Journal of Materials and Environmental Science
ISSN : 2028-2508
e-ISSN : 2737-890X
CODEN : JMESCN

J. Mater. Environ. Sci., 2024, Volume 15, Issue 1, Page 72-83

http://www.jmaterenvironsci.com

Physicochemical Characteristics and Heavy Metals Assessment of Surface Water and Sediment from Idim Idaang Stream in Ibiono Ibom, Akwa Ibom State, Nigeria

Anweting, I. B.[1*] Ebong, G. A.[1] Okon, I. E. [2, 3], Etuk, H. S[1] and Etim, I. S.[1]

[1]*Chemistry Department, University of Uyo, Uyo, Akwa Ibom State, Nigeria*
[2]Department of Chemistry, Ahmadu Bello University, Zaria, Kaduna, Nigeria
[3]*Transport Technology Centre, Nigerian Institute of Transport Technology, Zaria, Nigeria*

**Corresponding author Email address: idongesitanweting@uniuyo.edu.ng*

Received *08 Sept 2023,*
Revised *28 Dec 2023,*
Accepted *02 Jan 2024*

Keywords:
- ✓ *Physicochemical parameters,*
- ✓ *Heavy Metal,*
- ✓ *Digestion,*
- ✓ *Water Quality,*
- ✓ *Standard Limits***.**

Citation*: Anweting, I.B. Ebong, G.A. Okon, I.E., Etuk, H.S. and Etim, I.S. (2024) Physicochemical Characteristics and Heavy Metals Assessment of Surface Water and Sediment from Idim Idaang Stream in Ibiono Ibom, Akwa Ibom State, Nigeria, J. Mater. Environ. Sci., 15(1), 72-82*

Abstract: This study evaluated physicochemical parameters and heavy metals of surface water and sediment from Idim Idaang, Ibiono Ibom Local Government Area, Akwa Ibom State, Nigeria. The physicochemical parameters examined were temperature, pH, turbidity, electrical conductivity, total dissolved solids (TDS), total suspended solids (TSS), total alkalinity, dissolved oxygen (DO), total hardness, bi-carbonate and salinity as chlorine. The quality evaluation revealed that all the physicochemical parameters were found to be within the standard limits except for dissolved oxygen. The heavy metals examined include lead (Pb), mercury (Hg), cobalt (Co), arsenic (As), iron (Fe), copper (Cu), cadmium (Cd), chromium (Cr), manganese (Mn), nickel (Ni) and zinc (Zn). Atomic Absorption Spectroscopy (AAS) was used for heavy metals analysis. Heavy metals concentrations in the water followed the trend Hg =As < Co < Ni < Cr < Pb < Cd < Mn < Cu< Fe < Zn, similarly that of sediments was Hg = As < Co < Cr < Pb < Cd < Ni < Zn < Mn<Cu < Fe. In the water, the concentrations for Pb, Cd, Zn and Fe were higher than the WHO limits. In the sediment, the concentrations for Pb, Cd, Ni, Mn and Fe were higher than the WHO limits. Correlation between metal concentrations in the sediment and in the water was high with $r = 0.752$. The water quality index (WQI) showed a significant value of 29.37 which signified that the stream was save for drinking in terms of the physicochemical parameters studied.

1. Introduction

Heavy metals such as zinc, lead, cadmium, chromium, mercury and copper can cause serious health problem to both plants and animals in ecosystem (Etuk *et al.,* 2023a; Okon *et al.,* 2023a; Etuk *et al.,* 2023b; Karim *et al.,* 2016a; Karim *et al.,* 2016b). Virtually all metals, including essential micronutrients, are toxic to aquatic ecosystem. Although some metals such as manganese, iron, copper and zinc are essential micro-nutrients, many others such as mercury, cadmium and lead are not required even in small amount by any organism (Nairat *et al.*, 2020). Metals can never be totally eliminated once they enter a water body. They remain persistent in sediment and slowly get released causing serious hazards to aquatic life forms as they further move up in the food chain (Oyeyiola *et al.*, 2020). The toxicity of metals may depend on the physical and chemical characteristics of water. The physicochemical properties of water may also indicate the quality of water.

Surface water is a natural water source which collects from water running across the surface of the ground (Barry, 2019). As this water runs across the ground surface, it picks up microorganisms, organic matter and minerals. Sediment is matter (sand, dirt, gravel) that settles to the bottom of the water (Okon *et al.*, 2022), surface waters serves various purposes ranging from drinking, sources of fish, irrigation to recreation but frequently these waters are polluted. Water pollution is one of the most important environmental problems faced by third world countries (Barry, 2019). The significance of various substances in water is obvious and it is their level that gives measure of the quality of the water. Due to industrialization, majority of the compounds released into the water have affinity for particulate matter, therefore the chemical composition of bottom sediments reflects the input of discharged substances to the marine environment.

