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Geochemical Pollution Assessment of Sediment Metal from Lower Region of the Ogun River, Nigeria

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Abstract

From depths of 0-5 cm, 5-10 cm and 10-15 cm, sediment samples were collected from three locations in the lower region of the Ogun River Basin, namely Mokoloki, Oke-Oko and Kara. The samples were obtained using Van Veen sediment grab after which they were stored in well labeled polythene bags for onward transportation to the laboratory. For pH and conductivity, samples were determined in-situ using standard methods by the American Public Health Association of 1992 while Organic Carbon was determined by the Wakley Method. The sediments were then air dried before analysis for particle size and metal concentration. Induced Couple Plasma Mass Spectrometry (ICP/MS) was used to determine metal concentrations. Data obtained were used to determine the geochemical pollution intensities for the various sediment samples. The results of physicochemical analyses revealed all sediment samples to be alkaline, while particle size analysis showed that the sediments were sandy. All metal concentrations for Cu, Pb, As, Zn, Hg, Cd, and Cr were lower than the Environment Canada Sediment Quality Guideline standards of 35.70 ppm, 35.00 ppm, 0.60 ppm, 123.00 ppm, 5.90 ppm, 0.17 ppm and 37.50 ppm, respectively. The low metal concentrations obtained from the trace metal analyses were confirmed with an 'unpolluted status' obtained for all sediment samples analyzed using the geochemical accumulation index formula. Results showed that metal concentrations in these areas are low and do not pose a threat to the survival of living organisms living in sediments or the surrounding environment.

Keywords: Sediment; heavy metal; geochemical; Ogun River; pollution

Introduction

Sediments represent an essential component of aquatic ecosystems because they support both autotrophic and heterotrophic organisms. Autotrophic (self-nourishing) organisms are those able to synthesize food from simple inorganic substances (e.g., carbon dioxide, nitrogen, and phosphorus) and the sun's energy. Sediments with very high metal concentrations represent an important environmental concern, because once discharged into rivers, metals rapidly become associated with particulates and are incorporated in bottom sediments. Sediments can integrate contaminants over time and are in constant flux with the overlying water. Most metals have no known biological function in the aquatic ecosystem but they act synergistically with other chemical species to increase toxicity [1]. Since metals are non-biodegradable, they become persistent in the environment thus causing more harm to sediment dwelling organisms.

Increase in bioavailability of toxic metals with increasing total metal loading in sediments can be a potential threat to aquatic organisms and biota in the system. Biota can be negatively impacted by resuspension of sediment [2] and *Daphnia magna* have been shown to be susceptible to both physical (clogging digestive tract) and chemical stressors of resuspension conditions. Contaminants can be adsorbed from the sediment or water column, and can also travel up the food chain as larger predator species ingest contaminated prey [3]. From reports by Jaji et al [4] the pollution of Ogun river water along its course is evidenced by high concentrations of pollution indicators, nutrients and trace metals above the acceptable limits. Surface water quality assessment in the dry season revealed manganese content from all sites in the dry season, lead concentrations from some sites in the dry season and cadmium concentrations from some sites in both seasons, were above the respective WHO limits. Due to inadequate waste disposal systems and the common practice among residents around the Kara area of disposing domestic waste directly into the Ogun River water, contamination by heavy metals from household waste are a cause for concern. Heavy vehicular traffic in the Mokoloki and Kara areas could also lead to elevated lead concentrations.

The objective of this research is to determine the physicochemical levels and metal concentrations of the lower region of the Ogun River Basin and to determine their pollution status since sediments serve as habitat for various aquatic biota. The analyses of heavy metals in sediment cannot be overemphasized because it permits detection of pollutants that may be either absent or present in low concentrations in the water column [1].

