Physicochemical and Heavy Metal Indices of Oba River, Ogbomoso, South-West Nigeria.

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ABSTRACT

This research aimed at assessing physico-chemical characteristics and occurrence of heavy metals in water samples from Oba River. The physico-chemical characteristics and concentrations of heavy metals were determined using standard methods. Data were analyzed using SPSS version 25.0. Practically, all the physico-chemical characteristics assessed fell within acceptable standards by World Health Organization and Nigeria Standard for Drinking Water Quality (NSDWQ). Cobalt, chromium, cadmium and lead were undetected from the water samples. Nickel and copper were only detected during the rainy season, while iron was extremely high during the rainy season. The anthropogenic activities around Oba River had insignificant effect on the water quality considering the water physico-chemical characteristics and heavy metals analysis. However, high iron concentration in Oba River during rainy season should be further researched to identify the source(s) and continuous management of the water body is required.

Keywords: Physico-Chemical, Heavy Metals, Season, Oba River, Ogbomoso, Nigeria

INTRODUCTION

Climate change together with anthropogenic activities brings about profound alterations in the hydrological cycle; hence, water quality degradation has become a critical global challenge[1]. Untreated or incompletely treated industrial effluents, indiscriminate disposal of domestic waste, and farm runoffs are the principal contributors to surface water pollution and decline in water quality[2&3.] Seasonal variations in anthropogenic activities along with natural processes including temperature and precipitation upset the quality of river water and result in different qualities per season[4&5]. Seasonal variations in physico-chemical properties have an intense impact on the fish health, dispersion and population density of both fauna and flora in any aquatic ecosystem[6&7]. Monitoring of water quality is the first step that leads to management, conservation and sustainable utilization of aquatic resources. Water quality is most often underemphasized, it is therefore essential to be acquainted with water quality parameters and their management which have significant impact on aquatic organisms[8].

Oba River is an age long means of livelihood to villagers living along its axis as well as villages nearby through the sales of the fishes captured from it and the use of its water for irrigation farming, besides its various domestic uses for the Ogbomoso populace. Oba River is being fed with water from diverse streams, principally from Afon and Asa Rivers. Consequently, the river is subject to pollution, particularly from the water sources and runoffs from farming and household domains[9]. Therefore, it is very germane to monitor the water conditon of Oba River. Although many studies have been reported on Oba River, there is paucity and dearth of information on the water condition of the river. This research aimed at evaluating the water quality of Oba River in terms of the seasonal variations in the physico-chemical characteristics and concentrations of selected heavy metals in the water samples from Oba River.

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MATERIALS AND METHODS

The Study Area

Oba River (8° 7' 59. 9442" N; 4° 14' 59. 9238" E) is situated at Ikose, Oriire Local Government Area, Ogbomoso, Oyo State. Water samples were obtained from this river at three different sites (A: Upstream; B: Midstream and C: Downstream) of the following coordinates in DMS (Degree Minutes Second) A: 8º11'8.96'' N and 4º12'2.42''E; B: 8º11'5.19''N and 4º12'0.75''E; and site C: 8º11'2.63''N and 4º12'1.12ºE'. The river elevation is 305m with Geographical Positioning System of 3m accuracy. The sites were carefully chosen along the length of the river according to notable activities around each site.

Collection of Water Samples

Surface water specimens were obtained from three sampling locations bi-monthly between 8.00 a.m. and 12 p.m. for the months of May through October, 2023, representing the rainy season; and November, 2023 through April, 2024, representing the dry season. Samples were obtained with the assistance of a local fisherman into plastic bottles, which had been previously soaked in 3% nitric acid and washed with distilled water before sampling[10]. Physico-chemical Characteristics including: temperature, pH, electrical conductivity (EC), total dissolved solids(TDS), salinity, alkalinity, dissolved oxygen (DO), total hardness(TH), biochemical oxygen demand (BOD), total suspended solids(TSS), nitrate, chloride, sulphate, calcium hardness, magnesium hardness, and phosphate, were determined using the conventional methods of Association of Official Analytical Chemists[11].

