

SEDIMENT CHARACTERISATION AND METAL CONTENT OF ELEIYELE RIVER, IBADAN, NIGERIA

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Abstract

Sediment analysis is one way of evaluating the quality of a water body because sediments are the sink of pollutants in any water body. Samples were collected fortnightly for 6 months at 5 sampling points and analysed for heavy metals (Fe, Mn, Zn, Pb, Cr, Cu, Ni, and Cd), Nitrate, Nitrite, Phosphate and particle size. The degrees of metal pollution were evaluated using the following pollution indexes; Enrichment ratio (ER), Pollution load index (PLI) and Geo-accumulation index (Igeo). Metal concentration was highest at station 3 but most of the metals (Cr, Ni, Pb, Fe) exceeded the tolerable values provided by FEPA. The ER showed a low value for Mg, Cr and Ni (<1) while Zn and Pb showed mild enrichment (>3). The PLI of lower values implies non-appreciable input from anthropogenic sources. The Igeo values falls between 0-1 suggesting negligible contamination from these metals in the sediment samples. Nitrate is highest at station 1 (3.986mg/kg), Nitrite ranges from 0.271 mg/kg - 0.108 mg/kg. Phosphorus is highest at station 3 (5.102mg/kg) and lowest at station 5 (2.181mg/kg). The textural class of sediment at most stations (Stations 1, 2, 3 and 4) is Fine sand while its coarse sand at station 5.

Keywords: heavy metals, grain size, pollution

Introduction

Metals have toxic effect on living organisms especially at high concentration which makes pollution by heavy metals a global problem (Ghrefat and Yusuf, 2006). Nair *et al* (2006) reported that heavy metals enter aquatic ecosystems through natural sources and anthropogenic activities including industrial or domestic sewage, rain runoffs, agricultural activities, landfills, oil pollution, shipping and harbor activities and atmospheric deposits. Heavy metals dissolved first in water, adsorbed, and finally accumulated on the bed sediments acting as sinks (Farshid *et al.*, 2015).

Various adverse effects of sediment contamination and water include behavioral changes, increased cancer risk and reproductive toxicity in fish, reproductive failure in fish-eating birds and mammals, and decreased biodiversity in aquatic ecosystem. Human health is endangered when these sediments and water contaminants bioaccumulate in fish and birds edible tissues consumed by humans (Lasheen and Ammar, 2009).

This work covers sampling of the sediment of Eleiyele and its analysis to determine the level of contamination and its quality. This became paramount due to the level of anthropogenic activities, resulting into a great discharge of wastewater and solid materials into the water body, which makes the water sediment

vulnerable to pollution. Analysis of sediment is becoming very important in determining and evaluating qualities of the total ecosystem of a body of water, in addition to the water sample analysis been practiced for years (Haslam, 1990). Mucha *et al.*, (2003) described sediments as the ultimate sink of contaminants in the aquatic system, which makes its analysis very important. Natural and human activities are capable of releasing pollutants to the overlying water, where organisms in the water column can be exposed (USEPA, 2001). When sediments are contaminated, it can cause lethal and sub-lethal effect in benthic and other sediment associated organisms (USEPA, 2001).

Sediment is an integral component of the aquatic ecosystem which provides habitat, feeding, spawning and rearing areas for many aquatic organisms, and so protecting and maintaining its quality is an important part of restoring and monitoring the biological integrity of our Nation's water as well as protecting aquatic life, wild life and human health (Issa *et al.*, 2011). The study was conducted to determine the concentration of some chemical parameters and selected metals of the river sediment.

