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ASSESSMENT OF HEAVY METALS CONTAMINATION OF SURFACE WATER AND SEDIMENT OF A TROPICAL MANMADE LAKE SOUTHWESTERN NIGERIA

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ABSTRACT: *Developing countries including Nigeria are faced with increase generation of domestic, industrial, and agricultural wastes that enter into the surrounding water bodies; and pollutants settle on the sediment (the ultimate sink of contaminant in aquatic environment). These large amount of chemical substances (including heavy metals) released into aquatic environments has put it at risk which could inadvertently pose serious public health hazard. This study assessed the heavy metal concentrations of the surface water and sediments of Dandaru Reservoir, in Ibadan, Nigeria. The level of contamination of lake water and sediment were use to determine the degree of pollution and its potential effects on the environment and public health. Physical and chemical parameters and heavy metals were determined in the lake water using standard methods from April, 2015 to March, 2016 at five different sites of human activities. The physico-chemical parameters determined were within the limits specified by NESREA and WHO. All metals that were assessed were present in water and sediments (except nickel which was not determined in sediment). Metal concentration in the water followed the following trend Mn,>Fe>Pb>Ni>Zn>Cu>Co>Cd>Cr. Also, metal accumulation in sediments was Fe>Zn>Mn>Pb>Cu>Co>Cd>Cr. The average I_{geo} class for the sediments in all the stations was 0-2 indicating uncontaminated to moderately contaminated levels. The concentrations of Pb, Cd, Ni and Mn in water exceeded the NESREA AND WHO standards for domestic water use and aquatic life. These could have adverse effects on the environment and health of people that utilize the water and fish of the Dandaru Reservoir. Effective monitoring of the livelihood activities and discharges into the reservoir are recommended to prevent further deterioration of the reservoir.*

KEYWORDS: Heavy metals, Sediment, Contamination factor, Geo-accumulation index, Dandaru Reservoir

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INTRODUCTION

Nigeria has numerous rivers with several tributaries in addition to many natural lakes and manmade lakes, The estimated total of the inland bodies of water was 12,547,082 ha .. Due to the accelerating population growth, coupled with increase in urbanization, industrial and agricultural land use, there is increase in generation of domestic, industrial, and agricultural wastes which are often discharged into these water bodies. These wastes introduce wide diversity of pollutants into the receiving water bodies; having undesirable effects on the aquatic ecosystem, on fisheries and making the water unfit for human consumption.

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Further pollution and degradation of Nigeria's freshwater resources should be forestalled for the protection of water quality and aquatic ecosystem as a vulnerable resource, essential to sustain life and development.

Dandaru Reservoir is created by damming the Ogunpa River (one of the three major rivers in Ibadan, Nigeria) which has overflowed its bank several times and flooded the surrounding vicinity. One of the purposes of the reservoir is to store water in order to prevent flooding. The reservoir has also been stocked with fish species which are been exploited for artisanal fishing; use for aquaculture, and water is abstracted from the reservoir by the College Hospital.

The reservoir receives input from various anthropogenic activities (car wash, Mechanic workshop, cement/ block industry, high vehicular activities, Secretariat Office complexes) along the Ogunpa River, the Agodi Zoological Garden and University College Hospital, Ibadan.

Heavy metals are produced from a variety of natural and anthropogenic sources. Metal pollution can result from direct atmospheric deposition, geologic weathering or through the discharge of agricultural, municipal, residential or industrial waste products.[1] Heavy metals are one of the serious pollutants in our natural environment because of their toxicity, persistence bioaccumulation and biomagnifications in food chain.[2,3]

Rivers passing through urban and rural areas transport metals partly dissolved and partly adsorbed on suspended material. This suspended material settles on the bottom of lakes and accumulates in the sediment.[4] Heavy metals tend to be assimilated in sediment with organic matter, Fe/Mn oxides, sulphide, and clay thereby forming several reactive components, which are harmful to the environment.[5] Sediment is the ultimate sink of contaminants in the aquatic system and its analysis reflects the long term quality situation independent of the current inputs.[6,7] Sediments, as basic components of the aquatic environment, play an important role in elemental cycling and they are responsible for transporting a significant amount of pollutants and nutrients. The occurrence of bio-turbation and re-suspension processes, currents and waves, dredging and other anthropogenic activities may enhance the remobilization of contaminants at the sediment-water interface, thus resulting in bio-accumulation and bio-magnification processes along the whole trophic chain. Many aquatic animals of which man directly or indirectly rely upon for survival live in the sediment and several reports have shown that they are capable of accumulating high concentrations of heavy metals. [8, 9, 10]

The distribution of metals in sediments adjacent to settlement area can provide evidences of the anthropogenic impact on ecosystem and therefore aid in assessing the risks associated with discharged human wastes. Dandaru Reservoir being a source of fishes consumed by the Ibadan populace (due to being use for artisanal fishing and aquaculture purpose), point to the need for monitoring and evaluation of the water quality and sediment analyses. The aim of this study was to examine the physical, chemical and heavy metal concentrations of water and sediments from the reservoir; compare metal concentrations in the lake with standards for water quality and sediment, and levels recorded in the literature; use geo-accumulation index to measure the degree of heavy metal accumulation in the sediment and contamination factor to determine level of heavy metal contamination of sediment of Dandaru Reservoir.