Digestion of the Water Samples

Digestion of the water specimens was done by introducing 100 ml of water specimens from each sampling point into three different beakers. Five (5ml) of concentrated HNO_3 was added and the sample was evaporated on a hot plate to the lowest volume possible before precipitation. Another 5 ml of HNO_3 was added to the samples and a gentle re-fluxing was carried out using a condenser. Heating and addition of concentrated HNO_3 continued until the samples became lightly colored. Two (2 ml) of concentrated HNO_3 was added to dissolve the residue on the wall of the beakers. The wall of the beakers and the watch glasses were thereafter washed down with deionized water. Digested samples were filtered and made up to 50 ml and then analysis of selected heavy metals including lead, zinc, nickel, iron, cobalt, copper, cadmium and chromium were determined in the digested water sample using Atomic Absorption Spectrophotometer with designated model AAS- Perlin-Elmer 4100 ZL[9].

Data Analysis

Data were analyzed using descriptive statistics (mean and standard error of mean). The level of significance of differences in the values of the parameters was assessed using the student's t-test in two categorical data. Variability in the data was evaluated using the coefficient of variation. Analysis of variance (ANOVA) using SPSS statistical package 25.0 was used in the comparison of data where values of $p < 0.05$ were considered significant.

RESULTS

Analysis of Water Specimens

Physico-chemical and Heavy metals parameters

Water specimens from the three collection points (A, B and C) of Oba River were analyzed for various physico-chemical and heavy metals parameters and compared statistically with the standards of W.H.O. and N. S. D.W.Q. to determine the extent of pollution in the water body. The results of the mean monthly values of each of the analyzed parameters were presented in Tables 1 and 2. Values of physico-chemical and heavy metals parameters varied significantly across the rainy and dry seasons but no statistically significant

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variations across the sites (P>0.05) was observed as shown in the Tables 1 and 2. Cobalt, chromium, cadmium, and lead are reported as "ND" (not detected) at all the sites and the both seasons, suggesting that their quantities are below the detection limit.

Table 1: Mean Values of Physicochemical Characteristics and Heavy Metal Concentrations of Water Samples from Oba River

PARAMETERS	SITE A	SITE B	SITE C	P-VALUE	Regulatory Limits	
					NSDWQ (2017)	WHO (2011)
Ph	6.90±0.05	6.96±0.04	6.96±0.04	0.586	6.5-8.5	6.5-8.5
Temperature (°C)	26.39±0.25	26.78±0.13	26.53±0.16	0.349	Ambient	-
Electrical Conductivity (ds/m)	0.18±0.02	0.18±0.01	0.17±0.01	0.888	1000	25
Total Dissolved Solids (mg/L)	109.31±4.74	103.63±3.09	103.94±2.65	0.462	500	500
Salinity (mg/L)	0.0003±0.0001	0.0002±0.0000	0.0002±0.0000	0.097	-	< 40*
Alkalinity (mg/L)	26.44±3.14	20.13±1.57	20.94±1.13	0.085	-	<120
Dissolved Oxygen (mg/L)	54.94±9.60	54.95±9.51	54.99±9.68	1.000	-	6
Total Hardness(mg/L)	109.06±2.52	107.63±2.69	111.25±2.46	0.604	150	100-150
Biochemical Oxygen Demand (mg/L)	119.25±3.57	126.19±1.62	124.56±1.57	0.121	250	10
Total Suspended Solids (mg/L)	2.40±0.07	2.34±0.08	2.40±0.06	0.822	1500	<1500
Nitrate (mg/100ml)	0.16±0.01	0.17±0.01	0.17±0.01	0.596	50	50
Chloride (mg/100ml)	35.14±0.42	35.03±0.64	36.32±1.27	0.505	-	250
Sulphate (mg/100ml)	0.18±0.00	0.20±0.03	0.17±0.01	0.222	100	250
Calcium (mg/100)	53.45±1.28	51.96±1.36	53.92±1.20	0.531	-	-
Magnesium (mg/100ml)	54.43±1.72	53.86±1.62	55.19±1.56	0.847	20	-
Phosphate (mg/100ml)	0.36±0.01	0.37±0.01	0.37±0.01	0.610	-	0.05
Iron (mg/l)	88.78±22.82	89.15±22.96	88.74±22.86	1.000	0.3	0.3
Copper (mg/L)	0.04±0.01	0.03±0.01	0.03±0.01	0.332	1	2
Zinc (mg/L)	0.31±0.07	0.29±0.06	0.29±0.06	0.974	3	0.1

