

Geochemical and Mineralogical Assessment of Sediments in Canal and Lagoon Parts of Lagos, South-western, Nigeria

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Abstract

Indiscriminate dumping of refuse and discharge of untreated industrial waste into the drainage systems and vehicular emissions has affected the quality of most sediments deposition for its geological and civil engineering purposes. This work is based on the assessment of sediments in canal and lagoon parts of Lagos, Nigeria, for its geochemical and mineralogical formation. The clay fraction ($< 63\mu\text{m}$) in the sediments were processed and analyzed for their heavy metal contents using Atomic Absorption Spectrophotometry (AAS) and Inductive Coupled Plasma-Mass Spectrometry (ICP-MS) respectively. The sediments were also studied for their mineralogical compositions by X-ray diffraction. The clay mineralogy is predominantly consisting of Kaolinite, Goethite and Quartz. The results of heavy metals in sediments showed that canal sediments consist of Pb, Zn, Cu, As, Co, Cr, Cd, Hg, Fe and Ni while lagoon sediments are Pb, Zn, Cu, As, Co, Cr, Cd, Hg, Fe, and Ni. Based on the Geoaccumulation indices, the sediments are unpolluted with respect to Zn, Cu, Ni, Co, Cr, and Fe. However, the canal and lagoon sediments are variably polluted with respect to Pb, As, Cd, and Hg. The canal and lagoon sediments are unpolluted to moderately polluted with respect to Pb and As. In the case of Cd, the sediments are highly polluted. As far as Hg is concerned both sediments of the canal and lagoon are very highly polluted. With the exception of copper having (KD) value of less than 1. Possible contamination sources are from industrial and anthropogenic sources. These need to be monitored and controlled effectively.

Keywords

Heavy metals, mineralogical, clay fraction, canal and lagoon.

1. Introduction and Concept

The reuse of dredged (marine) sediments in the civil engineering works most especially as a sand or a filler in concrete and mortar or as a combination with aggregates for the construction of road sub – bases and in geotechnical evaluation cannot be over – emphasized. In the last three decades, there has been much interest in the geochemical distribution and fate of heavy metals in the environment including water and sediment fractions. In particular, significant advances have been made in respect of mining- related metal pollution in different parts of the world. However, in addition to mining activities, urbanization, agricultural and industrial activities do cause pollution of drainage systems, especially in areas with inadequate land use plan and improper waste disposed systems.

In such urbanized centres, indiscriminate dumping of refuse and discharge of untreated industrial waste into the drainage systems and vehicular emissions usually cause heavy metal pollution. Though, sediments are said to represent the ultimate sinks for heavy metals in the environment (Gibbs, 1977) changing environmental conditions may lead to remobilization and release of sediment bound metal pollutants into water column and consequently into the trophic levels of the food chain. Trace metals contamination of sediments remains a global threat to biodiversity and humans (Joshua, *et al.*, 2016) and heavy metals in sediments are highly significant because of their persistent and bioaccumulative nature (Swarnalatha and Nair, 2017).

The implication of these increasing in bioavailability and toxicity may results to serious health and environmental consequences. Several authors have studied the concentration of metals in sediments as well as bioavailability of heavy metals in urban and industrial areas among who are (Malathi, 2013, Gandhi and Raja, 2014, Foerstner and Wittman, 1983, Olatunji and Abimbola, 2010, Basaham and El-Shater, 1994, Sakai, Kojima and Saito, 1986, Ajayi and Mombeshora, 1990, Sutherland, 2000). However, there is little information on the geochemical distribution and behavior of heavy metals in the developing countries where contamination may be as high as that of developed industrial countries (Paul and Pillai, 1993, Olade, 1987).

In Nigeria like many other developing countries, rapid population increase due to rural-urban migration in the last three decades, characterize most of the big cities and urban centres. Unfortunately, lack of proper land use plans,

poor sanitary and waste/sewage disposal facilities as well as low public awareness in terms of environment health issues had led to systematic deterioration of the environment.

Based on the above facts, this study focuses on the assessment of sediments of a biaxial canal of Allen and Sheraton, jointly known as "Iyaalaro" using Lagos lagoon as control, within Lagos metropolis, southwestern Nigeria. The area under study became necessary because of its location and function. These monitored streams are canals into which industrial waste and incessant domestic waters are being disposed which results to depletion in the quality of these sediments for their various uses particularly in the urban drainage system development.

1.1 Physical and Setting of the Study

The study area falls within latitudes $60^{\circ} 20'N$ to $60^{\circ} 40'N$ and longitudes $30^{\circ} 15'E$ and $30^{\circ} 30'E$. The Ikeja canal is a biaxial stream that runs one of its arms via Allen to Ikeja industrial estate, while the second arm passes behind Sheraton Hotel and truncate just before Toyin Street, Ikeja. Both arms intercept about 250m from Ojota- Maryland Bridge (a.k.a. Iyaalaro Bridge). Other tributaries such as Mende drain, Shomolu drain were also connected to it before discharging into the Lagos lagoon.