Physicochemical analysis is based on actual measurement of physical parameters such as turbidity, temperature, colour etcetera and chemical parameters such as, alkalinity, dissolved oxygen (DO), hardness, salinity among others. The physicochemical monitoring provides quantitative information about the presence of pollutants in natural streams. Changes in the physicochemical properties of water contribute to poor water quality (Faiza *et al.*, 2012; El Abdouni *et al.*, 2021; Okon *et al.*, 2023b). physicochemical contaminants find their way into the rivers from domestic, industrial effluents and agricultural field run-off. Metal content in streams may vary between the water column and bed sediments; however, variation in concentration of parameters depends on concentration from processes operating within the catchments (Bouknana *et al.*, 2014).

Poor water quality is the result of changes in physicochemical properties and high levels of heavy metals, which find their way into the water bodies through anthropogenic activities including impacts due to agricultural practices (Dhawde *et al.*, 2018; Bazzi *et al.*, 2020). Activities such as mining and construction alters physicochemical properties in the water sources, they change the pH of water, increase water turbidity, and also raise the total content of total dissolved solids and heavy metals. Eutrophication caused by changes in physicochemical properties causes the degradation of freshwater ecosystems. This paper aimed to evaluate physicochemical parameters and heavy metals of surface water and sediment from Idim Idaang stream in Ibiono Ibom Local Government Area, Akwa Ibom State, Nigeria so as to know their status and affirmed whether the studied water is polluted or not. This follows the fact that the Idim Idaang stream is a major source of drinking water for the people living around it.

2. Methodology

2.1 Study area

The study location is Ikot Antia, a village in Ibiono Ibom Local Government Area of Akwa Ibom State, Nigeria as shown in **Figure 1.** The administrative hub of the Ibiono Ibom Local Government Area is Okoi Ita. Ibiono Ibom is one of the Local Government Areas in Akwa Ibom State, South-South Nigeria. Ibiono Ibom is made up of clans, the clans include: Southern Ibiono Ibom, Northern Ibiono Ibom, Central Ibiono Ibom, Eastern Ibiono Ibom and Ikpanya. Ibiono Ibom is located on Latitude 5.207^0 or 5^0 12' 5'' North; Longitude 7.8931^0 or 7^0 53' 35'' East; with Elevation of 61 metres (200 feet), it covered an area about 9,193km^2, and population of 1,053,084 (National Population Census, 2010). The region is known for its cultivation and exportation of agricultural products such as cassava, oil palm, plantain, vegetables (Kamelan, 2014). The predominant dwellers of the study area engage in farming, fishing, hunting and civil service.

