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Determination of Physicochemical Properties and Heavy Metal Concentration in Water and Sediment Samples from Oguta Lake, Imo State Nigeria.

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ABSTRACT

This work was carried out to ascertain physicochemical properties and heavy metal concentration in water and sediment samples from Oguta Lake, Imo State Nigeria. Triplicate batches of the samples were taken from three sampling points along the river coast and the physicochemical parameters analyzed in the laboratory using gravimetric, titrimetric and spectrophotometric methods. The concentrations of heavy metals (Fe, Cd, Ni, Zn, Pb, Cu and Hg) in water and sediment were analyzed using Atomic Absorption Spectrophotometer. Pearson correlation multivariate analyses of variance (MANOVA) were used to analyze the inter-relationship amongst heavy metals in water and sediments. The results obtained showed that mean concentrations of physicochemical parameters ranged as follows: Temperature (26.04-29.35); pH (7.17-7.77); Free CO_2 (9.78-10.34); BOD (10.14-10.42); TDS (22.23-28.04); EC (0.30-0.49); DO (5.69-5.86); Total Hardness (18.49-21.00); Turbidity (15.03-17.76); Alkalinity (15.64-16.66); Sulphate, (2.19-2.55); Ammonium (0.26-0.40). Comparison with WHO guidelines indicated that most parameters assayed were within permissible limits. The mean concentration of heavy metals in water were: Pb (0.19±0.05); Cd (0.41±0.07); As (0.01±0.001); Ni (0.59 ±0.1); Mnw (0.02±0.006); Cu (2.24 ± 0.31) while mean concentration of heavy metals in sediment were: Pbs (0.26±0.04); Cd (1.04±0.15); As (1.02±0.16); Ni (1.22± 0.24); Mn (1.98±1.68); Cu (1.87 ± 0.58). Positive correlations were observed for the following pairs of metals in water and sediments: Pbw and Nis (r = 0.356), Cd and Ni (r = 0.237), Cuw and Mns (r = 0.325), Cdw and Pbs (r = 0.969*), Asw and Ass (r = 0.967) at $p< 0.05$. continuous monitoring of the river is strongly recommended.

Keywords: Oguta Lake, heavy metals, bioaccumulation, fish, insects, snail, Algae.

Introduction

In Nigeria and throughout the globe, industries are crucial to economic development and play an important role in raising living standards. Pollution of the aquatic environment with heavy metals have become a worldwide problem because the metals are indestructible and most have toxic effects on organisms [1-4]. These pollutants enter rivers and lakes from a variety of sources such as rock and soil directly exposed to surface water, in addition to the discharge of treated and untreated liquid wastes into water bodies. These harmful wastes and other dangerous industrial by-products constitute major sources of environmental pollutants [5].

Most industrial pollutants discharged into the environment contain organic and inorganic pollutants in dissolved, suspended, and insoluble forms [6-9]. Effluents discharged into the water bodies may affect fish and other aquatic organisms, either directly or indirectly. Most rivers and freshwater streams are seriously polluted by industrial waste water discharged from factories as these pollutants are not treated before discharging into available water bodies. A large amount of water used in industry turns into wastewater that pollutes surface and groundwater, posing health hazards as these ions from heavy metal do not easily degrade into harmless end products thus, they are toxic to humans and the surrounding environment [10].

Heavy metals are naturally occurring elements that have a high atomic weight and a density at least five times greater than that of water. They are persistent, bio-accumulative, and toxic micropollutants [11]. Their multiple industrial, domestic, agricultural, medical, and technological applications have led to their wide distribution in the environment raising global public health concerns over their potential effects on human health and the environment [12]. The concentration of heavy metals in an organism is the product of equilibrium between the concentration of the metal in an organism's environment and its rate of ingestion and excretion [13]. Toxic effects occur when excretory, metabolic, storage, and detoxification mechanisms are no longer able to counter uptake [14]. Unlike organic contaminants that lose toxicity with time by biodegradation, heavy metals cannot be degraded, and their concentration can be increased by bioaccumulation and biomagnification [15].