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METHODS

Dandaru Reservoir located in Ibadan, Oyo State was constructed by Oyo State Water Corporation for domestic use. The reservoir lies between latitudes 7°24 '16'N and 7°24' 27'N and longitudes 3°53' 32'E and 3°54' 30'E (Fig. 1). The total surface area of the lake is about 4 hectares. The reservoir has its source from Ogunpa River that flows through places including Ashi, Bodija, State Secretariat, before being dammed after the popular Agodi Zoological Garden. It is stocked with different species of fish such as *Gymnarchus, Tilapia, Clarias and Heterotis* species and also supplies water to University College hospital. The study area is located within the equatorial region which has a tropical wet and dry climate. Its wet season runs from March through October, while November to February forms the dry season. The mean total rainfall is 1420.06mm having a mean maximum temperature of 26.46 °C, minimum 21.42 °C and the relative humidity is 74.55%.

Five sampling stations were chosen along the course of Dandaru Lake on the basis of influx of wastewater and human activities. Table 1 shows description of the sites.

Sample Collection

Water samples were collected from April, 2015 to March, 2016 at the five sampling stations. Duplicate surface water samples were collected by immersing 1L prewashed plastic bottles (rinsed with lake water at each sampling point in order to condition the bottle with the lake water sample) about 50cm below the water surface and allowing it to fill. The bottles were stored in an ice chest and taken to the laboratory for the determination of total dissolved solids and biological oxygen demand. Water samples for heavy metal determination were collected in acid washed 1L polyethylene bottles. The bottles were rinsed thoroughly with deionised water after washing with dilute nitric acid (HNO_3). In the field the bottles were rinsed three times with the reservoir water and water sample was then collected at about 50 cm below the water surface. The water samples were acidified with concentrated nitric acid for preservation.

Sample Preparation

Water temperature, conductivity, DO, TSS and pH were determined in situ using Sper Scientific Water Quality Meter, with model number-AF.33594(calibration was done following the Instruction manual). The nitrate and phosphate contents of the water samples were determined through spectrophotometric screening.[11] using Milton Roy Spectronic 21D Spectrophotometer. Total suspended solids were determined gravimetrically.[11] The BOD was determined by calculating the difference in the amount of the initial DO reading and the DO reading after the 5days incubation period at 20˚C.

Sample Digestion

Heavy or trace metals were determined after digestion of the solution of the samples. Water sample digestion was carried out by taking 10 ml of the sample and adding 4ml Perchloric acid, 20 ml concentrated nitric acid and 2ml concentrated tetraoxosulphate VI acid. This was digested using Aluminum block digester 110. The mixture was heated until white fumes evolved and clear solution obtained. After digestion, the samples were allowed to cool and then transferred to 100 ml volumetric flask. This was made up to 100 ml with distilled water and thoroughly mixed. The samples were allowed to stand overnight to separate insoluble materials. Filtration was done through 0.45 µm Millipore type filter. Iron (Fe), Lead (Pb),

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Manganese (Mn), Zinc (Zn), Cobalt (Co), Nickel (Ni), Cadmium (Cd), Copper (Cu) and Chromium (Cr) were determined using Unican 929 Atomic Absorption Spectrometry.

Metal Analysis in Sediments

Sediment samples were air dried until they reached a constant weight before pH and metal analysis. Soil for pH analysis was sieved through a 2 mm mesh, mixed with 0.01 M calcium chloride ($CaCl_2$) to form a 1:2 (w/v) soil: $CaCl_2$ solution slurry, mixed for 1 hour, and pH was measured using Sper Scientific Water Quality Meter, with model number-AF.33594. Air dried sediment was sieved with 2mm sieve and 0.5mm sieve. 0.5g of the weighed sample was put into a digestion tube. 50ml of HNO_3 and perchloric acid (Double Acid) in ratio 2:1 respectively was transferred into the digestion tube placed in a digestion block inside a fume cupboard. Prior to this the digestion block was heated to 150 $^{\circ}$C before the digestion tube was placed in it and left for 2hours. The digestion was brought out and poured into a volumetric flask of 25ml. This was made up to 25ml with distilled water, mixed thoroughly and poured into a sampling bottle. The heavy metals (Fe, Cu, Pb, Mn, Co, Zn, Cr, Cd, and Ni) were then determined using Buck scientific model 210VGP Atomic Absorption Spectrophotometer. High purity metal standards endorsed by the Standard Organization of Nigeria (Fluka® Analytical, Sigma-Aldrich, Germany) were used for instrument calibration and accuracy checks. For quality assurance, we used standard sediment reference materials (Standard Organisation of Nigeria) for the selected metals.