Materials and Methods

1) Experimental methods

Sediments of depths 0-5 cm, 5-10 cm, 10-15 cm were collected from three locations of the middle region of the Ogun River course, namely Mokoloki, Oke-Oko and Kara between January and March, 2012. Five samples were collected per location/layer after which they were composited for each layer in a location. High vehicular movements and fishing were observed at Mokoloki and Kara areas while very low vehicular movements were seen at Oke-Oko. Sand dredging is a common feature at all three locations. Sediment samples were collected with the aid of a Van Veen sediment grab. The sediments collected were transferred into polythene bags and placed in an ice chest cooler for onward transportation to the laboratory. pH and conductivity were determined using standard methods by APHA [5] while organic carbon was determined by Black and Wakley's Method. At the laboratory, sediment samples were air-dried and sieved using a 2 mm sieve to remove coarse particles. The finer sediments (< 2 mm) were subjected to Induced Couple Plasma

Mass Spectrometry (ICP/MS) for determination of concentrations of copper (Cu), cadmium (Cd), zinc (Zn), mercury (Hg), nickel (Ni), lead (Pb), arsenic (As), chromium (Cr), and manganese (Mn) while the geochemical pollution indices were determined using the mathematical equation "Igeo = log 2 (Cn/1.5Bn)" introduced by Muller [6] (where Cn refers to heavy metal concentration in sediment of study area, Bn is the geochemical background value in average shale of element and 1.5 is the background matrix correction factor due to lithogenic effects while Igeo is the Geochemical Accumulation Index**)**

2) Sampling areas

The Ogun-River, located in Ogun-State, South West of Nigeria lies between latitude 6°35' and 8°58' North with Longitude 2°40' and 4°10' East. It rises from Iganran Hills, east of Shaki, Oyo state, South West, Nigeria (latitude 07°40' N and Longitude 03°20' E) [4]. The entire river basin (Ogun River) occupies an area of approximately 23,700 km^2 [7]. Three sampling sites were selected along the lower region of the Ogun-River course, namely: Mokoloki, Oke-Oko and Kara. Samples were collected from January to March, 2012.

3) Quality assurrance

Three replicates were taken per sample analyzed. A series of standard reference materials were used at the Acme Laboratory for sediment samples. These included STD OREAS 45CA, STD DS9 and BLK.

