate the quality of these water bodies with chemicals. An increase in heavy metal ion concentrations in such water environment could lead to elemental poisoning, when the water is consumed. Metal pollutants in the form of particles, metal ions, and organic and inorganic compounds would make the aquatic environment toxic [13]. In this type of situation, the aquatic life is also threatened as the metals diffuses and get accumulated in aquatic animals such as fish [14,15] which when consumed could result in various health implications.

River Lavun is situated close to the agricultural land that is most time cultivated and serve as a collection centre of rain ruin-off. The river water is also use for fishing, transportation, irrigation and for domestic purposes due to lack of portable water which could pose a serious health threat to the communities. Water is vital to human, animal and plant existence, and therefore the need to assess the physicochemical and elemental quality in order to proffer guidelines for its sustainable usage and/or make corrective steps to ensure its quality.

EXPERIMENTAL

Study area. This study is carried out on the lower part of River Kaduna called River Lavun, at Wuya Kpata, Bida North Central Nigeria on Lat. 9°08'21"N and Long. 5°49'57"E as previously described [5]. Water samples were collected from three (3) sites: Wuya Kpata (Site B), a settlement beside the river, Site A is about 400 m before the settlement while Site C is in the range of 400 m after the settlement along the river.

Collection of water samples. Water samples for determination of physicochemical properties were collected in one litre (1 L) capacity plastic containers which had previously been thoroughly washed, rinsed with 50 % nitric acid solution and finally rinsed in distilled water. The container was dipped in river water to about 30 cm below the surface facing the water current. The water was collected and filled to capacity to prevent entrapment of air and promptly closed and transported to the laboratory on ice.

Physicochemical Analysis

The water samples were collected once every month at three (3) different locations as stated, within the period of April to September 2014. Physicochemical parameters of river water such as temperature, pH, total alkalinity, conductivity, DO, BOD, COD, nitrate, and phosphate. They were determined using standard methods described by American Public Health Association, APHA [16].

pH and temperature measurement. The pH meter (Jenway 3505 bench top) was calibrated using standard solutions of pH 1,4,7,9 and 12. The electrode of the pH meter was rinsed with distilled water before and after each use. Twenty-five millilitres (25 mL) of water sample was placed in a beaker and the electrode probe immersed. After stabilization, the pH value was read and average value recorded. The temperature was taken at each point of sample collection using a mercury thermometer. Two reading were taken at each point before sample was collected and the average taken.

Conductivity measurement. Prior calibration of conductivity meter (Jenway 4010) was carried out with solution provided by the manufacturer. in accordance with instructions. Conductivity values in microsiemens (µS) of the water samples were measured, as follows: after priming, and washing with distilled water, the electrode probe was placed in a beaker containing 25 mL of each samples and readings taken and averaged.

Determination of dissolved oxygen (*DO*). A glass stoppered BOD bottle was used. At the site of sample collection, the BOD bottle was filled with water sample with no air trapped and stoppered. Two millilitre (2 ml) each of reagent A (manganous sulphate solution) and reagent B (alkaline potassium iodide solution) were added and stoppered. To the bottle, 2 ml sulphuric acid was added and shaken thoroughly. Ten millilitre (10 ml) of this solution was the transferred into a conical flask gently and a few drops of starch indicator was added. The solution was then titrated against 0.025N sodium thiosulphate solution and the end point noted when the initial blue colour turned colourless and the titre value and DO was calculated thus:

$$DO\left(\frac{mg}{l}\right) = \frac{Tv \times 0.025 \times 8 \times 1000}{10} \quad \ldots\ldots\ldots Eqn. 1$$

Where Tv is the titre value used in titration

Determination of biochemical oxygen demand (*BOD*). Levels of biochemical oxygen demand (BOD) mg/l, which is the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions, was measured by the difference in the dissolved oxygen content of sample on day one (D_1) and the dissolved oxygen content after five days of incubating the sample at 20°C in the dark (D_2).

$$BOD\left(\frac{mg}{l}\right) = \frac{D1 - D2}{P} \quad \ldots\ldots\ldots Eqn.2$$

where $D1$ = dissolved oxygen of sample immediately after preparation. $D2$ = dissolved oxygen of sample after 5 days of incubation

P = decimal volumetric fraction of sample used.

