Assessment of Heavy Metals and determination of Pollution Indices in Sediment of *Anyia-Ogologo* River, Rivers State

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ABSTRACT

Samples of the sediment from Anyia-Ogologo River, Mgbuosimini Community were collected, preserved and analyzed. The sampling covered a period of one year wet and dry seasons. Atomic Absorption Spectrophotometric technique was used for heavy metal analysis. Sediment pollution indices indicated no contamination, no or low pollution, deficient to minimal enrichment, low potential ecological risk and uncontaminated to moderately contaminated as revealed by contamination factor, pollution load index, enrichment factor ecological risk factor and geo-accumulation index respectively.

1.0 INTRODUCTION

Sediments, known as the, final sink for pollutants in aquatic systems are very important as they serve as a habitat, food source, spawning ground and rearing areas for many aquatic plants and animals (Issa et al., 2011). Thus, protection of the sediment quality of water bodies is necessary to maintain the integrity of the aquatic system (Issa et al., 2011). The problem of water and sediment pollution in the Niger Delta has been of concern to all stakeholders; due to the level of anthropogenic degeneration of the environment and water bodies, particularly from industrial and domestic sources (Daka and Moslen, 2013; Moslen and Miebaka, 2017). In order to properly monitor and restore the integrity of any water body, there is the need to adequately protect the sediment quality of that aquatic system. This will further help to preserve aquatic life, wild life and human well-being (Issa et al., 2011). Environmental toxicants or pollutants present in any ecological environment causes a reduction in the quality of such environment and its use by natural dwellers (plants and animals) in the environment (Krishna et al., 2009; Ibrahim et al., 2016). Contaminated sediments are major sources of pollution in estuaries and are repositories for many different organic and inorganic contaminants which can accumulate to concentrations that pose danger to aquatic ecosystems (Bryan and Langston, 1992). Studies have shown that heavy metals are significant environmental pollutants and their toxicity pose ecological, evolutionary, nutritional and environmental problems (Jaishankar *et al*., 2014; Nagajyoti *et al*., 2010). Heavy metals are of great significance in the environment as they can induce certain disease conditions when present above desirable levels, can get deposited on sediment and can later be immobilized depending on the prevailing condition within the environment (Marcus and Edori, 2016). Heavy metals are not biodegradable, and so can be concentrated along the food chain. Hence, their toxic effects are mostly felt or observed at points that are distant from the source of pollution (Tilzer and Khondker, 1993). Anya-Ogolo

River is one of such metropolitan rivers that receives industrial effluents, clinical wastes, and discharges from auto-mechanical workshops.

This work examined the sediment pollution using indices such as contamination factor (CF), enrichment factor (EF), ecological risk (ER), pollution load index (PLI) and geo-accumulation Index (Igeo).

2.0 MATERIALS AND METHODS

2.1 Study Area

The study was carried out in *Anyia-Ogologo* River in Mgbuosimini Community of Port Harcourt, Rivers State Nigeria. The community covers a landarea of about 4.2 km^2 and the length of the study path on the river stretches to about 1.14 km^2, with an average elevation of 4 m and an average slope of 0.8 %. The local people use the river for mainly fishing, washing and other municipal activities. The river headwater runs behind the community into which urban drainage empties, there is also evidence of dumping of waste products from homes on the river. The *Anyia-Ogologo* River plays host toa fish market which is important to the community. Fish farming and marketing are part of the culture of the inhabitants of the area.
The sampling stations were selected using a Geographic Positioning System (GPS) tool, and five (5) sampling stations were initially identified.
The sampling stations and their geographical coordinates using Geographical Positioning System (GPS) are presented in Table 1.