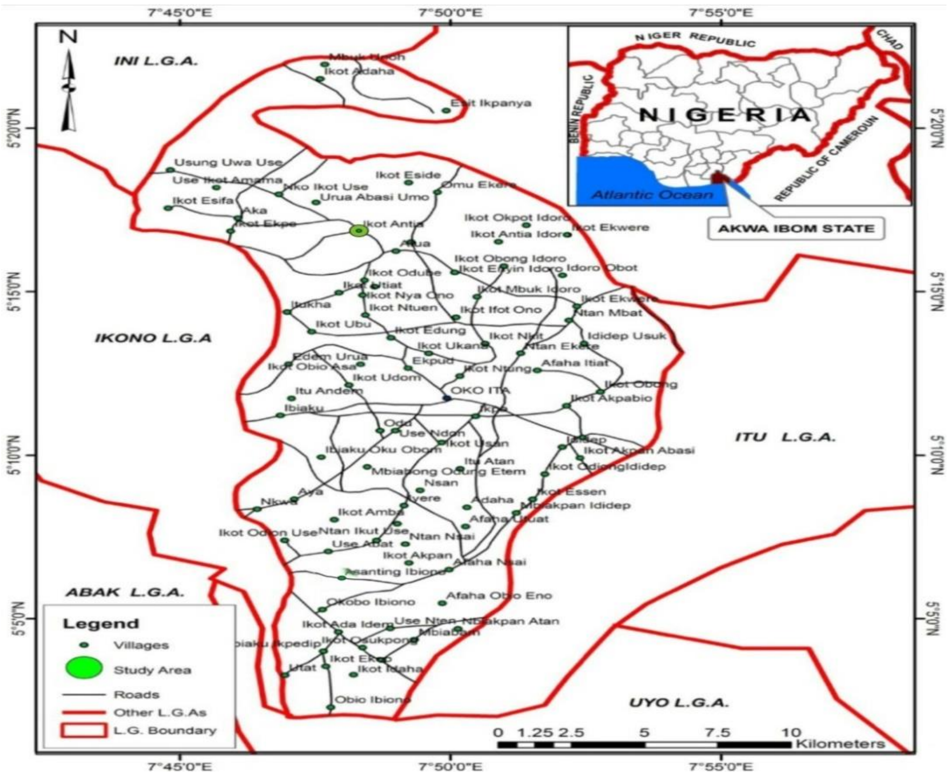

Figure 1. Map indicating the study area

2.2 Materials

All reagents used were of analytical grade and they were freshly prepared. All sampling containers and glass wares were washed with 0.05M HNO_3 solution and rinsed with deionized water. Apparatus used in laboratory work include oven, petro-dish, spatula, beakers, conical flask, Analytical weight balance, volumetric flask, measuring cylinder of needed capacity, burette, retort stand, white tile, funnel, flame photometer, heating mantle, pipette, cuvettes, methyl orange and Atomic Absorption Spectrophotometer (XplorAA GBS Model).

2.3 Sample collection

Water samples for the assessment of physicochemical characteristics were collected in a 1litre plastic bottle and kept in an ice chest until analysis within 24 hours. A 75 mL amber bottle was used to provide a suitable place for future determination of dissolved oxygen and the samples collected were fixed onsite using Winkler 1 and 2. Five drops of conc. H_2SO_4 acid was added to the sample to dissolve the precipitate formed. For determination of heavy metal levels, a 120 mL glass bottle was used to collect water samples, few drops of conc. HNO_3 was then added to the samples for preservation before the analysis.

Sediment was obtained from the same location at the midpoint on the cross-section of the stream that has the same amount of discharge. The sediment samples were collected using a plastic spoon by scooping the top layer of sediments and then stored in a pre-cleaned 1000ml polyethylene container, labeled, and transported to the laboratory for storage in freezers awaiting analysis. Samples were air-dried in the laboratory and crumbs found in the sediment were removed. Sediments were also sieved through a 2mm sieve to remove coarse particles.

2.4 *Digestion of samples for heavy metal analysis*

The sediment (0.5gm) was digested in borosilicate glass tube with the addition of nitric acid and perchloric acid (4:1), a the residue was dissolved with concentrated HCl and the final process diluted as much as 25mL by putting the tubes in water bath for 5 - 6 hours to clear digestion of sample. After cooling, each sample was diluted up to 10 ml with distilled water and kept in plastic container. The water samples were used directly for analysis.

2.5 *Water quality assessment*

The assessment of the water quality of the studied stream was done using Water Quality Index (WQI). The WQI was calculated using standards of drinking water quality recommended by the World Health Organization. The Weighted Arithmetic index method (Brown *et al*., 2018) was used for the calculation of WQI in this study. Three steps were followed for computing WQI.

(i) Each of the eleven (11) parameters was assigned a weight, wi according to its relative importance in the overall quality of water for drinking purposes.

(ii) The relative weight, Wr was computed using the equation below:

$$Wr = \frac{Wi}{\Sigma Wi} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad \dots.\text{Eqn. }1$$

Where, Wr = relative weight, Wi = weight of each parameter and ΣWi = sum of parameters.

(iii) A quality rating scale, qi for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down by WHO (2011) and WHO (2022).

$$qi = \frac{Ci}{Si} \qquad \dots\dots\dots\dots\dots\dots\dots.. \qquad \text{Eqn. }2$$

where, qi = quality rating, Ci = concentration of each chemical parameter in each water sample in mg/l and Si = NSDW/WHO drinking water standards for each parameter. In order to compute the WQI, Si was first computed for each of the chemical parameter, which was then used to determine the WQI using the following equations:

$$Si = Wi \times qi \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{Eqn. }3$$

Therefore WQI (Water Quality Index) = $\sum Si$

Where, Si = sub index of each parameter and qi = rating based on the concentration of each parameter. **Table 1** shows classification values for water quality index (WQI) for drinking water (Brown *et al.*, 2018).