The levels of metal contamination of sediment (CS) in relation to background concentration of the element (CB) were expressed as contamination factor (CF), calculated as shown in Equation 1 below:

CF = CS/CB [12]

According to the classification[12], *CF* <1 points to low contamination factor, 1≤ *CF* <3 indicates moderate contamination factor, 3≤*CF* <6 points to considerable contamination, and *CF* ≥6 suggests very high contamination factor.

Geoaccumulation index was calculated using the formula proposed by [13]as follows:

$I_{geo} = \log_2 C_n / 1.5B_n$

Where,

C_n = measured concentration of heavy metal in sediments

B_n = geochemical background concentration of the element

1.5= background matrix correction due to terrigenous effect

The following are descriptive classes for increasing Igeo values proposed by: [13]

Igeo Value	Igeo Class	Designation of sediment quality
>5	6	extremely contaminated
4-5	5	strongly to extremely contaminated
3-4	4	strongly contaminated
2-3	3	moderately to strongly contaminated
1-2	2	moderately contaminated
0-1	1	uncontaminated to moderately contaminated
0	0	Uncontaminated

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Statistical Analysis

Data obtained from this study were subjected to descriptive and analysis of variance statistics. Statistical significance was indicated at $P<0.05$.

RESULTS

Physical and Chemical Parameters of Water.

Spatial variation in the physico-chemical parameters of water is shown on Table 2. The pH of the Dandaru Lake in the study ranged between 6.95 - 7.88 (mean = 7.55±0.21). Highest pH (7.59±0.20) was recorded in station 4 and there was no significant difference in pH between the stations. The mean air temperature (29.98^{o}C ± 2.85) and water temperature (27.62 ^{o}C ±2.70) did not differ significantly between stations. In all the stations, the temperature was higher in the air than water. The mean electrical conductivity of the reservoir was 405.09 mg/L ± 58.34 (range, 273 - 583 mg/L), between the stations it ranged from 391.50 mg/L ±70.82 to 410.54 mg/L ± 45.20. The mean TDS (259.07 mg/L ± 38.56; range 182-389 mg/L) and mean TSS (0.79 ± 0.25 mg/L; range 0.30-1.33) did not differ significantly between stations. There was significant difference in DO between the stations with highest concentration recorded in station 1(6.34 ± 1.39 mg/L) and least in Station 5 (5.30 ± 1.54). The mean BOD of the water was 3.60 mg/L ±1.66 (range, 0.43 - 9.12 mg/L) and the concentration showed no statistical difference between stations. The mean nitrate, 4.23 ± 2.67 mg/L (range 0.05-17.10 mg/L) and phosphate 0.28 mg/L ± 0.34 (0.00-1.83 mg/L) showed no significant difference between stations.

Heavy Metals Concentration in Water

The water of Dandaru Lake was characterized by higher levels of Mn and Fe, the metals are arranged as follows in respect of their concentration, Mn,>Fe>Pb>Ni>Zn>Cu>Co>Cd>Cr. The concentration of Pb in the lake varied from 0.00 – 1.13 mg/L (0.08 ± 0.19 mg/L). The average concentration of Pb did not differ significantly between the stations (Table 2). The concentration of Ni in the lake varied between ND to 1.00 mg/L (mean, 0.08±0.15 mg/L). The mean concentration of cadmium, 0.03±0.05 mg/L (range 0.00-0.20 mg/L) did not differ significantly between stations. The concentration of Cr varied from 0.00 – 0.06 mg/L (mean 0.01 ± 0.01mg/L). Highest Mn concentration was recorded in station 3(1.29±1.27 mg/L) and least in station 4(0.50±0.73 mg/L). The concentration of Fe ranged from 0.00 – 10.60 mg/L (mean 0.81 ± 1.82 mg/L). The mean Cu concentration of the lake was 0.05±0.07 mg/L (range, 0.00-0.21 mg/L). Comparison of heavy metals contamination of some lakes in Nigeria with this study is shown on Table 3.

Heavy Metals in sediment of Dandaru Lake

The pH of the sediments during the study was <4 in all stations, thus acidic. The bottom sediments of Dandaru Lake were characterized by higher levels of Fe, Zn and Mn; the metals are arranged as follows in respect of their concentration, Fe>Zn>Mn>Pb>Cu>Co>Cd>Cr. All metals in water occurred in bottom sediments; with metal concentrations much higher in sediments. The concentration of heavy metals in sediments were compared with sediments quality guidelines by [14, 15] to show the toxicity levels of studied heavy metals (Table 4). Heavy metal contaminations of sediment of some lakes in Nigeria were compared with the study on Table 5.

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Contamination Factor and Geoaccumulaton Index

The CF and I_{geo} values for individual studied elements in the sediments of the stations are shown on Tables 6 & 7.