Table 1: Identification of Sampling Stations with Geographical Coordinates

Station Name	Geographical Coordinates
STN1	4° 48' 27.6" N; 6° 58' 03.108" E
STN2	4° 48' 26.8" N; 6° 58' 02.202" E
STN3	4° 48' 24.0" N; 6° 58' 02.102" E
STN4	4° 48' 14.0" N; 6° 58' 01.66" E
STN5	4° 48' 11.5" N; 6° 58' 01.58" E

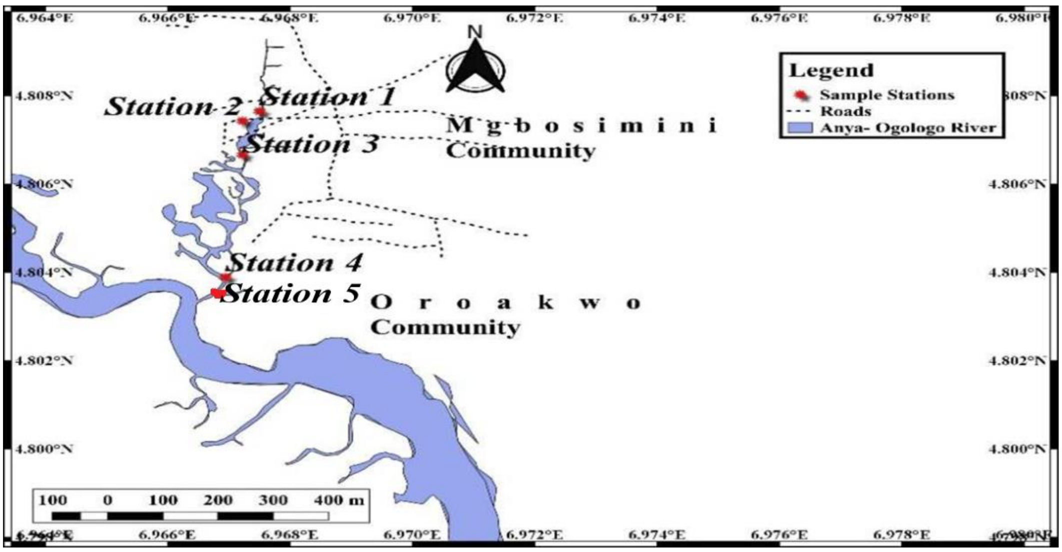


Fig. 1: Map of the Study Area

2.2 Sampling and Analysis

Sediment samples were collected using a Van Veen grab sampler as (Inengite et al., 2010). The sediment samples were collected in triplicate at each point, and mixed to form one composite sample and another composite sample collected about 5 m away from the first point at the same sampling station. Each sample was immediately wrapped in a waste bag to avoid contamination and taken to the laboratory. Each sediment sample from a station was air dried for 12 hrs and were ground in a mortar and pistil to the finest particles. Two (2 g) grams of the air-dried sediment samples were weighed using electronic Sartorius Analytical balance Model 2842. The weighed sediment sample was placed in a 50 ml beaker and to each was added 3 ml of concentrated nitric acid (HNO_3), 1 ml perchloric acid ($HClO_4$) (60%) and 1 ml conc. sulphuric acid (H_2SO_4) in the ratio of 3:1:1 and heated on a hot plate to near dryness. The content of each beaker was diluted with 10 ml of distilled water up to the mark and then filtered with Whatman No 1 filter paper. The filtrate was then preserved in a sample bottle for a few days before being analyzed for the heavy metals using Atomic Absorption Spectrophotometer **model**.

2.3 Data Analysis

Statistical analysis, mean and correlation, were done using SPSS software, version 20. Mathematical models were employed to determine the sediment pollution indices.

The Contamination Factor evaluates the ratio of contamination to that of background environmental heavy metal levels. Cf reflects preliminary contaminant enrichment in the environment.

$$C_f = \frac{C_m}{C_b} \qquad (1)$$

where Cm is the concentration of metal m; Cb is the pre-industrial concentration of metal m. Classification: CF < 1, low contamination; 1 ≤ CF ≤ 3, moderate contamination; 3 < CF≤ 6, considerable contamination; CF ≥ 6, very high contamination.

The geochemical load index (Igeo), is useful in evaluating heavy metal contamination based on the ratio of the concentration in the soil/water to the geogenic background levels. Evaluates the degree of metal contamination or pollution in the environment.

$$I_{geo} = \left(\frac{C_n}{1.5B_n}\right) \qquad (2)$$

where Cn is the measured concentration of the heavy metal; Bn is the environmental background value of the metal; 1.5 is the background matrix correction coefficient to moderate the impact of possible variations due to lithogenic and anthropogenic influences. Classification: Igeo ≤ 0, uncontaminated; 0 < Igeo ≤ 1, uncontaminated to moderately contaminated; 1 < Igeo ≤ 2, moderately contaminated, 2 < Igeo ≤ 3, moderately to strongly contaminated; 3 < Igeo ≤ 4, strongly contaminated; 4 < Igeo ≤ 5, strongly to extremely contaminate; Igeo > 5, extremely contaminated (Caeiro *et al.,* 2005).