Table 1. Water quality index (WQI) classification for drinking water

Water Quality Index Level	Water Quality Status
0-25	Excellent water quality
25-50	Good water quality
51-75	Poor water quality
76-100	Very poor water quality
>100	Unsuitable for drinking

3. Results and Discussion

3.1 Physicochemical parameters

The standard limits for the physical and chemical determinants approved by World Health Organization (2011 and 2022) were used as standard to determine the quality index of the samples.

The results obtained from analyzing the concentration of eleven (11) evaluated physicochemical parameters (temperature, pH, turbidity, electrical conductivity, total dissolved solids (TDS), total suspended solids (TSS), alkalinity, dissolved oxygen, total hardness, bi-carbonate and salinity as chlorine) are presented in **Table 2.** Water quality assessment was also calculated from the results of the parameters and was compared in-line with the recommended standard limits as set out by WHO as presented in **Table 3.**

Table 2. Physicochemical parameters of surface water (SW)

S/N	Parameters	WHO Limit	Measured Val in SW (mg/L
1	Temp (^{0}C)	30 - 32	30.10
2	pH	6.5-8.5	5.66
3	Turbidity (NTU)	5	1.48
4	Electrical Conductivity (µs/cm)	1000	73.70
5	Dissolved Oxygen (mg/L)	5.00	4.20
6	Total Dissolved Solid (mg/ L)	250	41.30
7	Total Suspended Solid (mg/L)	1500	0.13
8	Salinity as Cl^- (mg/L)	250	28.40
9	Total Hardness (ppm)	150	33.00
10	Total Alkalinity (mg/L)	200	45.00
11	Bi-Carbonate (mg/L)	30 - 400	54.90

Table 3 shows results for the physicochemical analysis of the water samples and its quality assessment. Temperature of the sample is within the recommended range by WHO (30 – 32 ^{0}C) as the value is 30.10^{0}C as shown in the result obtained as presented **Table 3.** pH value of drinking water is an

important index of acidity and alkalinity, it is also considered as an important ecological factor that provides an important piece of information in many types of geological equilibriums or solubility calculations (Edward, 2016). The result of the pH obtained was 5.66 as shown in **Tables 2 and 3,** though the result is below the values recommended by WHO and are slightly acidic but it align with the assumption of APHA (2018) that natural water has pH values in the range 4 to 9 and most are slightly basic due to the presence of bicarbonate and carbonates of alkali and alkaline earth metals. The result obtained from the analysis indicated that the sample has a turbidity of 1.48 NTU which is in line with the 5 NTU standard limit turbidity set by WHO for drinking water (WHO, 2019).

Table 3. Quality index of surface water (Idim Idaang Stream)

S/N	Parameters	WHO Limit	Measured Value in Surface Water (ci) (mg/L)	Assigned Weight (wi)	Relative Weight (wr)	Quality (qi)	Sub-Index (Si)
1	Temp (^{0}C)	30 - 32	30.10	4	0.1143	0.9710	3.8839
2	pH	6.5-8.5	5.66	4	0.1143	0.8086	3.2343
3	Turbidity (NTU)	5	1.48	3	0.0857	0.0099	0.0296
4	Electrical Conductivity (µs/cm)	1000	73.70	3	0.0857	0.0737	0.2211
5	Dissolved Oxygen (mg/L)	5.00	4.92	4	0.1143	0.8400	3.3600
6	Total Dissolved Solid (mg/ L)	250	41.30	3	0.0857	0.1652	0.4956
7	Total Suspended Solid (mg/L)	1500	0.13	2	0.0571	0.0001	0.0002
8	Salinity as Cl^- (mg/L)	250	28.40	3	0.0857	0.1136	0.3408
9	Total Hardness (ppm)	150	33.00	3	0.0857	0.2200	0.6600
10	Total Alkalinity (mg/L)	200	45.00	3	0.0857	0.2250	0.6750
11	Bi-Carbonate (mg/L)	30 - 400	54.90	3	0.0857	5.4900	16.4700
	Summation(∑)			35			29.37

Electrical conductivity (EC) is a direct function of total dissolved salts in water, in this study the value of EC (73.70 µs/cm) is within the limit (1000 µs/cm) given by WHO as shown in the result in **Tables 2 and 3.** This low EC value is very good as high conductivity may reduce the quality of the water by giving mineral taste to the water in line with (Kavcar *et al*. 2019). For industrial and agricultural activity, conductivity of water is critical to monitor. Water with high conductivity may cause corrosion of metal surface of equipment such as boiler. It is also applicable to home appliances such as water heater system and faucets.