Study Area

Eleiyele River lies between Latitude 7° 26' N and Longitude 3° 52' E in Eleiyele area of Ibadan

metropolis and with an altitude of 125m above sea level and an average depth of 6.0 above sea level. It experiences rainfall around May to November and December to April and it has an average temperature of 28°C. The dam was constructed in 1939 by the Oyo State water corporation on Ona River purposely for supply of pipe borne water to Ibadan city (Imevbore,

1967). In a bid to improve fisheries in man-made lakes, the Fisheries division of Ministry of Agriculture and Natural Resources Oyo state took over the management of the fishing activities in the reservoir in 1976 and hence the reservoir is presently being fished intensively by local fishermen

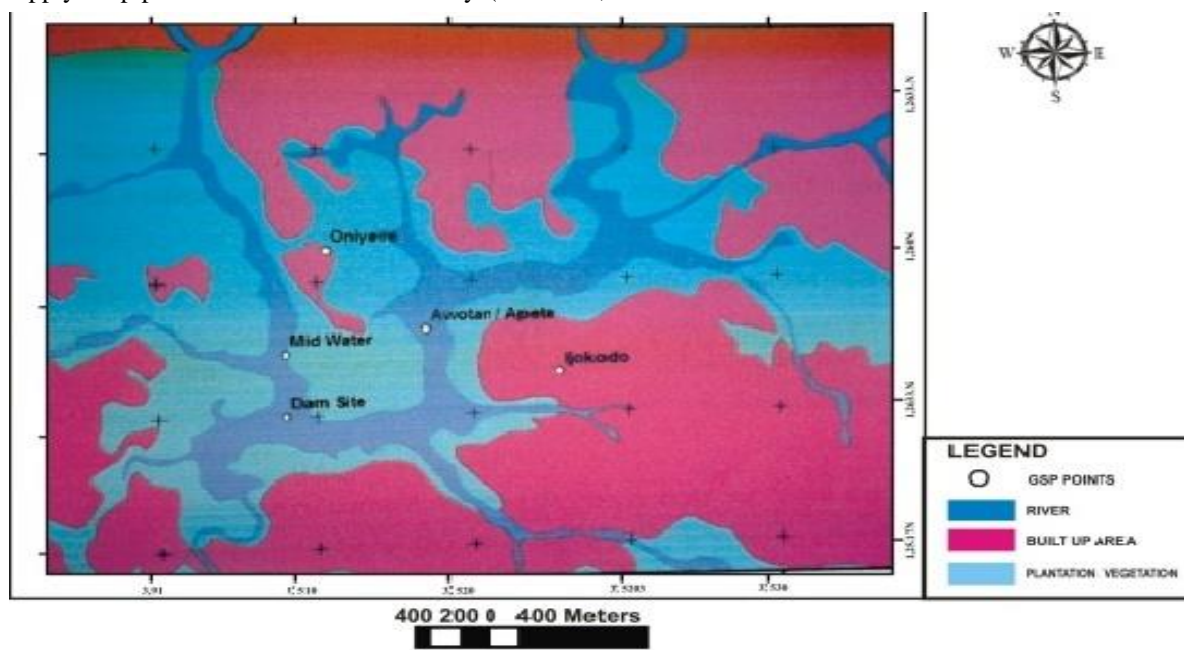


Figure 1: Map of Eleiyele River showing the sampling stations

Sampling Stations

Station A – Awotan (N 07° 25.488' E 003° 51.511') is the shore of the river, where fisher men land their catch, with other activities like fish smoking, bathing, cooking and at the upper part we also have mechanic workshop, fufu processors and garri processors.

Station B– Ijokodo (N 07° 25.386' E 003° 51.766'), this part of the water leads to the residential area that goes into Ijokodo area of Ibadan.

Station C – Oniyere (N 07° 25.671' E 003° 51.324'), is another end of the river that leads to farmlands own by residents around the water.

Station D- Arinkinkin/mid water (N 07° 25.435' E 003° 51.242'), it is the center of the water body.

Station E - Dam site (N 07° 25.300' E 003° 51.235') this is where the dam that supplies municipal water to the community is located.