Enrichment Factor (EF) is used to determine the level of human effects on heavy metals in soil. The metals enrichment factor in soil were determined using the equation below (Zia *et al*., 2017). EF evaluates the severity/pollution state of anthropogenic enrichment of individual heavy metal.

$$EF = \frac{\left({}^{M_s}/_{C_{ref}}\right)}{\left({}^{M_{cr}}/_{C_{cr}}\right)} \qquad (3)$$

where ${}^{M_s}/_{C_{ref}}$ is the ratio of metal concentration in the sample to reference metal C; ${}^{M_{cr}}/_{C_{cr}}$ is the ratio of the background value of metal M to the reference metal C. In this research, iron (Fe) was selected as the reference because of its natural abundance in the earth crust of the study area. In EF determination, the reference values are included for normalization (to compensate for distortions from geogenic/anthropogenic activities). Classification: EF < 2, none to minor enrichment; 2 ≤ EF < 5, moderate enrichment; 5 ≤ EF < 10, significant enrichment; 10 ≤ EF < 25, severe enrichment; 25 ≤ EF < 50, very severe enrichment; EF > 50, extremely severe enrichment. The use of reference elemental values makes the EF index a more reliable indicator of heavy metal pollution.

Ecological Risk Factor (Er) assesses the ecological risk potential of a single.

$$Er = Tr \times Cf \qquad (4)$$

Where Tr = toxic-response factor a given metal and CF= the contamination factor for the measured metal. Toxic response factors values are given as; Cu = Pb = 5, Cd = 30, Zn = 1, As = 10, Mn = 1 and Fe not available.

Pollution Load Index (PLI) is an empirical pollution indicator expressed geometrically as a mean (nth root) of the EF of all the metals evaluated in a particular site.

$$\text{PLI for a single site} = (EF_1 \times EF_2 \times EF_3 \times \ldots \times EF_n)^{1/n} \qquad (5)$$

where n is the number of elements involved. Classification: PLI < 1, no or low pollution level; PLI = 1, baseline/background pollution; PLI > 1, progressive pollution.