DISCUSSION

The pH of the water sample of Dandaru Lake in the study (range 6.95 - 7.88; mean, 7.55±0.21) complied with [16, 17] guidelines for domestic water use. Furthermore, [18] reported pH range of 6.09 - 8.45 as being ideal for supporting aquatic organism including fish. The pH of water strongly determines the speciation and bio-availability of metals, dissolved heavy metals (ions) precipitate out of solution when their pH is raised to a given point (pH 7.5-11), the optimum pH for precipitation varies, depending on the type of metal [19, 20]. The mean P^H of each sampling point being >7.5 favored the precipitation of heavy metals. The mean TDS (259.07±38.56) and TSS (0.79 ± 0.25 mg/L) were below [16] guidelines of 500.0 mg/L and <10.00 mg/L, respectively. Solids in water are undesirable for they degrade the quality of drinking water, inhibit photosynthetic processes and reduce utility of water for different purposes. The mean conductivity of the lake (405.09±58.34 mg/L) fell below the limits specified by (900µs/cm). Conductivity depends on the presence of ions (cations and anions) in water, their total concentration, mobility and valence, and on temperature of water [11]. The mean DO value (5.30±1.54) of the Lake was within [16] (≥ 3) acceptable limit for aquatic life and drinking water; the statistical significant difference in DO between stations could be due to differences in vegetation cover (since this will affect the water temperature) and anthropogenic wastes. Fish can survive in dissolved oxygen range of 1.0-5.0mg/L but growth will be slow for prolonged exposure[21], [22.] Death of fish will occur below 1mg/L. The Biological Oxygen Demand (BOD) values of the lake did not exceed[16] and USEPA limits ≥ 6 and≥ 10, respectively. Biological oxygen demand is of vital importance in pollution monitoring. It is an index of aquatic pollution. A high BOD load can pose a threat to the aquatic environment by depressing the dissolved oxygen concentrations to levels that affect aquatic organisms. Levels of the essential primary productivity nutrients – nitrate (mean 4.23± 2.67 mg/L) and phosphate (mean 0.28±0.34 mg/L) in the Dandaru Lake during the study period were below the [16](9.1 and 3.5 mg/L, respectively) acceptable limits. The phosphate level was also below the [17]permissible limit < 5 mg/L. Phosphorous is an algal nutrient often contributing to excessive algal growth and eutrophication [23].

Heavy metal concentration of Dandaru Lake

The concentration of lead recorded in the all the stations exceeded the [16](0.05 mg/L) and [17](0.01mg/L) guidelines for domestic water use. Pb is a non-essential metal and is toxic to living organisms. The range of total Pb concentrations in natural water is between 0.05 and 10.0mg/L, whilst the dissolved Pb concentration normally does not exceed 0.01mg/ [24]. The concentrations of Pb recorded in this study were above the benchmark value. Any trace of lead in water is considered unsafe. At very low concentrations, Pb accumulates in the body[25]; it's harmful to children under the age of six, and causes mental and physical retardation. Kidney damage, high blood pressure and anemia are cause of Pb poisoning[17]. The mean value of Cd obtained for each station was above the [16](0.01mg/L) and [17](0.003mg/L). The adverse human health effects of lead and cadmium include neurological disorders and kidney and brain damage.

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The mean concentration of Ni in all the stations exceeded 0.1mg/L threshold values by[16], [17]. Nickel is a natural ubiquitous element of the earth and in water (0.001 to 0.003mg/l;[26]). Nickel toxicity is generally low, but elevated concentration can cause sublethal effects [27, 28]. Cobalt mean values recorded during this study were below the permissible limits by [16](0.20mg/L) and [17]value is not available. Mn is an essential micronutrient, being a major component of many enzymes and is of moderate toxicity to aquatics organisms [29, 30]. High concentration of Mn in domestic water gives characteristic metallic taste and staining properties[31]. The mean values of Fe obtained in all the stations were above the [16](0.5 mg/L) and [17](0.3 mg/L) guidelines for drinking & domestic use except station 1. High occurrence of Fe on Earth lead to it's being more abundant in freshwater than other metals [25].

The values recorded for Cu and Zn during this study did not exceed [16](0.10 1mg/L) and [17](1.0 mg/L) permissible limits, respectively. The concentrations recorded for the metals in this study are above those recorded in Asejire and Eleyele Lakes [32, 33, 34] except Ni (0.9ppm), Fe (11.9ppm) and Zn (0.075 to 0.0789 ppm). Abiona et al., 2012 obtained higher CO, Mn and Fe and lower Pb and Zn in Dandaru Lake compare to the present study. Adekanmbi et al., 2015 however got lower concentrations than this study except for Zn.

The likeable sources of heavy metals into the Dandaru Lake include those brought into the lake from the source river (Ogunpa). Ogunpa River wind through the city of Ibadan, with various livelihood activities from its catchment area. These activities have generated wastes including domestic waste, car wash effluents, public offices wastewater, runoff from agricultural lands, emissions from car which enter the river. Also, waste water from hospital that enters into the reservoir through a drainage enroute the Agodi Zoological Garden is another possible source of metals.

