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Assessment of Physicochemical Properties of Water and Sediments in Ikpoba and Ogba Rivers, Edo State, Nigeria

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ABSTRACT: The importance of good water quality to environmental and human health cannot be over-emphasised and physicochemical properties are essential in assessing the quality of water around the world. This study therefore, assessed the physicochemical properties of water and sediments in Ikpoba and Ogba Rivers, Edo State, Nigeria, following standard procedures. The results obtained from the study showed that most of the analysed samples were within the safe limits recommended by the WHO. The values for the physicochemical properties of the water samples from both rivers were also within the permissible limits, except for pH (5.7 - 6.6) and dissolved oxygen (2.73 - 6.32mg/l), when values were compared with WHO recommendations. The results from the study also showed observed trends in the results of the various parameters determined by the seasons. Statistical analysis revealed the absence of significant differences ($p < 0.05$) between the physicochemical and WHO recommendations for water and sediments from both rivers with very few exceptions. It was then recommended that periodic monitoring and assessment of water and sediments in the study area be carried out.

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Rivers are vital sources of water for various human activities and ecosystems, serving purposes such as drinking, irrigation, sanitation, industrial use, and recreation. However, the quality of surface water in rivers can be influenced by both natural phenomena and human activities. Natural events like floods and erosion introduce sediments, nutrients, and other substances into the water, affecting its physicochemical properties and overall quality (Nitasha and Janjiv, 2014). On the other hand, anthropogenic sources of pollution, including direct waste disposal, industrial effluent discharge, agricultural practices (such as pesticide and fertilizer application), and improper sanitation, significantly contribute to water pollution in rivers (Debels *et al.*, 2005; Dapam *et al*., 2016). These activities introduce pollutants that poses various risk to human health and the environment (Darvishi *et al*., 2016). Heavy metals, elemental nutrients, particulate matter, and microorganisms are common contaminants found in river water. Heavy metals such as lead, mercury, and cadmium are known to be toxic and can have adverse effects on human health, including neurological disorders, gastrointestinal issues, carcinogenic effects, and birth defects (Mitra *et al*., 2022). Microorganisms present in polluted water can cause a range of diseases, varying in severity depending on the specific pathogens involved (Khayan *et al*., 2019). Waterborne diseases such as cholera, typhoid fever, and dysentery can be transmitted through contaminated water sources (Khayan *et al*., 2019). Rivers not only serve as essential water resources but also as habitats for diverse living organisms, including microorganisms, invertebrates, and fish. However, they are susceptible

to contamination from various sources, such as agricultural runoff, industrial discharge, and domestic effluents. Physicochemical changes represent the presence of contaminants that can enter rivers through the disposal of these effluents. Evaluating the physicochemical properties of water and sediments can provide valuable insights into the extent of pollution and its potential impacts on the rivers' ecosystems. Physicochemical parameter such as the pH of water is a critical indicator of its quality, influencing water solubility and nutrient content (Amadi *et al.*, 2010; Ching *et al.*, 2015). Electrical conductivity, another important parameter, depends on the presence, concentration, and mobility of ions, as well as temperature (Saxena and Sharma, 2017). Turbidity, the measure of water clarity, indicates the presence of suspended particles. Excessive turbidity can impair light penetration, affecting aquatic life and ecosystem dynamics (Onoyima *et al.*, 2022). Additionally, the concentrations of various ions, heavy metals, and nutrients in the water and sediments reflect the degree of pollution and potential ecological consequences (Onoyima *et al*., 2022). Therefore, the objective of this paper is to assess the physicochemical properties of water and sediments in Ikpoba and Ogba Rivers, Edo State, Nigeria.

MATERIALS AND METHODS

Study Area: This investigation was carried out in Benin City, Edo state, Nigeria. Ikpoba and Ogba rivers were the areas of focus in this study. They are the main freshwater bodies which pass through Benin City. Both are tributaries of the Ossiomo River which eventually is emptied into the Benin River. Ikpoba and Ogba rivers are characterized by similar natural and anthropogenic activities. Anthropogenic activities which occur near these rivers include vehicle repair and maintenance work, release of wastewater from markets, fishing activities, washing and, depending on the season, boat transportation. Ikpoba and Ogba rivers serve as habitats for diverse species of plants and aquatic animals.