Dissolved Oxygen (DO) is a very important water quality parameter and also an index of physical and biological processes going on in water. The result obtained was 4.92 mg/L (**Tables 2 and 3)**, which is little lower than the recommended value (5.00) by WHO. Further decreased in the DO may impact on aquatic organisms as they need oxygen for survival (Iqbal *et al*. 2019), moreover, water low in dissolved oxygen has an unpleasant smell while waters high in dissolved oxygen are good for drinking purposes. Total Dissolved Solid (TDS) present in the sample was 41.30 mg/L (**Tables 2 and 3)**. The value is within the recommended value (250 mg/L) by WHO. This low level of TDS observed shows good quality. Golterman (2018) asserted that water with high TDS is generally of inferior palatability and may induce an unfavourable physiological reaction in the consumer. High concentration of dissolved solid in water is also responsible for hardness, turbidity, odour, taste, colour and alkalinity, hence the maximum permissible concentration of TDS is 250 mg/L in potable water. Result from the analysis revealed that the sample has total suspended solid (TSS) value of 0.13 mg/L (**Tables 2 and 3)**. Golterman (2018) postulated that increase in suspended solids in water is proportional to the increase in the extent of pollution and also account for odour and colour, hence the result portray that the water is safe and portable for consumption.

Salinity as Chloride (Cl^-) ion is present in appreciable amounts in all natural waters, hence the water sample contain chloride ion 28.40 mg/L (**Tables 2 and 3)** which is within the WHO limit value (250 mg/L). Ademorati (2019) reported that excess chlorides in water are usually taken as index of pollution and that natural levels in rivers and other fresh waters are usually in the range 15-35 mg/L Cl^-. Hence, with 28.40 mg/L obtained for salinity, the water is safe. The result obtained as presented in **Tables 2 and 3** shows that the sample contains 33.00 ppm as total hardness and this is within the WHO limit (150 ppm). APHA (2009) reported that hardness is caused by metallic salt (ion) of calcium and magnesium and sometimes iron. These salts are usually in the form of bicarbonate, sulphates and chlorides and that water hardness could be temporary or permanent. The result revealed that total alkalinity was 45.00 mg/L (**Tables 2 and 3)**, this was within the WHO limit of 200 mg/L. Verma *et al*. (2019) postulated that the change in alkalinity depends on carbonates and bicarbonates, which in turn depend upon release of CO_2. Change in carbonates and bicarbonates depend upon release of CO_2 through respiration of living organisms. The concentration obtained for bicarbonate was 54.90 mg/L, this was within the WHO limit rane of 30 - 400 mg/L.

3.2 Water quality of the Idim Idaang Stream

The overall water quality index (WQI) value of 29.37 as shown in **Table 3** revealed that the overall quality of the stream was safe for drinking with respect to the physicochemical parameters studied since the value (29.37) fall under the range of 25-50 classification, which signifies good water quality as indicated in **Table 1**.

3.3 Heavy Metal Analysis

The results obtained from analyzing the concentrations of eleven heavy metals (Pb, Hg, Co, Ar, Fe, Cu, Cd, Cr, Mn, Ni and Zn) is presented in **Table 4. Table 4** presents the concentration of metals in the water and sediment samples. The following concentrations (mg/L) were obtained from the water sample (Pb = 0.062, Hg= 0.001, Co = 0.002, As= 0.001, Fe = 3.142, Cu = 1.874, Cd= 0.262, Cr= 0.046, Mn = 0.345, Ni = 0.004 and Zn = 3.418). From the sediment sample, the following concentrations (mg/L) were obtained (Pb = 0.183, Hg = 0.001, Co = 0.002, As = 0.001, Fe = 6.218, Cu = 2.092, Cd = 0.853, Cr = 0.034, Mn = 1.853, Ni = 1.032 and Zn = 1.589). From the analysis, the concentrations in mg/L for Hg (0.001) Co (0.002) and As (0.001) were the same for both sediment and water. Apart from Cr and Zn, concentrations in sediment for Pb, Fe, Cu, Cd, Mn and Ni were higher ($p = 0.05$) than in water, this is illustrated in **Figure 2**. This correspond with the postulation of Abeh *et al*. (2007) that sediment is the major depositories of heavy metals in aquatic environment. The concentrations (mg/L) 0.062, 0.262 3.418 and 3.142 where higher than the WHO limits of 0.010, 0.003, 3.000 and 0.300 for Pb, Cd, Zn and Fe respectively, this reveals that the water have been polluted by Pb, Cd, and with heavy pollution by Zn and Fe.