Heavy Metals in sediment of Dandaru Lake

The concentration of Pb varied between ND to 698.34 mg/kg (mean = 85.79 ± 98.63mg/kg). The effect low range and threshold effect level (TEL) sediment quality guidelines were exceeded in all the stations and indicate possible toxic effect on aquatic organisms. The mean concentration in station 3 also exceeded the probable effect level of the [15]guidelines. The concentration of Cd ranged from ND to 9.00mg/kg (1.33 ± 2.30 mg/kg). The effect low range and threshold effect level were exceeded in all the stations which suggest probable toxic effects on aquatic organisms. However, the recorded values were below the effect medium range and probable effect level sediment quality guidelines.

The determined data for Cr was 0.00 – 26.10 mg/kg, mean = 4.57 ± 28.2 mg/kg ; the mean concentration for Cr and Cu in the sampling stations were below the ERL and TEL of both sediment quality guidelines and these strongly suggest no toxic effect on aquatic organism is likely to occur. The Fe and Mn concentrations ranged from 7.50-62462.62 mg/kg (mean 11346.62 ± 15356.28 mg/kg) and ND – 1160.25 (mean = 229.08 ± 279.40 mg/kg, respectively. They are excluded from the sediment quality guidelines, since they are usually considered not to have adverse effects on marine organisms [25].

The concentration of Zn in the sediments in Dandaru Lake during this study varied between 12.40 – 2,450.11 mg/kg (mean = 344.21 ± 482.27 mg/kg). Spatially, all the mean concentrations exceeded the ERL and TEL sediment quality guidelines. The probable effect level was also exceeded by the determined mean concentration of Zn in station 2 (478.73 ± 677.24 mg/kg); station 4, (389.79 ± 680.85 mg/kg) and station 5 (364.76 ± 419.2 mg/kg).

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However, the effect medium range was only exceeded by mean concentration of Zn in station 2 (478.73 ± 677.24 mg/kg). These results strongly suggest toxic effects on aquatic organisms in the Dandaru Lake.

Geoaccumulation Index (I_{geo})

The average I_{geo} class for the sediments in all the stations was 0-2 indicating uncontaminated to moderately contaminated levels. The negative Igeo values are the results of relatively low levels of contamination for some metals in some cores and the background variability factor (1.5) in the Igeo equation [35]. Igeo values give the advantage of not aggregating all the pollutants into one value and therefore treating each heavy metal independently, giving a good picture of the extent of individual heavy metal pollution[5]. Thus, heavy metals contamination of the Dandaru Reservoir during the period of this study was due to Pb, Cd and Zn.

Contamination Factor

The contamination factor for Pb in the sediments varied from 3.2 to 7.1, this indicates considerable to very high contamination. The CF values (4.2 – 4.7) for cadmium in the sediments of the lake shows considerable contamination. Zinc contamination factor ranged between 1.9 to 5.0, this indicates moderate to considerable contamination. The CF for Cr (0.04 – 0.1); Fe (0.1 – 0.3); Cu (0.2 -0.6) and Mn (0.2 – 0.4) indicates low contamination.

CONCLUSION

This study has established that the water and sediment of the Dandaru Reservoir are contaminated with heavy metals (lead, cadmium and zinc) from various livelihood activities along the Ogunpa River watershed. These may pose a danger to the local population who consume water and fish from the lake. Effective monitoring of the livelihood activities and discharges into the reservoir are recommended to prevent further deterioration of the reservoir.