The dominating low-lying marshy belt that runs east west is a remnant of the northern uplands that lies further northern around Abeokuta. The area falls into two distinct topographic features, the southern up lands (Jones and Hockey, 1964) that stand a little above 30metres, above sea level and low-lying coast, several points virtually close to sea level (Asiwaju- Bello and Akande, 2001). River systems that drain into the Lagoon are River Ogun, Majidun, Shasha and Oluwa. They are connected to river Benin by series of cracks. Other rivers include Opomu and Abesan, all flowing in a south ward direction into the Lagoon and cracks system.

1.2 Geology and Hydrogeology of the study area

The lithological character of the sedimentary outcrops of southwestern Nigeria signifies the nature and extent of the aquifer zones found in Lagos metropolis. There are four aquiferous systems in the metropolis (Oyegoke, 1986). The upper aquifer extends from ground level to twelve metres below the ground and consists of alternating layers of sand and clay.

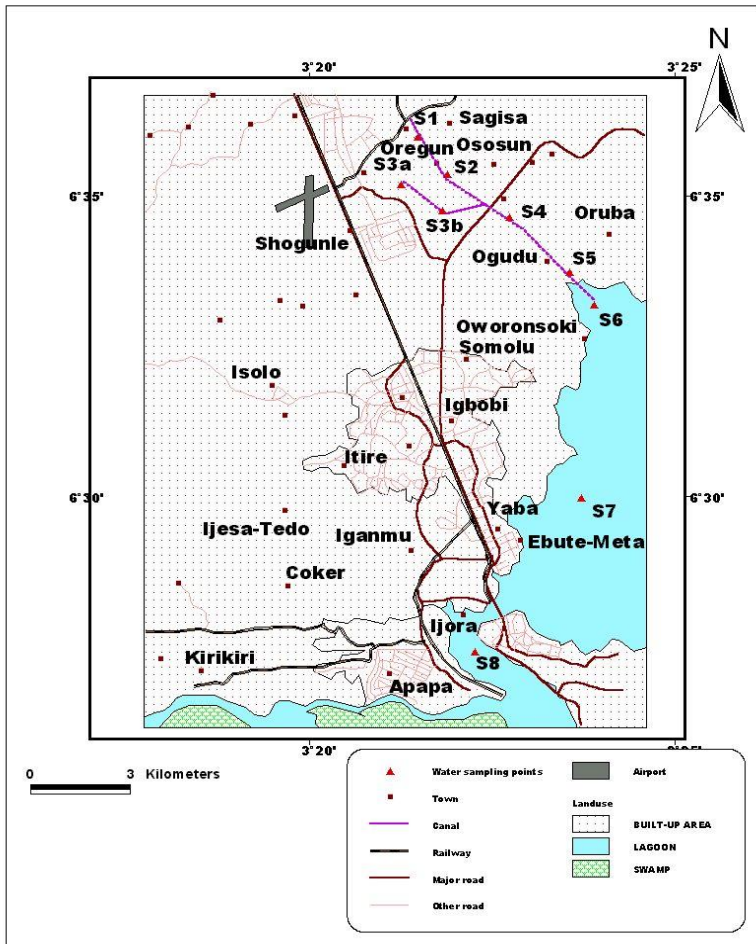


Figure 1 The location map of the study area

The second aquifer is 20m -70m below sea level, in the Northern part of Lagos and 40m-100m deep near the coast lines. The third aquifer is found in the central part at a depth range of 130m and 160m dipping towards the coast, where it depth ranges between 170m-210m with thickness ranging

from 15m-30m. The fourth aquifer is reached at 450m deep; it is separated from the third by a thick layer of shale of the Ewokoro formation. The thickness of the shale layer separating the second and third horizon is up to 130m in several parts of Lagos.

2. Methodology

A pre-cleaned bottomed grab instrument was used in the sampling. The grab was suspended with a rope to collect the sediments and turned/ emptied it into a polythene bags. These polythene bags were sealed properly to minimize aeration and labelled with tag containing vital and relevant information, such as location number. These sediment were then transported to the laboratory and air dried. About eight (8) sediment samples were collected from both canal and lagoon respectively.

The sample locations are Allen Avenue, Opebi, Sheraton, Ojota, Ogudu Iwaya, and Ijora. This method is considered suitable for the determination of minerals in soil as described by (Gems, 1987). Preliminary assessment of the suspended particles and clay fractions were analyzed strictly for heavy elements content. In addition, XRD, and particle size distributions were also carried out on the sediments for their petrological and mineralogical characterization. Finally, this study intends to highlight measures desirable for improving the quality of urban drainage system.