Table 4. Analysis of heavy metal parameters

S/N	**Heavy Metal Parameters** (mg/L)	**WHO Limit** (mg/L)	**Measured Value of Surface Water (mg/L)**	**Measured Value of Sediment (mg/L)**
1	Lead	0.01	0.062	0.183
2	Mercury	0.006	0.001	0.001
3	Cobalt	0.01	0.002	0.002
4	Arsenic	0.01	0.001	0.001
5	Iron	0.3	3.142	6.218
6	Copper	2	1.874	2.092
7	Cadmium	0.003	0.262	0.853
8	Chromium	0.05	0.046	0.034
9	Manganese	0.5	0.345	1.853
10	Nickel	0.02	0.004	1.032
11	Zinc	3.00	3.418	1.589

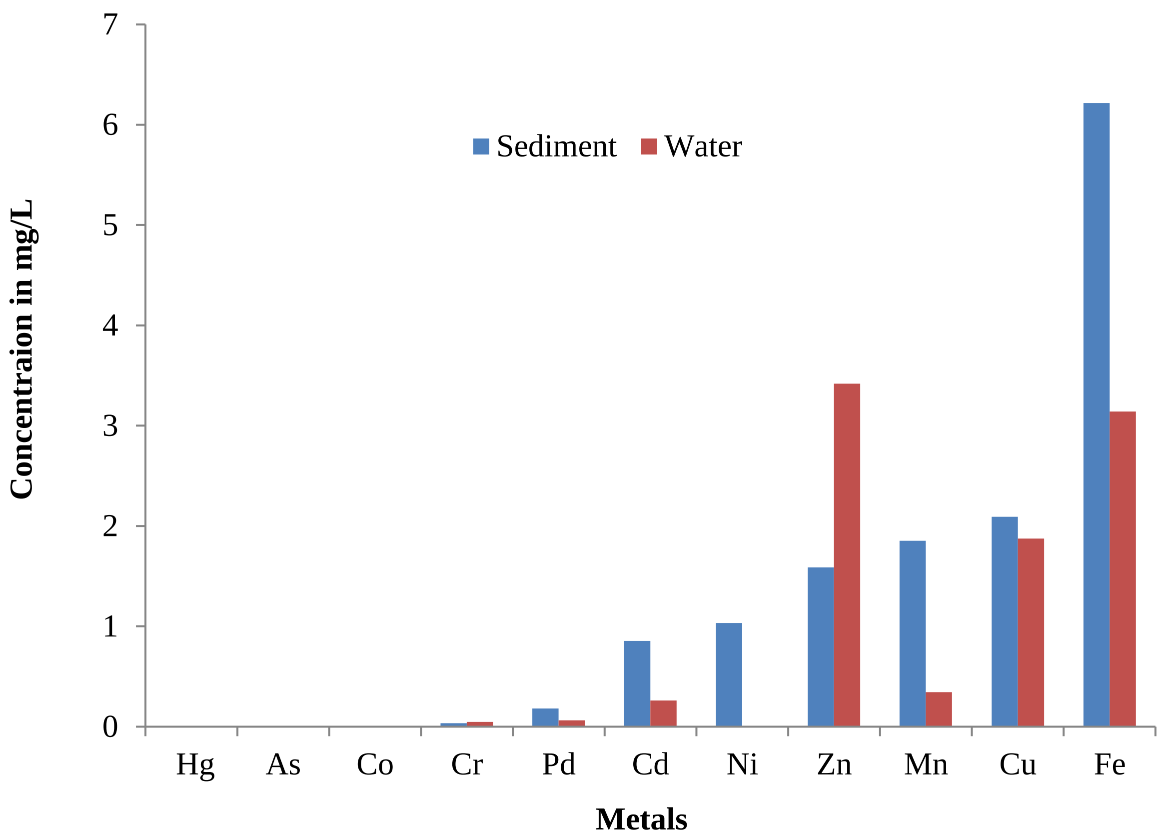

Figure 2. Comparison of metals in sediment and in of water

In the sediment, the concentrations (mg/L) 0.183, 0.853, 1.032, 1.853 and 6.218 were higher than the WHO limits of 0.01, 0.003, 0.020, 0.500 and 0.030 for Pb, Cd, Ni, Mn and Fe respectively, and this is an indication of the sediment pollution by metals. The correlation analysis between metal concentrations in the sediment and in the water gave positive correlation with coefficient of correlation (r) at 0.752, this high correlation suggest that sources of metals in sediment and water are somehow the same (Uzairu, 2009). The result obtained revealed that there is strong pollution of both water and sediment by Fe among other metals that caused pollution to the studied environment. The result obtained for Fe agrees with the reports by Nwajei *et al.* (2010) which proclaimed that iron occurs at high concentration in Nigeria soil. As warned by the Centers for Disease Control and Prevention (2003), iron overload can lead to hemochromatosis, a disease characterized by fatigue, weakness, joint pain, abdominal pain, or organ damage.
The high concentrations of some of these heavy metals in the sample may be due to accumulated effect of continuous release and deposition of wastes containing these metals in the river through erosion, indirect disposal of domestic and agricultural wastes, spilling of loaded crude amongst others. In the dry season, evaporation decreases the volume of the water and hence these metals could become more concentrated. These heavy metals, if gain excess into human system through either direct consumption of the water or food chain is capable of posing health problems.

Conclusion

The study aimed at evaluating quality of the water and sediment from Idim Idaang stream, Ibiono Ibom, Nigeria in terms of physicochemical and heavy metals characteristics. The physicochemical parameters studied (pH, turbidity, electrical conductivity, total dissolved solid, dissolved oxygen, biological oxygen demands, salinity as chloride, total suspended solid, total hardness and total alkalinity) were found to be mostly within WHO standard limits. Water quality index (WQI) with a value of 29.37 showed that the stream was save for drinking considering the physicochemical parameters studied. In the water, the