Determination of chemical oxygen demand (*COD*). A 20 mL of sample was measured into a flask of reflux unit and 10 mL of 0.025N potassium dichromate solution, a pinch of each silver nitrate and mercuric sulphate and 30 mL of sulphuric acid were added. The condenser was attached to flask and the flask heated on a heating mantle for two hours to reflux the contents. The flask was cooled and detached and its content diluted to 150 mL by adding distilled water. Some 2-3 drops of ferroin indicator solution was added and titrated against ferrous ammonium sulphate solution. At the end point, blue colour of content changed to reddish blue. Blank sample of distilled water was run simultaneously with this experiment and the COD was calculated, as stated the below equation.

$$COD\left(\frac{mg}{l}\right) = \frac{(Sample\ Tv - Blank\ Tv) \times 0.025 \times 8 \times 100}{Volume\ of\ Sample\ used} \quad \ldots\ldots\ldots Eqn. 3$$

where $Sample\ Tv$ = Titre value of the sample

$Blank\ Tv$ = Titre value of the blank

Determination of total alkalinity. Fifty millilitre (50 ml) of water sample was added into a conical flask followed by 2-3 drops of methyl orange indicator and titrated against 0.02N sulphuric acid until yellow colour solution turned orange (end point), titre value was read and total alkalinity calculated thus:

$$Total\ alkalinity\left(\frac{mg}{l}\right) = \frac{Tv \times 0.02 \times 50000}{\text{Volume of sample}} \quad \ldots\ldots Eqn. 4$$

where Tv is the Titre value

Determination of phosphate content. A 100 mL of sample was added into a volumetric flask followed by 1 drop of phenolphthalein indicator and 4 mL of vanadium molybdate reagent and then 10 drops of stannous chloride reagent. The mixture was allowed to stand for 10 minutes and then measured photometrical at a wavelength of 690 nm in a UV-Visible Spectrophotometer. From the calibration curve earlier produced using different concentrations (0.05, 0.15, 0.25, and 0.35 mg/l). The concentration of phosphate was computed using the formula:

$$Phosphate, PO4\left(\frac{mg}{l}\right) = \frac{Weight\ of\ PO4\ (mg)\ \times 1000}{\text{Volume of water sample (ml)}} \quad \ldots \ldots \textit{Eqn. 5}$$

Determination of nitrate content. A 25 mL of water sample was measured into porcelain basin and evaporated to dryness on a hot water bath. A 0.5 mL of phenol disulphuric acid was added to the residue. To the resulting solution, 5 mL of distilled water and 1.5 mL of potassium hydroxide solution was added and stirred for thorough mixing. The yellow colour supernatant was taken and the absorbance (S) was read on a UV- visible spectrophotometer at 410 nm wavelength. Distilled water was used as blank. Graph of absorbance against concentrations of various standard solutions was used to deduce the value of nitrate and expressed as mg/l.

Determination of elemental composition. Ten millilitre (10 ml) each of water samples were measured into a beaker and 10 ml mixture of $HNO_3 – H_2O_2$ (1:1) was added and digested for 2 hours at 160°C. The digest was cooled, filtered and transferred to 100 ml volumetric flask and filled up to the level with de-ionized water [17]. Digested water samples were analysed using flame Atomic Absorption Spectrophotometer (model AA240FS, Varian), at the Multi-User Science laboratory Ahmadu Bello University Zaria. The dilution factor of the sample was used to determine the final concentration of the various elements in water. The elements assessed were calcium (Ca), silver (Ag), cobalt (Co), iron (Fe), cadmium (Cd), manganese (Mn), lead (Pb), zinc (Zn), nickel (Ni), magnesium (Mg), copper (Cu), potassium (P) and sodium (Na).

RESULTS

Physicochemical properties of water samples. Results of the physicochemical tests carried out on water samples from River Lavun at different points during the period of April to September 2014 are presented in Tables 1 and 2. The pH values showed that the river water was slightly acidic (6.61-6.79 mg/L) in the peak of rainy season (September) but alkalinic in the beginning of rainy season April. The DO, BOD and COD during the sampling period showed similarity in the pattern of the values and the three parameters were generally lower during the months of April (beginning of rainy season) but highest in the peak of rainy season (September). The values of DO ranged from 6.00 – 16.00 mg/L. The highest value of 16 mg/L was observed in September, which is the peak of rainy season. The BOD showed similar pattern with DO. COD values were generally high, as much as twice of the values of DO and BOD in each of the month. The increase in the values of OD, BOD and COD between April and September were generally significant. The conductance varied from 35 – 53 (µS/cm) with general trend of higher values in the beginning of rainy season (April), and lower values in the peak of the rainy season. There was high significant difference ($p<0.05$) between values in April and September. The nitrate contents remained fairly constant in April and September while the phosphate concentration was significantly higher in September (peak of rainy season). Temperature values were inversely proportional to the values of DO.