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Cobalt (mg/L)	ND	ND	ND	-	-	-
Chromium (mg/L)	ND	ND	ND	-	0.05	0.05
Cadmium (mg/L)	ND	ND	ND	-	0.003	0.003
Lead (mg/L)	ND	ND	ND	-	0.01	0.01
Nickel (mg/L)	0.24±0.06	0.29±0.08	0.24±0.06	0.839	0.02	0.03

*p-value < 0.05 indicate significance

Table 2: Seasonal Variations in the Mean Values of Physico-chemical and Heavy Metal Concentrations of Water Samples from Oba River

PARAMETERS	Season		P-VALUE	Regulatory Limits	
	Rainy	Dry		NSDWQ (2017)	WHO (2011)
pH	6.90±0.04	6.98±0.04	0.141	6.5-8.5	6.5-8.5
Temperature (°C)	27.03±0.05	26.10±0.17	*0.001	Ambient	-
Electrical Conductivity (ds/m)	0.13±0.00	0.23±0.01	*0.001	1000	25
Total Dissolved Solids (mg/L)	96.08±0.73	115.17±3.02	*0.001	500	500
Salinity (mg/L)	0.0002±0.0001	0.0002±0.0001	0.815	-	< 40
Alkalinity (mg/L)	23.75±2.39	21.25±0.86	0.33	-	<120
Dissolved Oxygen (mg/L)	92.11±0.26	17.81±0.15	*0.001	-	6
Total Hardness(mg/L)	116.38±2.04	102.25±0.48	*0.001	150	100-150
Biochemical Oxygen Demand (mg/L)	129.46±0.98	117.21±2.07	*0.001	250	10
Total Suspended Solids (mg/L)	2.50±0.06	2.26±0.04	*0.003	1500	<1500
Nitrate (mg/100ml)	0.19±0.01	0.14±0.00	*0.001	50	50
Chloride (mg/100ml)	37.76±0.70	33.23±0.24	*0.001	-	250
Sulfate (mg/100ml)	0.20±0.02	0.17±0.00	0.071	100	250
Calcium (mg/100)	57.32±0.77	48.90±0.26	*0.001	-	-
Magnesium (mg/100ml)	60.11±0.80	48.88±0.36	*0.001	20	-

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Phosphate (mg/100ml)	0.37±0.01	0.36±0.00	0.545	-	0.05
Iron (mg/l)	177.50±0.23	0.28±0.02	*0.001	0.3	0.3
Copper (mg/L)	0.06±0.00	0.00±0.00	*0.001	1	2
Zinc (mg/L)	0.54±0.01	0.05±0.00	*0.001	3	0.1
Cobalt (mg/L)	ND	ND	-	-	-
Chromium (mg/L)	ND	ND	-	0.05	0.05
Cadmium (mg/L)	ND	ND	-	0.003	0.003
Lead (mg/L)	ND	ND	-	0.01	0.01
Nickel (mg/L)	0.51±0.01	0.00±0.00	*0.001	0.02	0.03

*p-value < 0.05 indicate significance

DISCUSSIONS

Physicochemical Analysis of Oba River

The pH values of the three sites fell within the neutral range. Site B shows a slightly higher pH than Sites A and C. Variations in pH can have implications on the overall water quality and can be indicative of different sources of pollution, such as industrial discharge or agricultural and urban runoffs[12]. Levels of pH across all sites are within the acceptable range specified by both NSDWQ[13] and WHO[10], with means ranging from 6.90 ± 0.05 to 6.96 ± 0.04. Deviations from neutral pH exert significant ecological impacts[14]. There was insignificant variation between the average pH values at the rainy and dry seasons.