Sample Collection and Preparation: Water and sediment samples were taken from selected locations along the stretch of the Ikpoba and Ogba rivers. On each river, six (6) sampling locations were selected to reflect the upstream and downstream parts of the rivers. Sampling took place monthly from November 2021 to January 2022. The various sampling points for the study are shown in Figure 1.

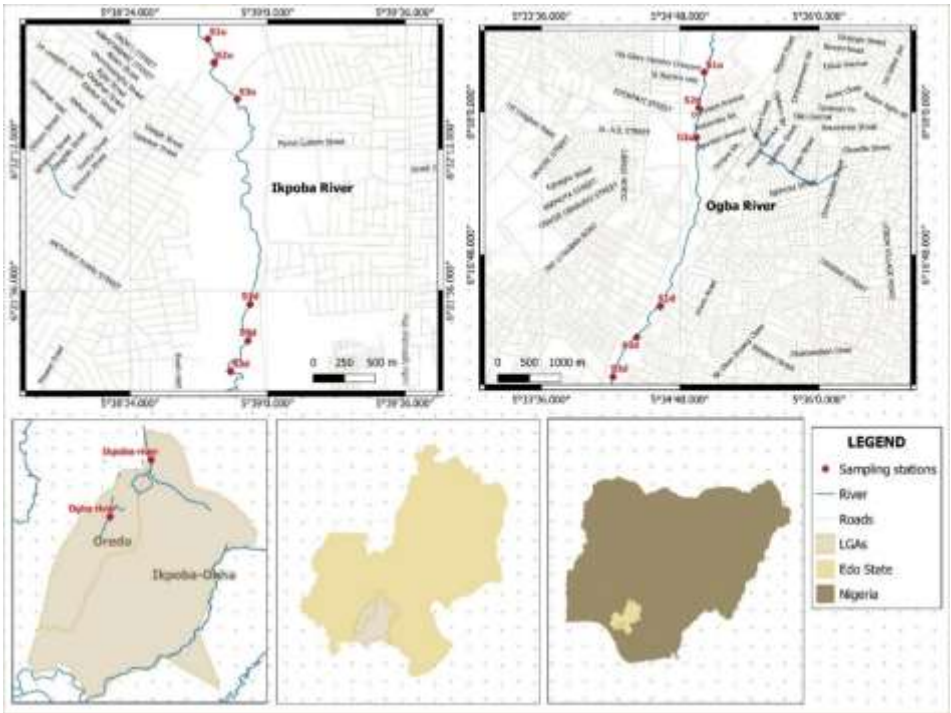

Fig 1: A map of the study areas indicating the sampling locations

Water Samples: Water samples were collected using 1-litre sterilized sampling bottles, while water samples for biochemical oxygen demand analysis were collected using BOD bottles. Samples were collected by submerging the bottles until they were filled, upon which they were corked, properly labelled and stored under ice. They were then transported to the laboratory for analysis.

Sediment Samples: Sediment samples were collected by grab sampling. Samples were wrapped in foil and properly labelled. After transportation to the laboratory, sediment samples were oven-dried and sieved using a 2mm mesh sieve.

Physicochemical water analysis: The determination of physicochemical parameters were carried out in accordance with the method described by APHA (2005). The pH of water was determined using a HANNA pH meter. Electrical conductivity and total dissolved solids (TDS) was measured using a HACH conductivity meter. Total solids (TS) was determined by the gravimetric method and total suspended solids (TSS) was determined by subtracting TDS from TS. Spectrophotometry was employed in the determination of turbidity, sulphate, nitrate and phosphate. Chloride was determined by titration with silver nitrate solution. The concentrations of dissolved oxygen (DO) and biochemical oxygen demand (BOD) were determined by way of Winkler titration.

Physicochemical sediment analysis: The pH and electrical conductivity of sediment were determined in water using a HANNA pH meter and a HACH conductivity meter, respectively. The organic carbon content was determined via the Walkley and Black method and organic matter was calculated from the obtained value. Ammonium nitrogen was determined using Kjeldahl wet digestion method. Phosphorus was determined via the Bray-1 method.

Statistical and Data Analysis: The determination of means and standard deviations of the values obtained for physicochemical properties and heavy metal concentrations in all samples was done using Microsoft Excel 2016 Sheets. Comparison of the values obtained for both rivers was done by way of paired samples t-tests were carried out using IBM SPSS Statistics version 16.