3.1 Results and Discussions

The distribution of the heavy metals in the clay fractions of the canal and lagoon sediments (Table1) shows that metals occurred in relatively high concentration with the exception of copper (Cu) and iron (Fe). The lagoon sediment is enriched in Iron (Fe) with average of 94.60mg/kg. These concentrations are much low compared to crustal background value of 5.4 x 10⁴mg/kg of Fe and igneous bedrock composition of 27000 mg/kg of Fe and respectively. In contrast, Lead (Pb), Mercury (Hg), Cadmium (Cd) and Arsenic (As) occurred in high concentrations with average of 40.73mg/kg for Pb, 27.76mg/kg for Hg, 3.62mg/kg for Cd and 2.30mg/kg for As; and, 25.70mg/kg for Pd, 2.70mg/kg for Hg, 3.06mg/kg for Cd and 4.03mg/kg for As) in both the canal and lagoon sediments relative to the average crustal values and igneous bedrock compositions.

Nickel concentrations with average of 3.03mg/kg and 2.67mg/kg are also slightly high in the canal and lagoon sediments compared to 0.8mg/kg igneous bedrock composition. Copper (Cu), Chromium (Cr), Cobalt (Co) and Zinc (Zn) occurred generally in concentrations less than 1mg/kg in both the canal and lagoon sediments. Indications of contamination in the sediments are clearly revealed by Pb, Hg, Cd and As with concentration values above the crustal average. The order of these elements concentration in canal sediment is Fe> Pb> Hg> Cd> Ni> As> Cu> Cr> Co> Zn and in lagoon sediment, Fe> Pb> As> Cd> Hg> Ni> As> Zn> Co> Cr> Cu.

Strong positive correlation is an indication that the sources of the metals are related to common anthropogenic inputs rather than geogenic. Geogenic contribution would have been dependent on chemical factors including relative solubility and /or mobility of each metal. The negative correlations are suggesting different sources.

In summary, the observed enrichment of the metals in the sediment underlies the basic fact that fine grained (<63µm) constituents, especially clay minerals usually acts as sinks or scavengers for accumulation of metals. The x-ray analysis of the clay fractions obtained from representative samples (Tables 2, 3 and 4) show predominance of Kaolinite (33.35-74.56) % and Goethite (12.2-53.75) % along with some quartz and traces of haematite, rutile and illite. The high 53.75% goethite in the canal sediment at Ojota may be reflecting the peculiar situation of dumping of disused metal wares and swampy nature of the location. However, the dominance of kaolinite and goethite reflects the nature of the detritals into the Canal and lagoon. The sediment sources are mostly kaolinite and ferruginous clays and sandstones. The clay mineralogy also reflects the prevailing warm, humid, tropical climatic condition of southwestern Nigeria with widespread lateritic and advance weathering processes. The possible contribution of smectites from nearly Atlantic sea is not apparent in the Lagos lagoon sediment studied. Nonetheless, in coastal waters, it has been appreciated that movement of clay mineral mixtures across boundaries between fresh and saline water at high current velocities usually result in the selective transport of different clay species, Whitehouse and Mc Carter (1958).

Table 1 Heavy metals concentration in canal and Lagoon sediments (mg/kg)

Sample Description	Pb	Zn	Cu	As	Co	Cr	Cd	HHg	Fe	Ni
Allen canal (L1)	49.13	0.28	1.41	1.70	0.38	0.91	4.27	27.44	5.10	3.5
Oregon canal (L2)	40.55	0.29	1.78	3.80	0.42	0.44	4.12	28.54	7.10	2.40
Ojota/Iyaaloro canal(L3)	32.51	0.25	1.60	1.40	0.52	1.16	2.48	27.29	243.30	3.20
Maximum	49.13	0.29	1.78	3.80	0.52	1.16	4.27	28.54	243.30	3.50
Minimum	32.51	0.25	1.413	1.40	0.38	0.44	2.48	27.29	5.10	2.40
Mean	40.73	0.27	1.60	2.30	0.44	0.84	3.64	27.76	85.17	3.03
Ogudu lagoon (L6)	15.83	0.34	0.00	3.10	0.34	0.31	3.12	26.23	88.80	1.90
Iwaya lagoon (L7)	35.15	0.32	0.02	3.10	0.27	0.19	3.29	27.34	111.80	3.25
Ijora lagoon (L8)	26.12	0.31	0.00	5.90	0.29	0.40	2.78	27.35	94.60	2.90
Maximum	35.15	0.34	0.02	5.90	0.34	0.40	3.29	27.35	118.80	3.20
Minimum	15.85	0.31	0.00	3.10	0.27	0.19	2.78	26.23	88.80	1.90
Mean	25.70	0.32	0.007	4.04	0.30	0.30	3.06	2.70	98.40	2.67
Crustal average [17]	12.50	70	50-51	1.8-2	22	100	0.15-2	0.02-0.1	5.4×10^4	75
[18]	16.00	80.00	97.00	1.80	3	20	0.19	0.03	2.7×10^4	0.8