Bioaccumulation is an increase in the concentration of a chemical in a biological organism over a period of time compared to the chemical's concentration in the environment [16]. These compounds which are certain non-essential chemicals that are persistent in the environment, therefore accumulate in living tissues any time they are taken up and stored faster than they are metabolized or excreted and occur when certain toxic chemicals and pollutants such as trace elements, pesticides or polychlorinated biphenyls (PCBs) are absorbed by terrestrial and aquatic animals. They are highly soluble and can be stored in fats, and when the fatty tissues are used up for energy, the compounds are released and could cause acute poisoning which leads to eco-toxicological problems. The longer the biological half-life of the toxic substance the greater the risk of chronic poisoning, even if the environmental levels of the toxin are not very high [17]. Majority of these persistent pollutants such as trace elements, pesticides or polychlorinated biphenyls (PCBs), and hydrocarbons are introduced into the environment basically by various anthropogenic activities, ranging from oil exploration, bunkering activities, pipe line vandalization, mining activities in the deep sea (which processes involve the extraction of minerals and metal ores like zinc, cobalt, silver, aluminum and gold), as well as other industrial and domestic activities in catchment areas.

Agricultural activities like the application of synthetic fertilizers and pesticides for the purpose of boosting food production and arresting food insecurity, also contribute to the pollution of the aquatic environment through runoffs water that leaches these chemicals into nearby water bodies. Once in the environment, these toxic substances can endanger public health by being incorporated in the food chain [18]. In addition, some natural processes like volcanic eruption can as well discharge these compounds into the environment. These compounds thus released into terrestrial or aquatic environments directly are not easily destroy through any biological processes, thus they are Persistent Environmental Pollutants (PEPs) and they are easily assimilated at a very faster rate than they can be degraded, thus bioaccumulate in the tissues of aquatic organisms, which will gain access to the final consumers like man at the apex of food chain [19]. Aquatic organisms are thus, exposed to a myriad of chemicals in their environment.

Though some of these chemicals occur in trace concentrations in the environment, yet they may be selectively accumulated by organisms to much larger concentrations that can cause toxicity. It is rather of great concern that over 80% of the industries in Nigeria discharge their solid wastes, liquid and gaseous effluents containing toxic concentration of heavy metals and other pollutants into the environment without any prior treatment, while just only 18% undertake rudimentary recycling prior to disposal [20]. The study aims to analyze the heavy metals accumulation in fish, water and sediment from Oguta Lake, Imo State Nigeria.

Materials and methods

Study Area

The study area was carried out in Oguta lake Imo state Nigeria. It is a lean 'finger lake' formed by the damming of the lower Njaba River with alluvium [2]. It is the largest natural lake in Imo State, Southeastern Nigeria; within the equatorial rainforest region of Niger Delta. Oguta Lake's catchment area comprises the drainage area of the Njaba River and a part of the River Niger floodplain in the region south of Onitsha [22]. The lake is situated in Oguta about 50 kilometres (30 mi) from the junction of the Ndoni and Orashi River. It is about eight kilometres (5 mi) long from east to west and 2.5 kilometres (1+1⁄2 mi) wide. The stream from Njaba River is the major inflow to Oguta Lake [22]. The other three tributaries are Awbana, Utu and Orashi. The Orashi River flows past Oguta Lake in its southwestern portion. The lake is important to the people of oil-rich Njaba-River basin including Oguta, Orsu, Mgbidi, Nkwesi, Osemotor, Nnebukwu, Mgbele, Awa Awo-OmammaAkabo as a source of water, fish, tourism and an outlet for sewerage.