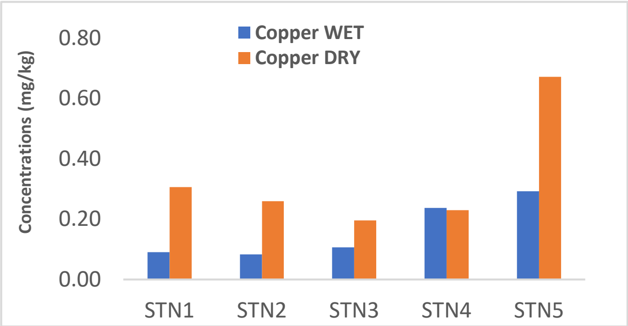
3.0 RESULTS

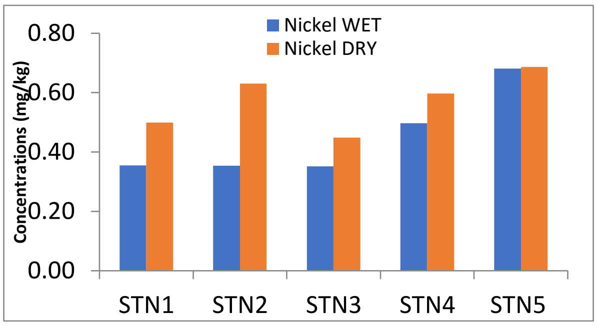
Heavy Metals: The mean levels of copper ions in sediment ranged from 0.08±0.06 mg/kg to 0.29±0.02 mg/kg in wet season and 0.20±0.12 to 0.67±0.06 mg/kg in dry season. Nickel ions in sediment ranged from 0.35±0.06 mg/kg to 0.68±0.12 mg/kg in wet season and 0.45±0.05 mg/kg to 0.83±0.06 mg/kg in dry season. Cobalt ions in sediment ranged from 0.03±0.02 mg/kg to 0.12±0.02 mg/kg in wet season and 0.03±0.02 mg/kg to 0.12±0.02 mg/kg in dry season. Manganese ions in sediment ranged from 0.16±0.06 mg/kg to 0.24±0.13 mg/kg in wet season and 0.19±0.08 mg/kg to 0.30±0.03 mg/kg in dry season. Cadmium ions in sediment ranged from 0.01±0 mg/kg to 0.02±0.01 mg/kg in wet season and 0.01±0 mg/kg to 0.02±0.01 mg/kg in dry season. Lead ions in sediment ranged from 0.11±0.03 mg/kg to 0.80±0.07 mg/kg in wet season and 0.13±0.02 mg/kg to 0.76±0.06 mg/kg in dry season. Zinc ions in sediment ranged from 0.65±0.04 mg/kg to 1.08±0.08 mg/kg in wet season and 0.24±0.06 mg/kg to 0.47±0.02 mg/kg in dry season. Iron in sediment ranged from 63.56±1.61 mg/kg to 69.65±17.0 mg/kg in wet season and 70.97±12.88 mg/kg to 74.05±4.15 mg/kg in dry season. Chromium ions in sediment ranged from 0.30±0.12 mg/kg to 0.46±0.32 mg/kg in wet season and 0.15±0.05 mg/kg to 0.75±0.05 mg/kg in dry season.

Table 2: Pearsons Correlation Index

	Cu	Ni	Co	Mn	Cd	Lead	Zinc	Iron	Cr
Cu	1								
Ni	.961**	1							
Co	-0.131	-0.126	1						
Mn	0.795	.909*	-0.031	1					
Cd	.899*	0.856	0.269	0.671	1				
Lead	0.769	.914*	-0.044	.966**	0.683	1			
Zinc	0.498	0.707	-0.024	.909*	0.389	.925*	1		
Iron	-0.815	-0.626	0.052	-0.387	-0.749	-0.277	0.032	1	
Cr	0.345	0.337	0.823	0.25	0.717	0.307	0.137	-0.281	1

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).


Copper WET
Copper DRY
Concentrations (mg/kg)
0.80
0.60
0.40
0.20
0.00
STN1
STN2
STN3
STN4
STN5