Materials and Methods

Sample Collection and Laboratory Analysis

Sediment samples were collected bi-monthly for 6 months (Nov 2010 - April 2011) using Van veen grab (0.1m²). The samples were collected at each station and placed in labelled polyethylene bags.

Particle Size Analysis

Sediment sample of 100g from each sampling point was dried in the oven for 3 ½ hours at 550°C, after cooling, each sample was passed through a set of sieve and was shaken carefully; the weight of each sieve with its retained soil was recorded.

Chemical Analysis

Sediment samples were transferred into labelled trays for air drying at room temperature in the laboratory. Nitrite was determined according to the method of determination of Nitrate in 2M KCl soil extracts by Flow Injection Analysis. Available Phosphorus was determined using a dilute acid-fluoride

extractant according to the Methods of soil analysis: Part 2 by Olsen and Sommers (1982).

Heavy Metal Determination

The samples for heavy metal analysis were digested using the HNO₃ digestion procedure as modified, and then analyzed using Atomic Absorption Spectrophotometer (AAS) LAAS-210 according to the methods of soil analysis part 2.

Data Analysis

Particle sizes of the sediment samples were subjected to descriptive statistics; percentages, mean and standard deviation were used. The degree of metal pollution in the sediments was determined using Enrichment Ratio (ER), Pollution Load Index (PLI) and Geo-accumulation Index (Igeo).

Enrichment Ratio (ER): Enrichment factor analysis, a method proposed by Simex and Helz (1981) to assess trace element concentration, is mathematically expressed as:

$$\text{Enrichment ratio (ER)} = \frac{(C_x/F_e)_{\text{sample}}}{(C_x/F_e)_{\text{background}}}$$

Where, C_x stands for concentration of metal 'x'.

The background value is that of the world surface rock average (Martin and Meybeck 1979) given in Table 1. Fe is taken as a normalization element while determining enrichment ratio (ER) because even at a low percentage, Fe (OH)₃ in aquatic system, has a controlling influence on heavy metal distribution (Rath *et al.*, 2005; Chakravarty and Patgiri, 2009).

Pollution Load Index (PLI): Pollution load index (PLI), for a particular site, was evaluated following the method proposed by Tomilson *et al.*, (1980). This parameter is expressed as:

$$PLI = (CF1 \times CF2 \times CF3 \times \dots \times CFn)^{1/n}$$

where, n is the number of metals (seven in the present study) and CF is the contamination factor.

The contamination factor was calculated from the following relation:

$$CF (\text{Contamination factor}) = \frac{\text{Metal concentration in the sediments}}{\text{Background value of the metal}}$$

The PLI value of >1 is polluted, whereas <1 indicates no pollution

Geo-accumulation Index (Igeo): The geo-accumulation index (Igeo), introduced by Muller (1979)

for determining the extent of metal accumulation in sediments, and has been used by various workers in their studies (Glasby *et al.*, 1988; Bhosale and Sahu 1991; Singh 1999; Rath *et al.*, 2005; Chakravarty and Patgiri 2009). Igeo is mathematically expressed as: $Igeo = \log_2 C_n / 1.5B_n$ where, C_n is the concentration of element 'n' and B_n is the geochemical background value [world surface rock average given by Martin and Meybeck (1979)].

The factor 1.5 is incorporated in the relationship to account for possible variation in background data due to lithogenic effect. The geo-accumulation index (Igeo) scale consists of seven grades (0-6) ranging from unpolluted to highly polluted.

Results

Particle size distribution of sediment samples

The percentage sand was highest at all sampling stations, with very little silt composition; sediment in station E was composed of 18.82% of gravel. Physically the sediments in all the sampling points with the exemption of station E exhibited a very fine texture, smooth and elastic in nature, while station E has a very coarse texture. The sampling stations were not significant (p>0.05).

Chemical Composition of Sediment Samples

The concentration of the chemical parameters analysed in the sediment sample is shown in table 2. All the parameters do not exhibit any significance difference (P > 0.05) in their spatial and temporal distribution.