The river route Njaba and Orashi via Oguta Lake to the coast, passing through Awo-omamma, Mgbidi, Oguta, Ndoni, Abonnema, Degema made Oguta, Osemotor, Awo-omamma and surrounding towns important commercial centres of international trade mainly for oil palm. Oguta Lake also served as a Biafran army marine base during the Nigerian Civil War [22].

Figure 1: Map of Nigeria showing the location of Oguta Lake (Wikipedia, 2021).

Sediment Samples

The methodology of [23]. Surface sediment samples will be collected at low tide by the grab method using Eckman grab samples from 3 to 4 points at each location. Grab bottom sediment samples will be collected and kept in plastic containers which would have previously been treated with 10% nitric acid for 24 hours and rinsed with de-ionized water. The samples will be transported to the Laboratory and stored frozen. The samples will later be oven-dried to constant weight at 105°C, ground to powder and then sieved through a 650µm stainless sieve to remove ungrounded matter. 10grams of the sieved sediments will be weighed into an acid-washed plastic polythene bottle and digested in a 100ml solution of conc. HNO3 and HCl acids (1:1 ratio). The mixture will be vigorously shaken in a mechanical shaker and then filtered through No 42 Whatman filter paper [24]. Standard solutions of the metals will be prepared from their 1000 ppm stock solutions for calibration.

Water Samples

Water samples will be collected from the study area into 2-litre plastic sampling gallons using standard method described by American Public Health Association, (1992) and transported to the laboratory for further analysis.

SAMPLE ANALYSIS

Physicochemical Parameter

Important physicochemical parameters like turbidity, pH, conductivity, Total Dissolve Solid, dissolved and temperature of the wastewater and groundwater samples will be tested before and after treatment according to the drinking water guidelines. Turbidity will be tested using turbidimeter, pH will be tested using pH meter, conductivity using conductivity meter, Total dissolved solids (TDS) by using Digital Conductometer, Dissolved Oxygen will be determined by titration using modified Winklers method as given by [25] and temperature using basic thermometer. All of these parameters will be tested accordingly

Heavy Metals

The concentrations of the heavy metals (Mg, K, Zn, Pb, Cd, Fe, Ni and V) in the study samples will be determined using a Varian Atomic Absorption Spectrophotometer (Perkin Elmer Analyst AA 200 equipped with a high sensitivity nebulizer) as described by [25].

Statistical Analysis

The data generated from the study were analyzed using tables, charts, and one-way analysis of variance.

Results and Discussion

Results

Physicochemical parameters of water samples collected from Oguta Lake

The physicochemical properties of water samples collected from Oguta Lake is shown in Table 1. Results obtained from sample analysis revealed Temperature range of between 26.04-29.35 which falls within WHO (2019) standard for drinking water. The mean pH value of the Lake was 7.32±1.77. The values indicated neutral level with which ranged from 7.17-7.77 across the sampling points. pH values were observed to be below 7.00 - 8.50 benchmark stipulated by the WHO. Mean values of Free CO_2 (ppm) were observed to be 10.11±1.02 which ranged between 9.78-10.34. The result obtained from the study indicated biochemical oxygen demand (BOD) values ranging from 10.14-10.42 mg/L which was below WHO set values of <10.00. The value of total dissolved solids ranged between 14.0 – 28. 22.23-28.04 mg/L with an overall mean of 250.00 Mg/L. Electrical conductivity varied from 0.30-0.49 µs/cm with a mean value of 0.46±0.14. Dissolved oxygen content of the study areas/locations ranged from 5.69-5.86 mg/L with an overall mean value of 5.91±0.48. However, values obtained for DO was below > 5.00 benchmark by the WHO permissible limit. The measured values of total hardness in the river water samples ranged from 18.49-21.00 with a mean value of 19.46±2.20. The concentrations of TD in the Lake were observed to within 150.00 stipulated by the WHO. Concentration of Turbidity, Alkalinity (Mg/L), Sulphate, (Mg/L) and Ammonium (Mg/L) (NTU) ranged between 15.03-17.76; 15.64-16.66; 2.19-2.55 and 0.26-0.40 NTU respectively.