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APPENDIX

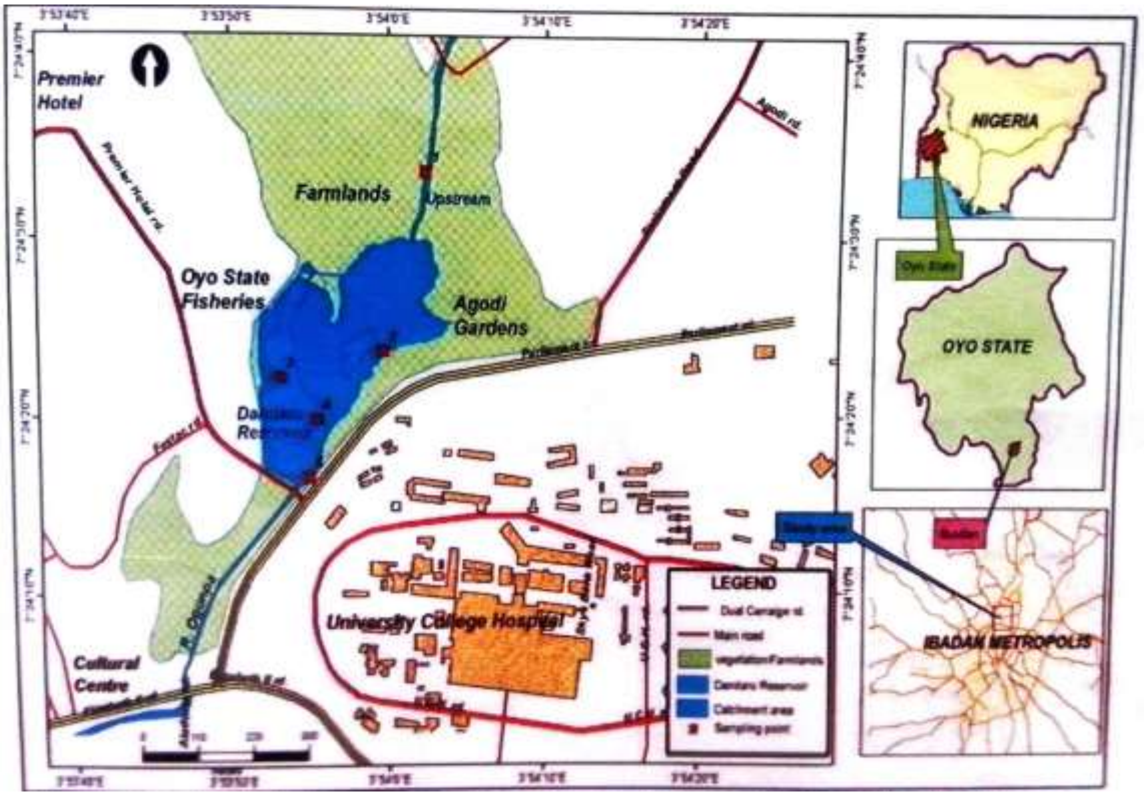

Figure1. Map of study area showing sampling points

Table1: Sampling Stations Description

Station	Coordinates	Description
1	Latitude 07˚ 24.561'N; Longitude 003˚ 53.039'E	Upstream of the Dandaru Reservoir; farming activities on adjacent land
2	Latitude 07˚ 24.396'N; Longitude 003˚ 53.994'E	Close to Agodi Garden and received effluent from University College Hospital
3	Latitude 07˚ 24.371N; Longitude 003˚ 53.884 E	Centre of the reservoir. Fishing activities occurred here; solid wastes dumped into reservoir were encountered
4	Latitude 07˚ 24.332' N; Longitude 003˚ 53.923″ E	Within the reservoir; 1.55 km downstream of Station 3
5	Latitude 07˚ 24.277″ N; Longitude 003˚ 53.915″E	Exit of water near the dam; solid wastes were encountered

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Table 2: Spatial variation in physico-chemical parameters of water in Dandaru Lake

Parameters	Stations					Mean±SD (Range)	F-Value	P-values	Sig.
	1	2	3	4	5				
pH	7.53±0.16	7.54±0.25	7.54±0.18	7.59±0.20	7.53±0.24	7.55±0.21 (6.95-7.88)	0.175	0.950	P>0.05
Air Temp. (ºC)	31.17±3.38	29.25±2.29	31.22±2.53	29.79±2.48	28.45±2.79	29.98±2.85 (23.70-39.90)	2.374	0.063	P>0.05
Water Temp. (ºC)	27.58±2.61	27.78±3.26	28.60±2.42	27.15±2.36	26.97±2.92	27.62±2.70 (20.60-33.60)	3.890	0.622	P>0.05
Depth (cm)	61.92±64.70	13.75±15.30	19.47±20.88	19.18±22.05	21.48±24.82	27.15±37.75 (0.00-129.00)	3.886	0.008	P>0.05
Conductivity (µS/cm)	406.94±50.74	408.13±80.39	391.50±70.82	408.33±43.63	410.54±45.20	405.09±58.34 (273-583)	0.198	0.938	P>0.05
TDS (mg/L)	261.08±24.01	264.94±56.27	249.96±45.40	260.00±30.79	259.33±33.01	259.07±38.56 (182-389)	0.235	0.918	P>0.05
TSS (mg/L)	0.79±0.27	0.78±0.30	0.77±0.26	0.80±0.23	0.79±0.24	0.79±0.25 (0.30-1.33)	0.024	0.999	P>0.05
Dissolved Oxygen (mg/L)	6.34±1.39	5.40±1.27	5.83±1.36	4.68±1.45	4.23±1.46	5.30±1.54 (2.10-9.90)	4.533	0.003	P<0.05
BOD (mg/L)	4.04±1.95	3.75±1.46	4.44±1.51	2.81±1.56	2.97±1.43	3.60±1.66 (0.43-9.12)	2.314	0.069	P>0.05
Alkalinity (mg/L)	44.41±1.95	39.14±9.59	44.35±17.36	40.73±10.63	46.05±13.32	42.93±13.40 (15.00-83.00)	0.536	0.710	P>0.05
Nitrate (mg/L)	4.00±2.61	4.73±2.30	4.10±2.10	4.96±4.06	4.96±4.06	4.23±2.67 (0.05-17.10)	0.652	0.628	P>0.05
Phosphate (mg/L)	0.20±0.15	0.43±0.40	0.26±0.51	0.28±0.32	0.24±0.21	0.28±0.34 (0.00-1.83)	0.755	0.559	P>0.05
Lead (mg/L)	0.04±0.05	0.12±0.23	0.05±0.10	0.13±0.32	0.07±0.11	0.08±0.19 (0.00-1.13)	0.600	0.664	P>0.05
Nickel (mg/L)	0.09±1.33	0.06±0.08	0.07±0.08	0.05±0.07	0.15±0.28	0.08±0.15 (0.00-1.00)	0.790	0.537	P>0.05
Cadmium (mg/L)	0.02±0.03	0.03±0.05	0.02±0.04	0.03±0.06	0.04±0.07	0.03±0.05 (0.00-0.20)	0.416	0.796	P>0.05
Cobalt (mg/L)	0.03±0.06	0.04±0.08	0.03±0.06	0.04±0.06	0.04±0.07	0.04±0.06 (0.00-0.28)	0.060	0.993	P>0.05
Chromium (mg/L)	0.01±0.01	0.01±0.01	0.01±0.02	0.01±0.02	0.01±0.02	0.01±0.01 (0.00-0.06)	0.255	0.905	P>0.05
Potassium (mg/L)	6.48±10.08	6.56±11.09	5.62±9.15	6.66±10.26	7.40±11.70	6.54±10.15 (0.000-35.70)	0.044	0.996	P>0.05
Manganese (mg/L)	0.93±1.46	1.11±1.29	1.29±1.27	0.50±0.73	0.76±1.06	0.92±1.18 (0.00-4.19)	0.792	0.535	P>0.05
Iron (mg/L)	0.04±0.07	1.36±3.03	1.37±2.12	0.35±0.74	0.92±1.38	0.81±1.82 (0.00-10.60	1.337	0.268	P>0.05
Copper (mg/L)	0.04±0.07	0.05±0.07	0.05±0.07	0.05±0.08	0.05±0.08	0.05±0.07 (0.00-0.21)	0.056	0.994	P>0.05
Zinc (mg/L)	0.03±0.04	0.09±0.17	0.08±0.17	0.04±0.02	0.03±0.03	0.06±0.11 (0.00-0.63)	0.838	0.507	P>0.05