Metal Concentration

The mean value of metals as shown in table 3. Most metals were observed to be higher at station 3; this area receives runoff from the adjacent farmland and also decays of surrounding plants and leaves of trees present in the station, although not significantly different (p>0.05) from other stations. Metals were also generally observed to be highest during the wet season (Nov, Mar, and Apr.) of the sampling period, There were no significant differences (p>0.05) in the temporal distribution.

The ER values given in Table 4 shows a low value for Mg, Cr and Ni (<1). The ER of Cu is about normal with values a little above one (>1), while Zn and Pb shows mild enrichment with values ranging between 1 and 4 (>3).

The calculated Igeo values, based on the world's surface rock abundance are presented in Table 6.

Table 1: Mean (\pm SD) of Particle size and textural class of samples at sampling station

*S.L	Silt (%)	Sand (%)	Gravel (%)	Textural Class
A	1.97 +0.78	98.05 +0.78		FINE SAND
C	1.71 +1.79	98.51 +1.79		FINE SAND
D	0.81 +0.89	99.19 +0.89		FINE SAND
E	0.49 +0.44	80.69 +10.24	18.82 +10.08	COARSE SAND

*S.L: Sampling Location

Table 2: Mean (\pm SD) of chemical parameters obtained during the sampling period

Chemical Parameters	Stations				
	A	B	C	D	E
Nitrate (mg/kg)	3.936 \pm 2.44	1.564 \pm 0.49	2.591 \pm 1.78	2.299 \pm 1.68	2.801 \pm 1.28
Nitrite (mg/kg)	0.271 \pm 0.17	0.108 \pm 0.03	0.179 \pm 0.12	0.158 \pm 0.12	0.193 \pm 0.09
Phosphorus (mg/kg)	2.218 \pm 0.98	3.26 \pm 1.22	5.102 \pm 6.29	3.174 \pm 2.51	2.181 \pm 1.22

Table 3: Mean Concentration of heavy metals (mg/kg) in Eleiyele river sediments and their world surface rock average (Background value)

*S.L	Mg(mg/kg)	Cu(mg/kg)	Fe(mg/kg)	Zn(mg/kg)	Cr(mg/kg)	Pb(mg/kg)	Ni(mg/kg)
A	0.03	10.32	0.75	50.06	8.51	17.31	2.96
B	0.04	9.79	0.65	72.38	7.69	16.89	5.73
C	0.05	11.52	1.04	79.91	36.23	23.81	9.11
D	0.05	9.54	1.05	54.41	9.26	16.62	6.66
E	0.02	6.67	0.69	37.02	8.10	8.98	2.30
*S.D	0.013	1.60	0.17	15.49	11.15	4.70	2.49
World Surface Rock Average	1.64	32	3.59	127	97	16	49

*S.D: Standard Deviation

*S.L: Sampling Location

Table 4: Enrichment ratio (ER) Values of heavy metals in Eleiyele river sediment

*S.L	Mg(mg/kg)	Cu(mg/kg)	Zn(mg/kg)	Cr(mg/kg)	Pb(mg/kg)	Ni(mg/kg)
A	0.10	1.54	1.86	0.42	4.13	0.29
B	0.15	1.70	3.08	0.44	4.62	0.64
C	0.11	1.24	2.14	1.29	4.08	0.64
D	0.10	1.01	1.44	0.33	2.82	0.47
E	0.05	1.09	1.49	0.43	2.32	0.24

**S.L: Sampling Location*

Table 5: Contamination factor and Pollution Load Index (PLI) of metals in sediments of Eleiyele River