concentrations for Pb, Cd, Zn and Fe were higher than the WHO limits, while in the sediment, the concentrations for Pb, Cd, Ni, Mn and Fe were higher than the WHO limits. The concentrations for Hg Co and As were the same for both sediment and water and apart from Cr and Zn, concentrations in sediment for Pb, Fe, Cu, Cd, Mn and Ni were higher than in water. There was high correlation between the metals in sediment and that of water, which suggest same source of sediment and water metal content.

References

Abeh, T., Gunshik, J., Adamu, M., (2007) Separation studies of trace elements level in sediment from Zarmaganda stream in Jos, Plateau state, Nigeria, *J. Chem. Soc. Nigeria,* 32(2), 218 -224.

Ademorati C.M.A. (2019) *Environmental Chemistry and Toxicology*. Ibadan: Foludex Press Ltd., pp.171-215.

American Public Health Association, (APHA) (2009) *Standard methods for the examination of water and wastewater* (21st Edition), American Public Health Association, p.117.

Barry, H. O. (2019). Towards a clean water for third world cities, *J. Environ*, 1(3), 113-127.

Bazzi I., El Mouaden K., Chaouay A., Ait Addi A., et al. (2020), Monitoring heavy metal contamination levels and microbiological pollution in seawater of Agadir coastal zones, *Indonesian Journal of Science & Technology* 5 (3), 463-469

Bouknana D., Hammouti B., Salghi R., *et al.* (2014) Physicochemical Characterization of Olive Oil Mill Wastewaters in the eastern region of Morocco, *J. Mater. Environ. Sci.* 5 (4), 1039-1058

Brown, R. M., Mccleiland, N. J, Deiniger, R. A. and O'Connor, M. F. (2018). A water quality index-crossing the psychological barrier, *Water Pollut. Res*, 6, 787-797.

Dhawde, R., Edokpayi, J., Odiyo, J., Durowoju, O. (2018) Physicochemical and bacteriological analysis of water quality in drought prone areas of pune and satara districts of maharashtra, India, *Environments MDPI*, 5(5), 1–20. doi: 10.3390/environments5050061.

Edward, E. J., (2016) *Practical information on surface water problems, the chemistry of water bulletin*, Johnson Water screen overseas Ltd, Northern Island, p.16.

El Abdouni A.; Bouhout S.; Merimi I.; Hammouti B.; Haboubi K. (2021), Physicochemical characterization of wastewater from the Al-Hoceima slaughterhouse in Morocco, *Caspian J. Environ. Sci.* 19(3), 423-429

Etuk, H. S., Ebong, G. A., Anweting, I. B., Okon, A. O., Ekot, A. E. (2023a) Sources and Health Risks of Inorganic Toxicants in *Gallus gallus* domesticus (broilers) from Poultry Farms in Uyo, Nigeria, *British J. Multidiscip. Advanced Stud: Sci.*, 4(5), 1-30,

Etuk H. S., Ebong G. A., Okon A. O., Anweting I. B. and Ekot A. E. (2023b). Spatial and seasonal variations, ecological and human risks of trace metals in major rivers within the oil producing zone of Nigeria. *World J. Pharm. Med. Res*. 5(2), 1–17.