The temperature measurements indicate minor differences among the sites, although these variations may seem insignificant, they can have significant impacts on various aspects of aquatic ecosystems. Features like solubility of specific compounds and the metabolic rates of aquatic organisms can be influenced by even slight changes in temperature[15]. Temperature readings fell within the range for ambient water bodies, with means ranging from 26.39°C to 26.78°C across the sites. Temperature plays a pivotal role in shaping other environmental factors such as pH, conductivity, and diverse manifestations of alkalinity and deviations from the norm can affect the overall health and biodiversity of the water body[16]. Most fishes are poikilothermic, their physiology is significantly impacted upon by temperature, as it influences their rate of metabolism and hence, their energy equilibrium and behaviour, as well as their locomotive and feeding manners[17].

The evaluation of electrical conductivity and total dissolved solids provide insights into the number of dissolved ions and minerals present in the water at each site. Interestingly, the values for EC and TDS show similar ranges across the sites, suggesting comparable levels of dissolved substances. These measurements are crucial in understanding the overall water quality and the potential for contamination[18]. EC determines the water's ability to conduct electrical current, which is influenced by dissolved ions. The values reported in the table 1 are well below the regulatory limit of 1000 µS/cm according to NSDWQ[13], indicating low levels of dissolved ions across all sites. Electrical conductivity was higher at the dry season than at the ray season. The higher electrical conductivity detected at the dry season can be attributed to decreased water volume and increased rate of evaporation while the lower value observed at the rainy season is attributable to water dilution[19].

Total dissolved solids represent the concentration of non-organic and organic particles dissolved in water. The TDS levels observed in the table are within the acceptable range specified by both NSDWQ[13] and WHO[10]

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standards, suggesting that the water quality in all sites is suitable for various uses. It is very essential to control TDS in water because high TDS levels can affect water condition and render it unfit for certain uses[20].

Salinity refers to the amount of dissolved salts in the water and its levels are very low across all sites, compared to the recommended threshold of 40 mg/L according to WHO[10], indicating freshwater conditions in the sampled sites. The slight variation in salinity levels observed among the sites indicates potential differences in the sources of water input and evaporation rates. Factors such as proximity to the coast, freshwater inputs from rivers, and evaporation rates can all contribute to variations in salinity[21].

Alkalinity measures how well water can buffer changes in pH and maintains stability. Alkalinity levels, which reflect the water's capacity to withstand changes in pH, fell within acceptable range according to WHO[10]. The alkalinity measurements from the three locations show some variations, which can be attributed to differences in the geological composition of the surrounding area, the incidence of carbonates and bicarbonates, and the impact of human activities. Understanding alkalinity is essential for assessing the water's ability to counteract acids and keep the pH constant[15].

Dissolved oxygen is a critical parameter for assessing the health of aquatic ecosystems. The differences in dissolved oxygen levels observed among the sites may be indicative of varying degrees of organic pollution and microbial activity. Higher levels of dissolved oxygen are generally associated with healthier ecosystems, while lower levels can indicate oxygen depletion due to pollution or excessive organic matter[12]. Dissolved oxygen concentration is vital for aquatic biota, and the values reported in the table 1 and 2 are higher than the minimum requirement of 6 mg/L specified by WHO[10], indicating that the water holds a significant amount of dissolved oxygen across all sites[20]. The DO at the rainy season was considerably greater than that of the dry season and this agrees with the report of Ajala and Fawole[22]. This seasonal variation can be attributed to increased aeration due to rainfall; influx of fresh water from tributary rivers and decreased resident time of polluted water[22]. Biochemical oxygen demand is a measure of the volume of oxygen needed by microorganisms to decompose organic particles the water holds. The BOD levels observed in this table exceeds the regulatory limits set by both NSDWQ[13] and WHO[10], indicating potential organic pollution in the sampling sites[23]. This agrees with the report of Ogundiran and Ayandiran[9], who also reported BOD values of samples obtained from the same river to be higher than the permissible levels.