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Table 3: Comparison of heavy metals contamination of some lakes

Metal	Asejire Lake (ppm) Aladesanmi *et al.*, 2013	Asejire Lake (mg/L) Jenyo-Oni and Oladele, 2016	Eleyele Lake (mg/L) Akinyemi *et al.*, 2014	Dandaru Lake (mg/L) Abiona *et al.*, 2012	Dandaru Lake Adekanmbi and Falodun(2015)	DandaruLake This Study
Pb	NT	0.0150 ± 0.028	0.032 ± 0.0576	0.002 ± 0.00	0.01-0.02	0.08±0.19
Ni	0.9	ND	0.036 ± 0.0227	NT	<0.01	0.08±0.15
Cd	NT	ND	0.026 ± 0.0331	NT	<0.01	0.03±0.05
Co	0.00	ND	NT	2.160 ± 2.50	NT	0.04±0.06
Cr	NT	ND	0.026 ± 0.025	NT	0.02-0.04	0.01±0.01
Mn	0.45	NT	NT	1.169 ± 0.009	0.31-0.41	0.92±1.18
Fe	11.9	NT	NT	1.272 ± 0.009	0.38 -0.54	0.81±1.82
Cu	0.00	0.0066 ± 0.000	0.035 ± 0.0723	NT	0.03 -0.59	0.05±0.07
Zn	0.35	NT	0.075 ± 0.0789	0.005 ± 0.00	1.16 – 2.11	0.06±0.11

(NT-Not Taken; ND–Not Detected)

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Table 4: Spatial variation in physico-chemical parameters of sediments in Dandaru Lake