Table 1: Physicochemical parameters of water samples collected from Oguta Lake

Parameters	WHO LIMIT	Oguta Lake	Range
Temperature (^oC)	30.00 - 32.00	26.16±2.89	26.04-29.35
pH	7.00 - 8.50	7.32±1.77	7.17-7.77
Free CO_2 (ppm)	<10.00	10.11±1.02	9.78-10.34
BOD (Mg/L)	< 10.00	10.29±1.27	10.14-10.42
TDS (Mg/L)	250.00	25.43±2.41	22.23-28.04

EC(µs/CM)	100.00	0.46±0.14	0.30-0.49
DO (Mg/L)	> 5.00	5.91±0.48	5.69-5.86
Total Hardness (ppm)	150.00	19.46±2.20	18.49-21.00
Turbidity (NTU)	150.00	17.16±2.12	15.03-17.76
Alkalinity (Mg/L)	200.00	16.35±1.2	15.64-16.66
Sulphate, (Mg/L)	250.00	2.25± 0.29	2.19-2.55
Ammonium (Mg/L)	-	0.37 ± 0.18	0.26-0.40

Heavy metal concentrations in water and sediment samples collected from Oguta Lake

The mean concentration of heavy metals from water and sediment samples in Oguta Lake is depicted in Table 2. Results obtained revealed variation in heavy contents in both water and sediment samples. Mean concentrations of Pb, Cd, As, Ni, Mn, and Cu in water ranged between; 0.18-0.20; 0.38 - 0.44; 0.01 -0.02; 0.53 -0.68; 0.01-0.03; and 2.18 - 2.37 respectively. The level of Pb, Cd, As, Ni, Mn, and Cu in sediment were ranged as follows: 0.22-0.27; 1.01-1.16; 1.00-1.05; 1.18-1.29; 1.44- 2.88; and 1.53 - 2.04. No values of Hg were detected in both water and sediment samples.

Table 2: Heavy metal concentrations in water and sediment samples collected from Oguta Lake

Parameters	Oguta Lake	Range
Pbw (Mg/l)	0.19±0.05	0.18-0.20
Cdw (Mg/l)	0.41±0.07	0.38 - 0.44
Asw (Mg/l)	0.01±0.001	0.01 -0.02
Hgw (Mg/l)	ND	-
Niw (Mg/l)	0.59 ±0.1	0.53 -0.68
Mnw (Mg/l)	0.02±0.006	0.01-0.03
Cuw(Mg/l)	2.24 ± 0.31	2.18 - 2.37
Pbs (Mg/g)	0.26±0.04	0.22-0.27
Cds (Mg/g)	1.04±0.15	1.01-1.16
Ass (Mg/g)	1.02±0.16	1.00-1.05
Hgs (Mg/g)	ND	-
Nis (Mg/g)	1.22± 0.24	1.18-1.29
Mns (Mg/g)	1.98±1.68	1.44- 2.88
Cus (Mg/g)	1.87 ± 0.58	1.53 - 2.04

The interrelationship between heavy metals in water and sediment samples from Lake Oguta, were analyzed using Pearson's correction matrix to see if some of the heavy metals are interrelated with each other and the results are presented in Table 3. Results obtained showed and strong positive correlation was observed at P < 0.05 for metals in water and sediment samples meaning that there was a strong association between these pairs, and common sources for the pairs of polluting substances. Positive correlations were observed for the following pairs of metals in water and sediments: Pb_w and Ni_s (r = 0.356), Cd and Ni (r = 0.237), Cu_w and Mn_s (r = 0.325), Cd_w and Pb_s (r = 0.969*), As_w and As_s (r = 0.967) at p< 0.05.