Elemental analysis of water. Composition of elements in the river water samples from different sampling points are presented in Tab. 3. Ag, Co and Pb were below detectable level during the sampling period and were irrespective of the sampling points. Highest concentration of calcium, potassium and sodium were recorded in August at site B. However, concentration of elements at site B was generally higher when compared with that of sites A and C. Except for K and Na, which increased in concentration from April to August, concentrations of other elements, decreased with increasing rainfall.

Table 1: Physicochemical properties of River Lavun across 3 sampling sites in April 2014 (Beginning of rainy season)

Parameter (Unit)	Site A	Site B	Site C	WHO standard
pH	7.85	8.19	8.29	6.5-8.5
Temperature (°C)	32.00	33.00	33.00	30.0
Conductance (µS/cm)	44.00	48.00	53.00	8-10,000
D.O (mg/L) *	8.00	6.00	6.00	3.0
B.O.D (mg/L) **	6.00	4.00	4.00	30.0
C.O.D (mg/L) **	16.80	14.30	14.40	80.0
Alkalinlty (mg/L) **	20.00	22.00	20.00	150.0
Phosphate (mg/L) **	0.90	0.85	0.90	6.50
Nitrate (mg/L) **	0.32	0.19	0.28	5.0

*****Higher than WHO standard **Lower than WHO limit

Table 2: Physicochemical properties of River Lavun across 3 sampling sites in September 2014 (Peak of rainy season)

Parameter (Unit)	Site A	Site B	Site C	WHO standard
Ph	6.61	6.67	6.79	6.5-8.5
Temperature (°C)	30.00	30.00	30.00	30.0
Conductance (µS/cm)	36.00	35.00	35.00	8-10,000
D.O (mg/L) *	14.00	10.00	16.00	3.0
B.O.D (mg/L) **	10.00	6.00	13.00	30.0
C.O.D (mg/L) **	16.90	20.00	18.60	80.0
Alkalinlty (mg/L) **	14.00	12.00	18.00	150.0
Phosphate (mg/L) **	2.23	2.28	2.26	6.50
Nitrate (mg/L) **	0.24	0.22	0.30	5.0

*****Higher than WHO standard **Lower than WHO limit

Table 3: Concentration of elements in water collected from River Lavun in 2014

Ele-ment	Site A			Site B			Site C			WHO std
	April	June	August	April	June	August	April	June	August	
Ca	2.23±0.005	4.81±0.002	13.01±0.003	6.68±0.009	6.17±0.002	22.78±0.007	7.86±0.007	6.22±0.002	4.64±0.005	-
Ag	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
Co	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
Fe*	29.18±0.007	33.04±0.003	34.00±0.003	48.49±0.007	33.02±0.002	5.52±0.006	48.94±0.009	32.24±0.008	4.87±0.004	0.3
Cd*	ND	0.05±0.006	0.03±0.003	0.005±0.007	ND	0.002±0.005	0.03±0.002	0.02±0.003	0.02±0.002	0.03
Mn*	ND	ND	ND	1.31±00.004	ND	1.54±0.008	3.87±0.004	0.21±0.006	ND	0.4
Pb	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.01
Zn	1.67±0.010	1.42±0.022	1.38±0.013	1.74±0.008	3.61±0.015	1.15±0.006	1.90±0.012	3.59±0.024	2.68±0.023	5
Ni*	0.13±0.009	0.16±0.007	ND	0.24±0.005	0.25±0.004	ND	0.11±0.006	0.10±0.005	ND	0.07
Mg	19.73±0.007	16.56±0.012	16.00±0.009	42.83±0.004	21.56±0.005	19.86±0.003	20.49±0.004	20.01±0.033	19.24±0.032	-
Cu	0.02±0.004	0.03±0.002	0.02±0.002	ND	0.001±0.001	0.29±0.002	0.03±0.003	0.02±0.002	0.25±0.002	2
K	37.00±0.012	32.00±0.009	50.00±0.012	40.00±0.006	42.00±0.011	67.00±0.016	40.00±0.014	40.00±0.024	50.00±0.004	-
Na	49.00±0.006	43.00±0.012	65.00±0.024	53.00±0.003	53.00±0.003	98.00±0.003	52.00±0.009	51.00±0.017	74.00±0.012	200

Key: *****Higher than WHO standard SD=Standard deviation ND=Not detected WHO= Word Health Organization

DISCUSSION

The results of physicochemical analysis of the River Lavun revealed that variation in climatic season have had some effect on the physicochemical properties of River Lavun. Temperature is one of the most important ecological features and it controls behavioural characteristics of organisms, solubility of gases and salts in water. It helps in the determination of other factors like pH, conductivity, and various forms of alkalinity. The variation observed is mainly related with the temperature of atmosphere and weather conditions [16].