Nickel WET
Nickel DRY
Concentrations (mg/kg)
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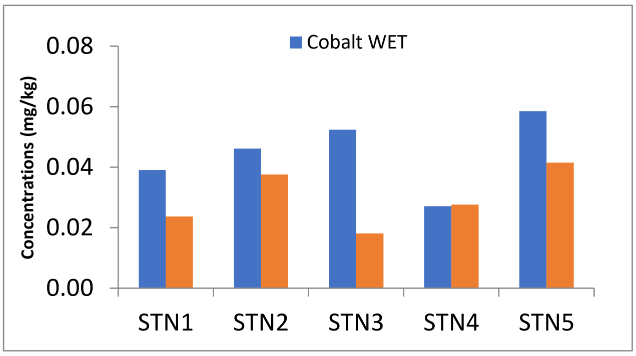
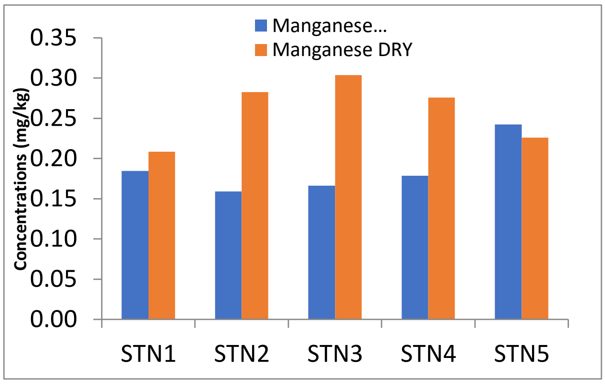
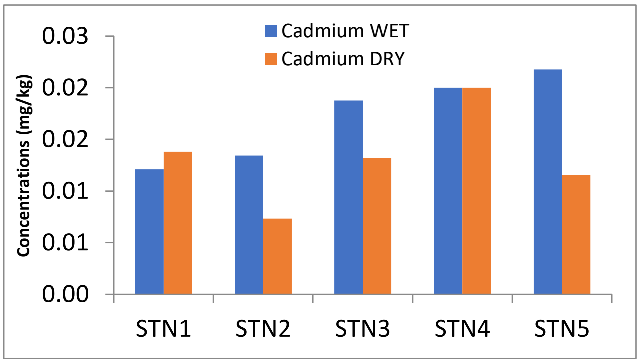
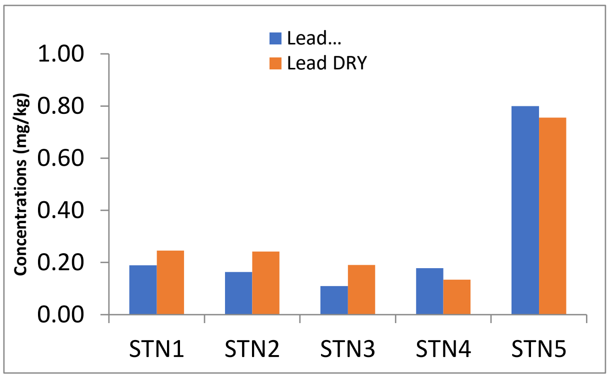
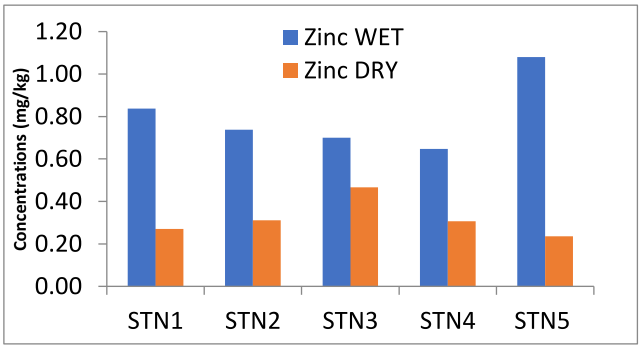
0.60
0.40
0.20
0.00
STN1
STN2
STN3
STN4
STN5

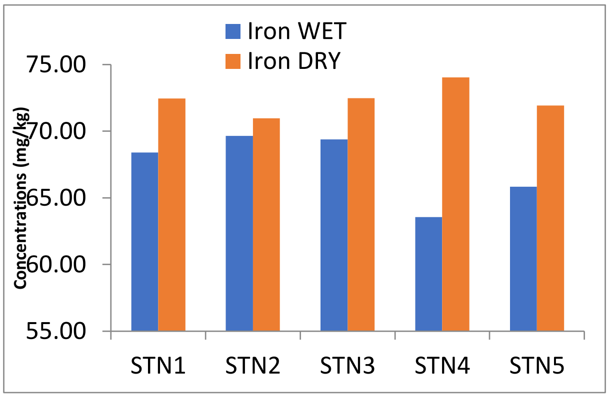

Cobalt WET
Concentrations (mg/kg)
0.08
0.06
0.04
0.02
0.00
STN1
STN2
STN3
STN4
STN5

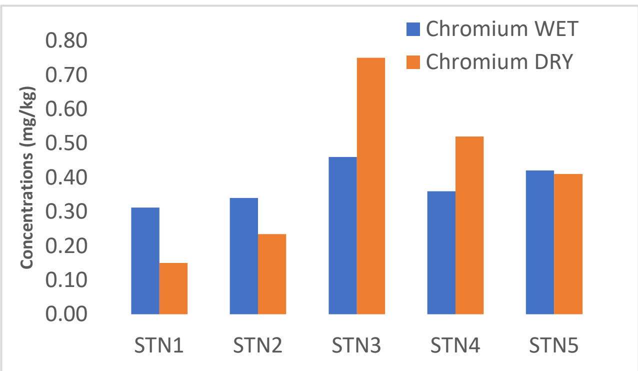

Manganese...
Manganese DRY
Concentrations (mg/kg)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
STN1
STN2
STN3
STN4
STN5