*S.L	Mg(mg/kg)	Cu(mg/kg)	Fe(mg/kg)	Zn(mg/kg)	Cr(mg/kg)	Pb(mg/kg)	Ni(mg/kg)	PLI
A	0.02	0.32	0.21	0.39	0.09	1.08	0.06	0.049
B	0.03	0.31	0.18	0.57	0.08	1.06	0.12	0.014
C	0.03	0.36	0.29	0.63	0.37	1.49	0.14	0.232
D	0.03	0.29	0.29	0.43	0.10	1.04	0.14	0.023
E	0.01	0.21	0.19	0.29	0.08	0.56	0.05	0.0004

**S.L: Sampling Location*

Table 6 Geo-accumulation indices of heavy metals in Eleiyele river sediments

*S.L	Mg(mg/kg)	Cu(mg/kg)	Fe(mg/kg)	Zn(mg/kg)	Cr(mg/kg)	Pb(mg/kg)	Ni(mg/kg)
A	-2.00	0.07	-0.08	0.03	0.02	0.17	0.02
B	-1.84	0.07	-0.11	0.03	0.02	0.17	0.03
C	-1.73	0.07	0.01	0.03	0.04	0.19	0.04
D	-1.79	0.07	0.01	0.03	0.02	0.17	0.04
E	-2.43	0.06	-0.09	0.03	0.02	0.13	0.02

**S.L: Sampling Location*

Discussion

Particle size distribution of sediment samples

The reason for the coarse nature of sampling site E may not be farfetched because the land area around the station slopes downward which gives way to erosion of soil particles to the sites and fast movement of water, there are less human activity around the sites also because the sites is very close to the area where the dam is located. It was reported that large pieces of sediment, like sand and gravel, are typically deposited in a fast moving river while smaller particles are carried away (Windows to the universe team, 2008).

Chemical Composition of Sediment Samples

It was established by Stanley and Hobbie (1981) and Paul and Clarke (1989) that nitrite concentrations in freshwaters are negligible, and the worldwide average concentration has been estimated to be 1 mg of nitrite/litre (Meybeck, 1982)

Metal Concentration

The presence of heavy metals in freshwater bodies was attributable to both natural processes and human activities (Nair *et al.*, 2006). Metals enter streams and rivers as a result of natural, physical and chemical processes such as weathering and leaching of soils and rocks. These processes result in "background" levels of metals in freshwater (Forstner and Wittman, 1981).

The background value which is the world surface rock average gives the normal abundance of an element (Martin and Meybeck 1979). The mean concentration levels of Mg, Cu, Fe, Zn, Cr, Pb and Ni in sediments of most of the locations are lower than the background values.

In comparing the metal concentrations obtained from the sediment samples with sediment quality guidelines, it revealed that these concentrations did not exceed the probable effect concentration (PEC) levels but most of the investigated metals (Cr, Ni, Pb and Fe) exceeded the tolerable values of metals (US EPA, 2001 and FEPA, 1991).

Lower values of PLI imply no appreciable input from anthropogenic sources or human activities around the water body But, CF values for Pb shows higher (>1) values due to the influence of external discrete sources like industrial activities, agricultural runoff and other anthropogenic inputs (Adel *et al.*, 2011). There is a general fluctuation in PLI values across the stations with station 3 with the highest value indicating dilution and dispersion of metal content with increasing distance from source areas.

However, relatively higher PLI values at Oniyere (0.232) which is station 3 might be due to increased human activity and

discharge of agricultural effluents since this area is close to farmlands own by residents around the water.

It is clear that the Igeo values for Mg and Fe fall in class '0' in all the five sampling stations indicating that there is no pollution from these metals in Eleiyele river bed sediments. The Igeo values for Cu, Zn, Cr, Pb and Ni fall in the range 0-1 suggesting negligible pollution from these metals.

Conclusion

The above findings show no or negligible contamination from the metals investigated in the sediment samples. The PLI shows that there is no appreciable input from human activities.

The present state of the sediment quality of Eleiyele river can be maintained and improved upon by intensifying effort on public enlightenment as to the negative impacts of discharging or emptying domestic and industrial waste into water bodies, because increase in organic waste impair the water and sediment quality of a water body.

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