Faiza, D., Deiniger, R. A., O'Connor, M. F., Gunshik, J., (2012) Analysis of physicochemical properties and heavy metals in drinking water from different sources in and around Ranchi, Jharkhand, India. *Vet. World*, 6(2), 220 -235.

Golterman, H. I., (2018) *Methods for physical and chemical analysis of fresh waters* (2nd Ed.) Billing and Sons Ltd. U.S.A. p.25.

Iqbal, F., Ali, M., Salam, A., Khan, B., Ahmad, S., Qamar, M., Kashif U., (2019) Seasonal variations of physicochemical characteristics of river soan water at Dhoak Pathan Bridge (Chakwal), Pakistan, *Int. J. Agric. Biol*, 4,89-92.

Kamelan, J., (2014) Cultivation and exportation of agricultural products: a case study of Ibiono Ibom Local Government Area, AkwaIbom State, *J. Agric. Resour*., 3(1), 56-61.

Karim S., Aouniti A., El hajjaji F., Taleb M., *et al.* (2016), Bioaccumulation of heavy metals in commercially important marine fishes (Palaemon Serratus and Solea Vulgaris) caught in the Mediterranean coast from the North East of Morocco, *Der Pharma Chemica*, 8(19), 515-523

Karim S., Aouniti A., Belbachir C., *et al.* (2016) Metallic contamination (Cd, Pb, Cu, Zn, Fe, Co) of the Octopus (Octopus Vulgaris Cuvier, on 1797) fished in the Mediterranean coast from the north east of Morocco, *Journal of Chemical and Pharmaceutical Research*, 8N°2, 821-828

Kavcar, P., *Sofuoglu*, A., Sofuoglu, S. C., (2019) A health risk assessment for exposure trace metals via drinking water ingestion pathway, *Int J Hyg. Environ. Health*, 212(2), 216–227.

Nairat N., Hamed O., Berisha A. (2022) Cellulose polymers with β-amino ester pendant group: design, synthesis, molecular docking and application in adsorption of toxic metals from wastewater, *BMC chemistry* 16 (1), 1-21

National Population Census (2010). 2010 National Head Count in Nigeria. Retrieved from https://www.npc/2010-population-census.com

Nigerian Standard for Drinking Water Quality (NSDWQ) (2007) Nigerian Industrial Standard NIS 554, Standard Organisation of Nigeria, 30.

Okon, I. E., Anweting, I. B., Nwokem, N. C., (2022) A Study on Heavy Metals Pollution Levels in Water and Sediment of River Kubani Dam, Zaria, Nigeria, *Pac. J. Sci. Technol.*, 23(2), 107 – 116.

Okon, I. E., Anweting, I. B., Danzarami, D. A., (2023a) Effect of Soil Heavy Metal Concentrations on Early Growth Performance of Cowpea (*Vignaunguiculata*) and Groundnut (*Arachis hypogea*) Seeds from Uyo, Nigeria, *J. Mater. Environ. Sci*., 14(5), 602 – 612.

Okon, I. E., Anweting, I. B., Udo, I. E., Danzarami, D. A., (2023b) Investigation into some physicochemical parameters and heavy metal status in bread from bakeries in Zaria, Nigeria, *J. Mater. Environ. Sci*., 14(6),711 – 719.

Oyeyiola, A. O., Olayinka, K. O., Alo, B. I., (2020) Correlation studies of heavy metals concentration with sediment properties of some rivers surrounding the Lagos lagoon. *Niger, J. Health Biomed. Sci*, 5(1):118-122.

Uzairu, A., Harrison, G.F.S., Balarabe, M. L., Nnaji. J.C., 2009 Concentration Levels of Trace Metals in Fish and Sediment from Kubanni River, Northern Nigeria, *Bull. Chem. Soc. Ethiop*, 23(1), 9-17.

Verma, P. U., Chandawat, D. K and Solanki, H. A., (2019) Pollution status of Nikol Lake located in Eastern Ahmedabad, *Environ, Monit. Assess* 210(8), 3603–3609.

World Health Organization (WHO) (2011) Guideline for Drinking Water Quality, (4th Edition.)

World Health Organization (WHO) (2019) World Health Organization Standard for Drinking Water. *Guidelines for Drinking Water Quality*, Recommendation, France, pp. 181.

World Health Organization (WHO) (2022) Guideline for Drinking Water Quality, (5th Edition.)

Yang, Z. and Shen, Z. (2019) Assessment of heavy metals in sediments from a typical catchment of the Yangtze River, China, *Environ. Monit. Assess*, 172, 407–417.

(2024): http://www.jmaterenvironsci.com