Table 3: Correlation of heavy metals in water and sediment samples in Oguta lake

	Pb_w	Cd_w	As_w	Hg_w	Ni_w	Mn_w	Cu_w	Pb_s	Cd_s	As_s	Hg_s	Ni_s	Mn_s	Cu_s
Pb_w	1													
Cd_w	0.034	1												
As_w	0.012	0.043	1											
Hg_w	0.009	0.012	0.017	1										
Ni_w	0.356	0.237	0.110	0.365	1									
Mn_w	0.144	0.124	0.116	0.178	0.264	1								
Cu_w	0.121	0.135	0.152	0.175	0.248	0.325	1							
Pb_s	0.969*	0.453	0.179	0.321	0.035	0.243	0.547	1						
Cd_s	0.078	0.917*	0.433	0.412	0.446	0.077	0.784	0.033	1					
As_s	0.022	0.039	0.967*	0.078	0.276	0.218	0.163	0.023	0.322	1				
Hg_s	0.009	0.014	0.012	0.000	0.023	0.015	0.017	0.009	0.005	0.010	1			
Ni_s	0.142	0.173	0.278	0.104	0.978*	0.287	0.423	0.034	0.066	0.076	0.013	1		
Mn_s	0.136	0.152	0.367	0.289	0.255	0.965*	0.752	0.061	0.034	0.092	0.021	0.078	1	
Cu_s	0.134	0.140	0.342	0.163	0.367	0.431	0.958*	0.032	0.078	0.022	0.011	0.034	0.025	1

* = Significant at P < 0.05 level

Discussion

Results of this study showed mean physicochemical parameters of water samples collected from Oguta Lake. Temperature range (26.04-29.35°C) of Oguta Lake falls within WHO (2016) standard for drinking water. The temperature values obtained in this study compare favorably with those reported by earlier workers in Imo River water. These earlier works include [26], (25.10 –26.11°C), [27], (26 – 30oC), [28] (25.10 – 27.8°C), and [29] (26 – 30°C). There was no significant difference in the temperature of all sampling stations and this is also similar to the report of Ezeonye (2009) who attributed minimal variation in temperature between stations to the absence of micro climatic variations in temperature.

The mean pH value of the Lake was slightly neutral. This variation might be due to high level of pollution. The overall pH range of 7.17-7.77 was almost within the range for inland water (pH 6.5 – 8.5) as reported by Antoine & Al-Saadi (2020). [30] reported pH range of 6.09 – 8.45 as being ideal for supporting aquatic life including fish. The pH range obtained in this study is within the acceptable level of 7.00 - 8.50 by the WHO.

The result obtained from the study indicated biochemical oxygen demand (BOD) values ranging from 10.14-10.42. The general high BOD values observed during in this study may be due to increased urban runoff which carried wastes from streets and sidewalks; nutrients from loan fertilizers, laces, games, chippings and paper from residential areas into the river. The results from this study agreed with the finding of [31]. [32] in his finding in assessment of water quality of Njaba River obtained BOD values 2.4 – 8.3 which disagrees with this study values but agrees with the results of [33].

Total dissolved solids test provides a quantitative measure of the amount of dissolved ions. It is used as indicator test to determine the general quality of water [34]. The values of total dissolved solids were within the range of values reported by [35], Duru&Nwanekwu (2019). Conductance qualitatively reflects the status of inorganic pollution and is a measure of total dissolved solid and ionized species in the water. Electrical conductivity varied from 0.30-0.49 µs/cm. The lower electrical conductivity recorded in this study might be due to water dilution. Ovie&Adeniji (2019) as well as Kolo&Oladineji (2020) observed a similar trend for Shiroro lake. Wide variations were observed in the sampling points. The wide variations suggest that considerable amount of dissolved ionic substances enter the river due to indiscriminate dumping of waste in the Lake. Conductivity value of 148 was observed by Ebigwai, Imemdimfen, Bright, Olowu, &Ekanem (2021) in Kwa River, Calabar which is higher than the values obtained in this study.