Table 2 - Clay mineralogy by X-ray diffraction Analysis Location (2), Oregon

MINERAL COMPOSITION	ANGLE ($^{0}2\theta$)	D-SPACING (Å)	INTENSITY (IM)	INTENSITY FACTOR (IF)	RELATIVE INTENSITY (IMF)	%MINERAL COMPOSITION
KAOLINITE	21.000	4.232	428	20	8560	74.56
GOETHITE	26.805	3.327	2304	1	2304	20.07
QUARTZ	36.675	2.451	88	7	616	5.327

Table 3 - Clay mineralogy by X-ray diffraction Analysis Location (4) Ojota

Mineral Composition	Angle ($^{0}2\theta$)	D-Spacing (Å)	Intensity (Im)	Intensity Factor (If)	Relative Intensity (Imf)	%Mineral Composition
KAOLINITE	35.44	2.342	38	20	760	33.35
GOETHITE	26.7	3.34	1225	1	1225	53.75
QUARTZ	35.025	2.562	42	7	294	12.9

Table 4 - Clay mineralogy by X-ray diffraction Analysis Location (7) Iwaya

Mineral	Angle ($^{0}2\theta$)	D-Spacing (Å)	Intensity (Im)	Intensity Factor (If)	Relative Intensity (Imf)	%Mineral
KAOLINITE	24.995	3.564	90	20	1800	69.8
GOETHITE	37.220	2.417	45	7	315	12.2
QUARTZ	26.760	3.333	462	1	462	18

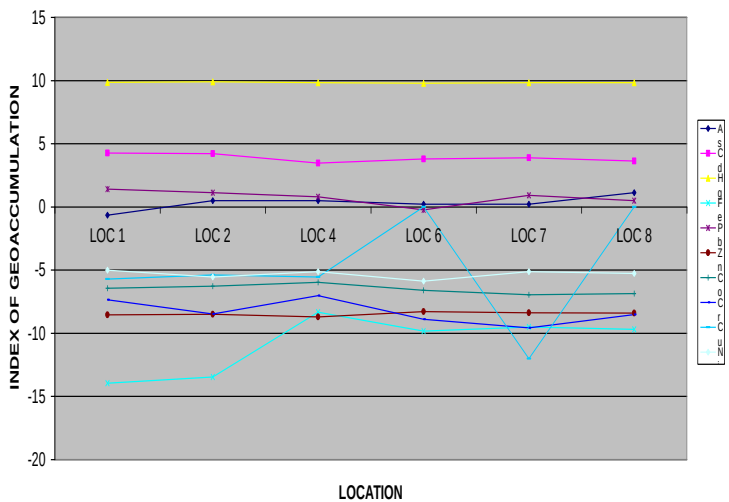


Figure 2 Profile of the Estimated Index of Geoaccumulation value for the sediment samples

4 Conclusion and Recommendation

It is evidently clear from this study that bottom sediments from the canal and lagoon are polluted by anthropogenic effluents (Industrial and Domestic). The degree of impact is considerably different. The heavy metals in

sediments such as Pb, As, Cd and Hg show significant contamination. The increase in concentration of Hg and Cd in the canal and lagoon at an alarming rate called for concern. Thus, the effluents need to be more monitored and aquatic life needs to be investigated for their toxic levels. This will help to prevent unforeseen endemic resulting from toxic metal accumulation from sea foods. Consequently, the following are some recommendations:

In view of the expected increase in industrialization and urbanization in Lagos metropolis, it is important to formulate pollution control policies that take into account the need to regulate discharges of contaminants into aquatic systems. It is also important to add that, as part of the objectives of pollution control, emphasis should be placed on the need to minimize waste generation. A periodic small scale scientific survey like this one should be encouraged from where baseline data are generated. The bottom sediments should be drilled to about 1m in depth to obtain core samples from where pollution history can be deduced.

This is hoping to further provide information, which enables the society and government to plan and react to environmental problems before they become serious, uncontrollable and catastrophic. In conclusion, for a complete mapping of the heavy metal distribution, more detailed biota, water and sediment sampling needs to be carried out. However, this study provides baseline information on the present anthropogenic impact of the environmental pollution in parts of Lagos. Hence, it could be useful for the management and sustainable development of Lagos metropolis.

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