Parameters	Stations					Mean ± SD (Range)	Long *et al.*, 1995		CCME, 2001	
	1	2	3	4	5		ERL	ERM	TEL	PEL
pH	3.33±1.49	3.35±1.50	3.38±1.53	3.36±1.51	3.35±1.50	3.35±1.39 (0.00-7.20)	-	-	-	-
Lead (mg/kg)	63.11±4.87	77.20±6.61	141.69±8.68	76.57±6.17	70.37±5.95	85.79±3.63 (0.00-698.34)	46.7	218	35	91.3
Cadmium (mg/kg)	1.25±0.54	1.33±0.10	1.39±0.40	1.40±0.64	1.26±0.18	1.33±0.30 (0.00-9.00)	1.2	9.6	0.6	3.5
Chromium (mg/kg)	4.60±2.97	5.64±1.34	3.91±0.06	5.52±2.38	3.17±1.21	4.57±2.55 (0.00-26.10)	81	370	37.3	90
Cobalt (mg/kg)	7.28±2.82	9.45±4.71	9.34±1..30	5.05±1.22	10.65±2.73	8.35±3.61 (0.10-40.58)	NA	NA	NA	NA
Iron (mg/kg)	14069.38± 2157.34	12304.55± 1577.80	11607.42± 1534.82	6652.69± 1066.38	12099.05± 1594.65	11346.62±1556.28 (7.50-62462.62)	NA	NA	NA	NA
Copper (mg/kg)	13.90±15.68	16.28±22.91	28.91±49.84	14.63±21.72	13.78±18.88	17.46±28.20 (0.00-159.00)	34	270	35.7	197
Zinc (mg/kg)	177.48±12.11	478.73±67.24	310.32±24.45	389.79±60.85	364.76±49.20	344.21±42.27 (12.40-2450.11)	150	410	123	315
Magnesium (mg/kg)	2.17±0.49	2.50±1.64	2.70±1.30	2.80±1.67	2.44±1.42	2.52±8.44 (0.00-33.49)	NA	NA	NA	NA
Manganese (mg/kg)	304.73±30.74	254.09±21.62	209.88±24.06	151.70±11.66	225.01±33.36	229.08±29.40 (0.00-1160.25)	NA	NA	NA	NA

ERL- Effective Low Range; ERM- Effective Medium Range; TEL- Threshold Effect Level; PEL- Probable Effect Level

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Table 5: Heavy Metals Concentrations of sediments of some lakes in Nigeria

Metals	Akan *et al*., 2012 Lake Chad (Kwatan Turare)µg/g	Jonathan *et al*., 2016 Lake Chad Dumba	Jonathan *et al*., 2016 Lake Chad Kwata	Jenyo-Oni and Oladele , 2016 Asejire Lake(mg/kg)	This Study Dandaru Lake(mg/kg) (mg/kg)
Pb	22.34 ± 1.34 - 42.12 ± 0.11	126.83 ± 10.24	100.23 ± 10.23	0.0740 ± 0.018	85.79±98.63
Cd	9.34 ± 1.23 - 20.34 ± 8.34	3.64 ± 0.13	0.01	0.0834 ± 0.037	1.33±2.30
Cr	28.34 ± 0.05 - 43.23 ± 4.33	98.75 ± 0.25	66.07 ± 5.80	0.0154 ± 0.004	4.57±6.55
Co	11.22 ± 1.56 - 21.23 ± 4.33	-	-	0.0266 ± 0.011	8.35±8.61
Fe	19.29 ± 3.22 - 32.86 ± 0.11	44327.94 ± 8.80	80877.06 ± 10.12	2.392 ± 0.015	11346.62±15356.28
Cu	25.11 ± 3.76 - 40.32 ± 1.09	19.39 ± 3.03	19.39 ± 5.01	NT	17.46±28.20
Zn	123.45 ± 32.45 - 165.34 ± 22.54	148.94 ± 13.62	101.31 ± 10.55	NT	344.21±482.27
Mn	43.56 ± 3.43 - 78.23 ± 2.55	1167.12 ± 10.15	1249.06 ± 10.12	NT	229.08±279.40

Table 6: Contamination Factors of some metals in sediment of Dandaru Lake

	Contamination Factor				
Metal concentration(mg/kg)	1	2	3	4	5
Lead	3.2	3.9	7.1	3.8	3.5
Cadmium	4.2	4.4	4.6	4.7	4.2
Chromium	0.1	0.1	0.04	0.1	0.04
Iron	0.3	0.3	0.1	0.1	0.3
Copper	0.3	0.2	0.6	0.3	0.3
Zinc	1.9	5.0	3.3	4.1	3.8
Manganese	0.4	0.3	0.3	0.2	0.3

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Table 7: Index of geoaccumulation (Igeo) values of heavy metals in Dandaru Reservoir

Station	Index of geoaccumulation (Igeo) Pb	Cd	Cr	Fe	Cu	Zn	Mn	I_{geo} Class	Sediment Quality
1	1.07	1.48	-5.06	-2.32	-2.25	0.32	-2.07	0-2	Uncontaminated to moderately contaminated
2	1.36	1.57	-4.64	-2.47	-2.06	1.75	-2.33	0-2	Uncontaminated to moderately contaminated
3	2.24	1.63	-5.06	-2.57	-1.22	1.12	-2.60	0-3	Uncontaminated to moderately contaminated
4	1.35	1.64	-6.64	-3.32	-2.18	1.45	-3.06	0-2	Uncontaminated to moderately contaminated
5	1.23	1.49	-5.64	-2.47	-2.32	1.36	-2.47	0-2	Uncontaminated to moderately contaminated
Average	1.52	1.57	-4.92	-2.64	-1.94	1.28	-2.47	0-2	Uncontaminated to moderately contaminated
*Average Shale	20	0.30	90	46000	45	95	850		

*Average Shale, World Geochemical Background Concentration

Turekian and Wedepohl (1961)

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