Dissolved oxygen content of the study area ranged from 5.69-5.86 mg/L. It agreed with the values obtained by Olawale (2021) in the study of physiochemical analysis of water from Asa river that ranged from 4.80 – 9.30. Domestic, agricultural, industrial effluent and waste discharge into rivers is a usual practice in Imo state and their environs and is the main reason for the pollution of the river. The findings agreed with the report of Okeke &Adinna (2018) where the dissolved oxygen of dry season fell within the range of 3.4 – 5.1. These findings agreed with the findings of Duru&Nwanekwu (2019) with DO values of 4.60 – 5.60. DO is one of the most important parameters in agriculture. It is needed by fish to respire and perform metabolic activities. These low levels of dissolved oxygen are often linked to fish kill incidents.

Total hardness is due to presence of bicarbonate, sulphate, chlorides and nitrates of calcium and magnesium. Hard water requires more soap and synthetic detergents for laundry and washing and contributes to scaling in boilers and industrial equipment (Ajayi &Osibunji, 2022). The result of hardness indicated low hardness values may probably be due to high dilution during wet season (18.49-21.00). Duru*et al.,* (2020) in the study of physio-chemical status of Nworie River found out that the total hardness in the water ranged from 10.6mg/L to 50.87. The results of this study agreed with the finding of Olawale (2019) in their study of Asa River water.

Turbidity is an important operation parameter in process control and can indicate problems with treatment processes; particularly coagulation, sedimentation and filtration. It causes undesired taste and odours which affects the process of photosynthesis for algal growth. In this study, turbidity values of 15.03-17.76 (NTU) were recorded indicating that biological process had little effect on the material in the water column. The variation observed could be attributed to the release of suspended particles as a result of sand mining activities in the area and this is in line with the report of Nkwoji, Yakub, Ajani, & Bellow (2018) and the work of Ezekwe*et al.,* (2020) who recorded turbidity of 14.6 in pond water at Imo River Basin area sampled.

The total alkalinity ranged from 15.64-16.66 mg/L with mean value of 16.35±1.2. Since alkalinity is pH dependent and a reversal of acidity, the higher value recorded in this study is expected. The alkalinity agreed with the range value of 16.25 – 16.66 with overall mean of 15.9.10 as documented by Olawale (2016). The mean value of sulphate was 2.25± 0.29. The sulphate values for the sampling points and location ranged from 2.19-2.55. Significant amount of sulphate is introduced into the river as a result of industrial agricultural and domestic activities. Concentration of Ammonium obtained in this study agrees with the report of Nwadinigwe, Udo, &Nwadinigwe, (2019).

Concentration of Heavy Metals (Pb, Cu, Cd, As, Hg, Ni, and Mn) in Water and sediment samples from the study area also varied. Results revealed a gradual build-up of heavy metals in the study points. Generally, higher levels of heavy metals were detected in water samples than sediment samples. Similar trend in heavy metal levels had been reported (Antoine, & Al-Saadi, 2020).

Conclusion

This study was carried out to evaluate accumulation of heavy metals in water and sediment samples by studying the physicochemical properties of surface water, sediments from Oguta Lake. Water quality characteristics, which include physicochemical parameters and seven heavy metals, were analyzed. The study established alteration of physicochemical parameters in Oguta Lake and gradual build-up of heavy metals as a result of prevailing anthropogenic activities in the vicinity of the Lake. These findings gave valuable information on physicochemical properties of Oguta Lake water and calls for continuous monitoring to check level of pollution in the River.

Recommendations

- Regular monitoring of the water and sediment qualities of the Oguta Lake should be carried out.
- Appropriate regulatory and enforcement agencies should ensure that effluents are properly treated before discharge into the Oguta Lake.
- Government should inform the populace around the Oguta Lake channel of the non-potability of the raw water.

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