RESULT AND DISCUSSION

The Physicochemical Properties of water samples from Ikpoba River as depicted in Figure 1, showing the mean minimum and maximum values, respectively, were as follows: pH value was 5.70 in December and 6.60 in January, electrical conductivity was 22.67µS/cm in December and 35.00µS/cm in November. Meanwhile suspended solids was 6.33mg/L in January and 28.33mg/L in November; for turbidity, 7.83mg/L was recorded in January and 42.33mg/L in November, chloride on the other hand was 10.59mg/L in January and 17.65mg/L in November, calcium, was 1.87mg/L in November and 2.41mg/L in December. The concentration of magnesium was 2.00mg/L in January and 3.65mg/L in December, dissolved oxygen was 2.73mg/L in November and 6.32mg/L in December, while biological oxygen demand was 1.80mg/L in November and 3.73mg/L in December. Sulphate had its minimum value as 3.83mg/L in January and maximum value as 11.00mg/L in November, phosphate was 0.12mg/L in November and 0.17mg/L in January, while nitrate was 0.11mg/L in December and January and 0.26mg/L in November and ammonium-nitrogen was 0.12mg/L in December and it increased to 0.20mg/L in January.

The data for the physicochemical properties of water samples from Ogba River (Figure 2), had a minimum and maximum value, respectively, considering the three months of sampling were as follows: pH, was 5.57 in November and 6.30 in January, electrical conductivity was 59.67µS/cm in January and 68.17µS/cm in December. Meanwhile suspended solids was 2.50mg/L in January and 37.80mg/L in November while for turbidity was 5.83mg/L in December and 56.50mg/L in November while chloride, had values 11.77mg/L in December and 15.30mg/L in November. Calcium concentration was reported to be 4.14mg/L in December and 8.69mg/L in November, magnesium was 1.95mg/ L in January to 2.60mg/L in December while dissolved oxygen was 3.15mg/L in January and 3.88mg/L in December. The minimum value obtained for biological oxygen demand was 1.77mg/L in December and maximum value was 2.85mg/L in January, sulphate values were obtained as 4.00mg/L in January and 15.50mg/L in November. Phosphate had a minimum value of 0.14mg/L in November and 0.42mg/L in December, while nitrate value was 0.15mg/L in December and 0.31mg/L in November; and ammonium-nitrogen was 0.24mg/L in January to 0.72mg/L in December.

On the whole, the physicochemical properties of the water were in line with the drinking quality guidelines recommended by the World Health Organisation (WHO, 2017). The only exceptions to this were pH (5.57 - 6.6) which fell below the recommended range in majority of the water samples and dissolved oxygen (2.73 - 6.32mg/l). The low pH values render the water unfit for human consumption, while the low dissolved oxygen levels are not favourable for aquatic organisms (Shehu, 2019). Similarly, low pH values have been recorded in previous studies and the same goes for dissolved oxygen (Okaa and Ogu, 2020; Onoyima *et al*., 2022). On the other hand, the values obtained for all other parameters including electrical conductivity, turbidity, suspended solids, biochemical oxygen demand, cations (ammonium, calcium and magnesium) and radicals (phosphate, sulphate and nitrate) were within the range of WHO limits (WHO,

2017). Additionally, there were steady variations in the results as the study progressed into the dry season. This points to the influence of reduced rainwater and runoff inputs during the dry season on the quality of water in the rivers. This agrees with studies by other researchers (Azeem *et al.,* 2016; Pereira *et al.,* 2021).