In natural waters, CO_2, H_2CO_3 and HCO_3^- are principal components that regulate pH. The lower pH values in the peak of rainy season, which is similar to the values, reported in Asa River Ilorin by Salaudeen [18]. This might be due to high organic content from the urban and agricultural runoff into the water body. Cude [19] reported that water containing high organic content such as abattoir wastes tends to be acidic.

Electrical conductivity reflects the overall degree of mineralization, and indicates the salinity of the water. Presence of ions, and their concentrations, mobility, and valence determines the electrical conductivity. The conductivity values are within the standards for drinking water [1]. Nitrate levels were generally low, indicating that sources of nitrate pollution such as fertilizers and wastewater discharges were not contributing factor in the study area. Alkalinity is the quantitative capacity of water sample to neutralize a strong acid to a designated pH [20]. This result is in agreement with the work of Ashish and Yogendra [21] who also observed relatively lower alkalinity value (91 mg/L) in the rainy season in River Kosi India as against 200 mg/L in winter.

Dissolved oxygen is a factor, which is used to determine whether the biological changes are brought about by aerobic or anaerobic organism. The slightly higher DO values in the peak of the rainy season indicate relatively mild organic pollution that might have resulted from sewage wastes from human settlement [22]. These results also agree with those of other researchers [21,23]. Values of BOD, which is a measure of oxygen in the water that is required by the aerobic organisms, shows the level of biodegradation of organic materials. The higher values in the peak of the rainy season also indicates presence of organic pollution.

Chemical oxygen demand is commonly used to indirectly measure the amount of organic compounds in water [24]. It points to a deterioration of the water quality caused by the discharge of industrial effluent and domestic sewage [20]. The COD values in this study followed similar trend with BOD values. Moderate COD values indicate industrial pollution. However, the only industrial plants relatively near the study area are the Niger state water treatment plant and the Plastic industry situated in Minna, about one hundred kilometres away which is not expected to play a major factor.

During the period of this study, Ag, Co and Pb were not detected in the water samples. Mn was only detected at points B and C. Iron (Fe) is one of the most abundant metals in the earth's crust. It's an essential trace element required by all forms of life. The average daily intake of iron has been estimated to be 17 mg/day for males and 9-12 mg/day for females [25]. Hazard of pathogenic organisms may be increased because of the presence of Fe since most of these organisms need Fe for their growth [26]. The Fe values of the different sites of river water samples were found to be above the permissible limit of standards for drinking water by WHO [1] and Nigeria Industrial Standard [27]. These high Fe values might be due to the run-off from domestic and urban wastes. This could lead to toxicity. Though excessive iron is not stored in the body, impaired ability to regulate iron absorption may result in siderosis in liver, pancreas, adrenals, thyroid, pituitary and heart and which could manifest as cirrhosis, adrenal insufficiency, heart failure or diabetics.

The Mn levels in the river exceed the permissible limit of standard of drinking water prescribed by NIS [27]. The higher Mn concentration may be attributed to the addition of agricultural run-off, sewage and domestic wastes in the river. Researchers [28,29] have also reported contamination by Mn of Ogun River, Abeokuta, South-west Nigeria and River Lanzun, Bida, Northern Nigeria respectively. Epidemiological studies have reported adverse neurological effect following extended exposure to high levels of Mn in drinking water could result [1].

Zinc is a ubiquitous metal present in the environment. The values though within the acceptable limit recommended by WHO, for drinking water, exceeded those recommended by NIS [27]. The higher value at point B could be as a result of increased human activities such as washing at this site. This is similar to the observation of Olagoke and Olatunji [29] on River Lanzun, a tributary to River Lavun.

The Copper (Cu) values of water samples at all the sampling points were above the permissible limits set by NIS [27] and WHO [1] for drinking water. Cu is a necessary nutrient for human health. High doses of Cu results in anaemia, liver and kidney damage, and stomach and intestinal irritation [30]. The higher Cu concentration might be due to the addition of agricultural run-off, sewage and domestic wastes in the river.

The water concentration of Ni was also above the permissible limit set by both the WHO and NIS. Allergic contact dermatitis is the most prevalent effect of nickel in the general population [1]. Nickel (Ni) is a moderately toxic element and consumption of water or food with high Ni content may cause serious problems. Similarly, Cd level in the river water samples were above permissible level. Cd is widely known to be a highly toxic non-essential heavy metal and it does not have a role in biological process in living organisms. Thus even at low concentration, Cd is harmful to living organisms [31].

Conclusion. The presence of heavy metals such as Fe, Mn, Ni and Cd above the allowable limit makes the River water unsafe for domestic use and consumption.

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