Total hardness measures the amount of calcium and magnesium dissolved in water, which can affect its suitability for consumption and industrial use. The values reported in the table fall within the permissible range, indicating moderate hardness (75 - 150 mg/L) levels across the sites[24]. Total suspended solids represent the concentration of particles suspended in water, which can affect water clarity and quality by decreasing the quantity of oxygen available to aquatic organisms. The TSS levels reported in the table are below the regulatory limit of 1500 mg/L, indicating relatively low levels of suspended solids in the sampled sites. Total Suspended Solids evaluates the aggregate amount of suspended solids in water and is an important parameter for monitoring water quality[20]. The seasonality profile of total suspended solids in Oba River was higher at the rainy season than at the dry season, this agrees with the report of Salaudeen[19].

Nitrate levels are within the regulatory standards, indicating negligible pollution from nitrogen-based chemicals such as animal or human waste and fertilizer runoff[22]. The seasonal values recorded for Nitrates in rainy season are statistically considerably higher than those at the dry season. This result is in consonance with the report of Ajala and Fawole[22] who reported higher value of nitrates during the rainy season than the dry season in the same Oba River. Chloride levels are likewise within permissible limits, indicating minimal contamination from chloride sources such as sewage and industrial effluents, which is consistent with Smith[14]. Sulphate levels fall within the acceptable range, indicating minor contamination from sulphate sources such as mining, agricultural runoff, domestic discharges, municipal and industrial effluents[25]. Calcium and magnesium levels are within permissible norms. Phosphate levels exceed the recommended threshold of 0.05 mg/L according to WHO[10], indicating potential contamination from agricultural runoff and wastewater discharges[22]. Phosphates values were observed to be slightly higher through the rainy season than through the dry season, which is also similar to the report of Ajala and Fawole[22].

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Heavy Metals Concentrations

Concentrations of copper and zinc fell within acceptable range with values below the regulatory standards by NSDWQ[13] and WHO[10] both during the rainy and the dry seasons, suggesting minimal contamination from anthropogenic sources[14]. Iron and nickel exceeded the permissible range throughout the rainy season. The absence of detectable levels of cobalt, chromium, cadmium, and lead suggests minimal contamination from these heavy metals, aligning with the regulatory limits[13]. Fawole et al., [22] also reported none detection of cadmium and lead from Oba River but reported their studied fish samples contained the two metals. On the contrary, Ogundiran and Ayandiran[9] reported presence of lead in water sampled from Oba River. Heavy metals like chromium, lead, cadmium and cobalt exert adverse effects on water quality. They constitute the primary pollutants responsible for water contamination stemming from several causes such as power plants, mining operations, electronic wastes disposal, agricultural and industrial runoffs, biomedical wastes disposal, and electroplating activities. The presence of these heavy metals poses a threat to aquaculture[26].

The concentrations of iron, copper, zinc, and nickel were notably higher at the rainy season than at the dry season. This suggests that factors associated with the rainy season, such as increased runoffs, domestic wastes disposal into water erosion during rainfall and leaching, contribute to higher metal concentrations in water bodies. The high quantity of iron (Fe) recorded in this study especially at the rainy season, may be because of increase in total dissolved iron in Oba River[22] and that the metal is naturally plentiful in Nigerian soil and no matter the source of it the eventual repository is still the aquatic body[27]. Conversely, the dry season recorded lower metal concentrations, possibly due to decreased precipitation and less input from surface runoff. However, it's crucial to monitor these metals continuously, especially at the rainy season, to ascertain their actual sources, assess potential environmental impacts and ensure water quality standards are met.

CONCLUSION

Practically, all the physico-chemical parameters assessed fell within the recommended standards by WHO and NSDWQ, suggesting that Oba River might not be polluted. Only BOD and phosphate exceeded regulatory limits. The concentrations of heavy metals in the water specimens proved suitable for aquaculture purpose since they fell within the acceptable limits specified by WHO and NSDWQ. Co, Cr, Cd and Pb were undetected; Ni exceeded regulatory limits and excessive Fe concentration was recorded during rainy season. A regular limnological research on Oba River is required in order to monitor its water quality for conservation and sustainable utilization. Furthermore, there is a need to initiate further research on Oba River to identify the definite cause(s) of extreme concentration of iron (Fe) in the river especially during the rainy season.

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