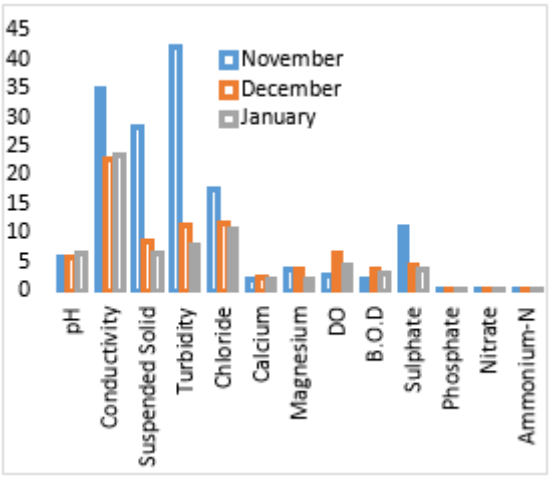

Fig 1: Physicochemical properties of Ikpoba River water samples

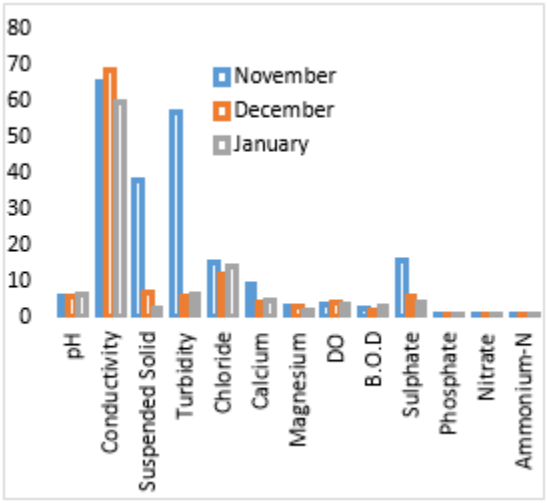

Fig 2: Physicochemical properties of Ogba River water samples

The WHO acceptable limit for sulphate in water is 250mg/l (WHO, 2017). In this investigation, none of the sulphate in water measurements recorded surpassed this limit. Phosphate in water has a standard maximum of 1mg/l, and none of the values collected surpassed this threshold. In the case of nitrate, no value was obtained above the permitted limit of 10mg/L. These findings indicated that the Ikpoba and Ogba rivers were not polluted by sulphates, phosphates, or nitrates. These findings are consistent with earlier research (Nnaji *et al*., 2010; Cavin, 2013). The allowable limit for ammonia is 35mg/l (WHO, 2017). The ammonium amounts in the samples were all within permitted levels, suggesting the lack of contaminating substances. All turbidity levels surpassed the prescribed limits, with the Ikpoba (7.83 - 42.33 NTU) and Ogba (5.83 - 56.50 NTU) rivers exhibiting significant turbidity that reduced as the dry season advanced. This tendency is caused by a reduction in river water volume and speed during the dry season (Azeem *et al*., 2016). A research conducted by Sunday (2018) had similar outcomes. The maximum chloride concentration in water is 250mg/l. The chloride amounts measured in the water samples tested in this investigation were all substantially below the limit. Calcium and magnesium concentrations measured in the water samples did not exceed the allowed limit of 50mg/l (WHO, 2017). The data from this study indicate that there was no contamination from chloride, calcium, or magnesium in the water from the Ogba and Ikpoba rivers. Previous research has shown similar results (Gupta *et al*., 2016; Sunday, 2018). Comparison of the results obtained for physicochemical analysis of water from both rivers revealed the absence of significant differences ($p < 0.05$) between the values for majority of the parameters. However, there were significant differences between the values of electrical conductivity ($p = 0.014$) and nitrate ($p = 0.023$). This is indicative of water contamination and so water treatment and monitoring should be carried out for both rivers to prevent any progress negative impact physicochemical alterations can incur on the living organisms present in the environment.

Physicochemical Properties of Sediments: The physicochemical properties of sediments collected from Ikpoba River (Figure 3), also had minimum and maximum values, respectively, as follows: pH was 4.28 in December and 6.35 in January; electrical conductivity was 62.67µS/cm in January and 106.00µS/cm in December, meanwhile organic matter was 0.11% in December and 2.96% in January. Organic carbon, had 0.06% in December and 1.72% in January, total nitrogen obtained 0.003% in both November and December, and 0.10% in January. Phosphorus on another hand obtained values 3.13mg/kg in November and 3.81mg/kg in December while ammonium-nitrogen had 0.08mg/kg in January and 1.10mg/kg in November. Similar data were obtained for sediments from Ogba River, as seen in Figure 4, the minimum and maximum values of the physicochemical parameters, respectively, were as follows: pH was obtained as 4.17 in December and 6.18 in January, electrical conductivity was 30.67µS/cm in January and 85.00µS/cm in November. Organic matter had values, 0.62% in November and 2.73% in January while organic carbon was 0.36% in November and 1.59% in January. Total nitrogen was

0.02% in November and 0.09% in January, meanwhile phosphorus was 1.67mg/kg in December and 4.49mg/kg in November and ammonium-nitrogen obtained 0.13mg/kg in January and 1.74mg/kg in November.