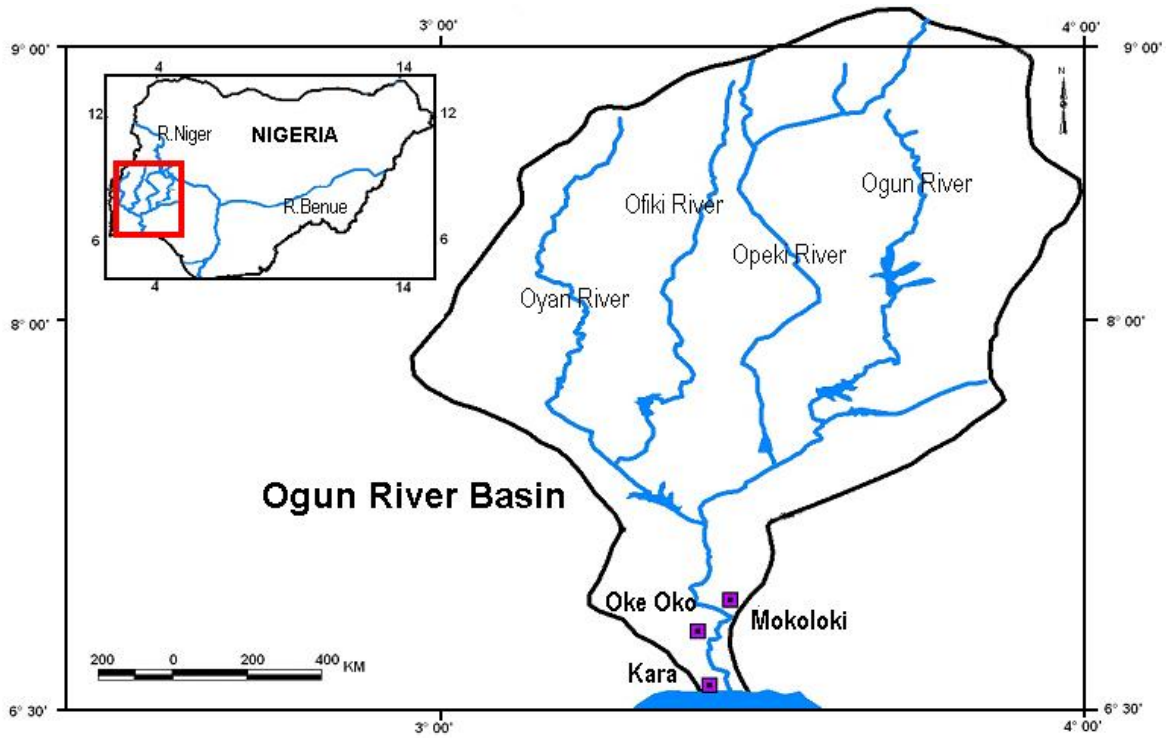

Figure 1 The Ogun River basin

Results and discussion

The sediment pH analysis (shown in Table 1) found pH values ranging from 7.81 (Oke-Okoi 0-5 cm) to 10.10 (Mokoloki 0-5 cm). Conductivity values ranged from 25.00 µs cm^{-1} (Mokoloki 0-5 cm and Mokoloki 5-10 cm) to 198 µs.cm^{-1} (Kara 0-5 cm). Particle size analysis categorized all sediment samples were sandy.

Sediment trace metal concentrations obtained for Cu, Pb, Zn, As, Cd, and Cr were all lower than the Environment Canada Sediment Quality Guideline standards of 35.70 ppm, 35.00 ppm, 123.00 ppm, 59.00 ppm, 6.00 ppm and 37.5 ppm, respectively. This result shows that the concentrations observed do not pose a threat to the sediment biota. High concentrations of toxic metals Pb, Cu, Cd are of great environmental concern. Pb toxicity can create problems such as kidney damage, neurotoxicity and problems with haemoglobin synthesis. Cadmium is highly toxic at very low exposure levels and has acute and chronic effects on aquatic animal health and environment. Long-term exposure to cadmium produces a wide variety of acute and chronic effects in aquatic animals. Whilst its prime site is the kidney [8,9], cadmium can also disrupt calcium metabolism causing hypercalciuria, leading to formation of stones in the kidney. At high concentrations, chromium has been shown to be a mutagen, carcinogen and a teratogen.

The alkaline pH and sandy texture of the sediments and low conductivity values of the areas sampled help to explain the low metal concentrations observed in areas sampled. According to Shelton and Capel [10], fine-grained particles and organic matter are natural accumulators of trace elements. DWAF [11] stated that metals such as Zn and Cd are most likely to have increased detrimental environmental effects as a result of low pH. High conductivity also accelerates retention of metals in sediments. Activities at the study area are predominantly fishing and sand dredging at Mokoloki and Oke-Oko. Animals are reared in the area, and an abattoir is sited at Kara. The low population density at Mokoloki and Oke-Oke would also imply minimal inputs of heavy meals into the river via domestic wastes.

All sediments sampled showed unpolluted status (0.00-0.10) when subjected to the Geochemical Pollution Intensity Analysis (Table 2). This is in conformity with the results obtained in Table 3 and Table 4 in which metal values were lower than the ECSQG thus indicating low metal toxicity.

Table 1 Levels (Mean) of physicochemical parameters of sediment samples obtained from the study area

Location	pH	EC µs/cm	Organic Carbon (%)	Sand (%)	Clay (%)	Silt (%)	Texture
Oke-Oko 0-5 cm	7.81±0.1	34.00±0.2	1.20±0.1	100.00	0.00	0.00	Sand
Oke-Oko 5-10 cm	8.18±0.1	31.00±0.1	2.39±0.2	94.60	0.00	5.40	Sand
Oke-Oko 10-15 cm	9.06±0.1	36.00±0.2	0.80±0.1	98.20	0.00	1.80	Sand
Mokoloki 0-5 cm	10.10±0.1	25.00±0.1	0.40±0.1	100.00	0.00	0.00	Sand
Mokoloki 5-10 cm	8.10±0.1	25.00±0.1	0.40±0.1	96.40	0.00	3.60	Sand
Mokoloki 10-15 cm	9.28±0.1	30.00±0.1	0.20±0.1	98.20	0.00	1.80	Sand
Kara 0-5 cm	8.83±0.1	198.00±0.2	0.60±0.1	96.40	0.00	3.60	Sand
Kara 5-10 cm	9.17±0.1	195.00±0.1	1.20±0.1	96.40	0.00	3.60	Sand
Kara 10-15 cm	9.53±0.1	189.00±0.1	0.40±0.1	98.20	0.00	1.80	Sand