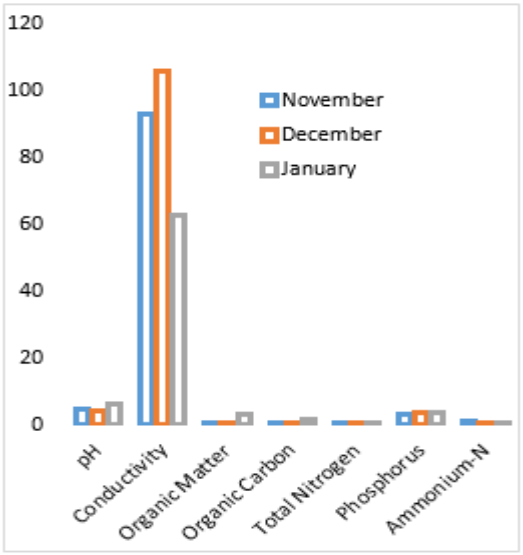

Fig 3: Physicochemical properties of Ikpoba river sediment samples

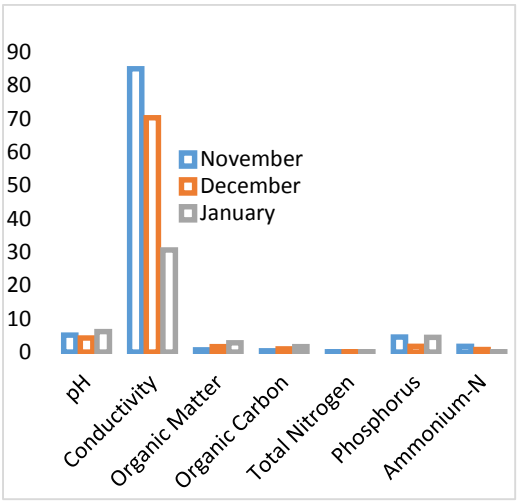

Fig 4: Physicochemical properties of Ogba river sediment samples

Sediments are essential to the health status of water bodies as they are sinks for pollutants and nutrients which enter water bodies. Sediments capture and release these pollutants or nutrients back into the water column depending of factors such as pH, temperature and other conditions within the aquatic ecosystem. Also, aquatic organisms can take up these substances directly from sediments (Pereira *et al.*, 2021). In this study, the physicochemical parameters assessed included pH, conductivity, organic matter, organic carbon, nitrogen, phosphorus and ammonium. The values obtained for these sediment properties were much lower those recorded in previous studies. In a study by Nnaji *et al.* (2010), the mean values recorded for pH, conductivity and organic matter were 5.99, 197.7µS/cm and 3.781%, respectively. In another study by Edori *et al.* (2019), the mean values recorded for pH, conductivity, organic carbon and organic matter were 7.20, 1.67E4µS/cm, 2.37% and 4.09%, respectively. There was a general increasing trend in the values of pH, nitrogen, phosphorus, organic matter and organic carbon sediments as the study progressed from November to January, for both rivers. On the other hand, ammonium-nitrogen decreased over the study period. These changes are attributed to the reduced inputs and eventual absence of rainwater and storm water in the dry season (Shehu, 2019). There were no correlations among the physicochemical properties of sediments from Ikpoba River. Correlation analysis of the physicochemical properties of the sediment samples collected from Ogba river indicated significant positive correlations (p<0.05) between organic carbon and organic matter; and total nitrogen and electrical conductivity. However, there were no significant differences (p<0.05) between the mean values of the physicochemical properties of the sediment samples from both rivers. This result suggest that the industrial and agricultural activities done in the studied riverine region did not cause major alterations in sediment physicochemical properties, however continuous environmental monitoring is necessary to maintain the water quality.

Conclusion: This study assessed water and sediment quality in two rivers in Nigeria and found that most samples were within safe limits. However, pH, electrical conductivity, nitrate and dissolved oxygen were lower than WHO recommendations. Monitoring and assessment are recommended to maintain a good quality of water within the recommended standards.

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