Table 2 Igeo values of sediments metal obtained from the study area

Location	Cu	Pb	Zn	Ni	Mn	As	Cd	Cr	Hg
Oke-Oko 0-5 cm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oke-Oko 5-10cm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oke-Oko 10-15 cm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mokoloki 0-5 cm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mokoloki 5-10 cm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mokoloki 10-15 cm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kara 0-5 cm	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kara 5-10 cm	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kara 10-15 cm	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Average Shale Value	45.00	0.30	95.00	0.18	50.00	20.00	13.00	90.00	850.00

Table 3 Values of Cu, Pb, Zn, Ni, and Mn in sediments obtained from the study area (ppm)

Location	Cu	Pb	Zn	Ni	Mn	As
Oke-Oko 0-5 cm	1.60±0.1	2.20±0.1	4.00±0.1	1.40±0.1	48.00±0.1	0.00±0.1
Oke-Oko 5 – 10 cm	1.40±0.1	2.00±0.1	4.00±0.1	1.50±0.1	42.00±0.1	0.00±0.1
Oke-Oko 10-15 cm	1.50±0.1	2.10±0.1	4.00±0.1	1.50±0.1	42.00	0.00±0.1
Mokoloki 0-5 cm	1.30±0.1	2.10±0.1	3.00±0.1	1.10±0.1	42.00	0.00±0.1
Mokoloki 5-10 cm	1.00±0.1	1.90±0.1	3.00±0.1	1.20±0.2	49.00	0.00±0.1
Mokoloki 10-15 cm	1.30±0.1	1.80±0.1	3.00±0.1	1.10±0.2	49.00	0.00±0.1
Kara 0-5 cm	3.30±0.2	7.20±0.2	18.00±0.1	1.60±0.1	101.00	0.00±0.1
Kara 5 -10 cm	1.70±0.1	5.10±0.2	13.00±0.1	1.20±0.1	65.00	0.00±0.1
Kara 10-15 cm	1.50±0.1	5.10±0.1	13.00±0.1	1.20±0.1	66.00	0.00±0.1
ECSQG	35.70	35.00	123.00	NS	NS	5.90

Note: ECSQG: Environment Canada Sediment Quality Guideline

Table 4 Values of Cd, Cr, and Hg in sediments obtained from the study area (ppm)

Location	Cd	Cr	Hg
Oke-Oko 0-5 cm	<0.10	7.00±0.1	<0.10
Oke-Oko 5 – 10 cm	<0.10	9.00±0.1	<0.10
Oke-Oko 10-15 cm	<0.10	9.00±0.2	<0.10
Mokoloki 0-5 cm	<0.10	7.00±0.1	<0.10
Mokoloki 5-10 cm	<0.10	7.00±0.1	<0.10
Mokoloki 10-15 cm	<0.10	7.00±0.2	<0.10
Kara 0-5 cm	<0.10	6.00±0.1	<0.10
Kara 5 -10 cm	<0.10	6.00±0.1	<0.10
Kara 10-15 cm	<0.10	6.00±0.1	<0.10
ECSQG	0.6	37.3	0.17

Note: ECSQG: Environment Canada Sediment Quality Guideline

Conclusion

All sediment samples showed low metal concentrations when compared to the Environment Canada Sediment Quality Guideline standards. Unpolluted status was also shown from the Igeo results obtained, indicating low toxicity of the heavy metals analyzed. The low heavy metal concentrations in the areas sampled are attributed to alkaline pH, sandy particle size texture and low conductivities.

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