Cadmium WET
Cadmium DRY
Concentrations (mg/kg)
0.03
0.02
0.02
0.01
0.01
0.00
STN1
STN2
STN3
STN4
STN5


Lead...
Lead DRY
Concentrations (mg/kg)
1.00
0.80
0.60
0.40
0.20
0.00
STN1
STN2
STN3
STN4
STN5


Zinc WET
Zinc DRY
Concentrations (mg/kg)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
STN1
STN2
STN3
STN4
STN5


Iron WET
Iron DRY
Concentrations (mg/kg)
75.00
70.00
65.00
60.00
55.00
STN1
STN2
STN3
STN4
STN5


Chromium WET
Chromium DRY
Concentrations (mg/kg)
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
STN1
STN2
STN3
STN4
STN5

Evaluation of Sediment Pollution Index

The impact of the activities related to the presence of heavy metal ions in the studied sediments, were evaluated using the contamination factor (CF), pollution load index (PLI), enrichment factor (EF), ecological risk (ER) and geo-accumulation index (I-geo). The calculated values are presented in Tables 3 - 6.

Contamination factor (CF) levels in the wet season ranged from 2.31×10^{-3} to 8.13×10^{-3} for copper; 1.01×10^{-2} to 1.95×10^{-2} for nickel; 1.31×10^{-3} to 6.20×10^{-3} for cobalt; 1.68×10^{-3} to 2.70×10^{-2} for cadmium; 1.34×10^{-3} to 9.40×10^{-3} for lead; 4.62×10^{-3} to 7.71×10^{-3} for zinc and 2.99×10^{-3} to 4.57×10^{-3} for chromium. CF levels in the dry Season ranged from 5.17×10^{-3} to 6.38×10^{-2} for copper; 1.26×10^{-3} to 2.28×10^{-3} for nickel; 1.18×10^{-3} to 3.95×10^{-3} for cobalt; 1.44×10^{-3} to 1.72×10^{-2} for cadmium; 1.27×10^{-3} to 8.89×10^{-3} for lead; 1.69×10^{-3} to 2.08×10^{-3} for zinc and 1.51×10^{-3} to 7.23×10^{-3} for chromium.
Pollution load index (PLI) levels in the wet Season was 3.92×10^{-3} for copper; 1.23×10^{-2} for nickel, 2.29×10^{-3} for cobalt, 2.04×10^{-2} for cadmium, 2.57×10^{-3} for lead, 5.62×10^{-3} for zinc and 3.71×10^{-3} for chromium. Pollution load index (PLI) levels in the dry Season was 8.18×10^{-3} for copper, 1.64×10^{-2} for nickel, 1.19×10^{-3} for cobalt, 1.51×10^{-2} for cadmium, 2.69×10^{-3} for lead, 2.14×10^{-3} for zinc and 4.34×10^{-3} for chromium.
Enrichment Factor (EF) levels in the wet Season ranged from 1.89×10^{-4} to 7.04×10^{-4} for copper, 5.80×10^{-4} to 1.18×10^{-3} for nickel, 3.16×10^{-3} to 5.90×10^{-3} for cadmium, 1.84×10^{-4} to 1.33×10^{-3} for lead, 4.66×10^{-4} to 7.51×10^{-4} for zinc and 5.10×10^{-4} to 7.42×10^{-4} for chromium. Enrichment Factor (EF) levels in the dry season ranged from 4.67×10^{-4} to 1.48×10^{-3} for copper, 7.87×10^{-4} to 1.45×10^{-3} for nickel, 2.17×10^{-3} to 4.15×10^{-3} for cadmium, 1.89×10^{-4} to 1.15×10^{-3} for lead, 1.5×10^{-4} to 3.14×10^{-4} for zinc and 2.42×10^{-4} to 1.34×10^{-4} for chromium.
Ecological Risk (ER) levels in the wet season ranged from 4.54×10^{-1} to 8.16×10^{-1} for cadmium, 6.00×10^{-3} to 9.14×10^{-3} for chromium, 1.15×10^{-2} to 4.07×10^{-2} for copper, 6.64×10^{-3} to 4.70×10^{-2} for lead, 5.03×10^{-2} to 9.73×10^{-2} for nickel, 3.10×10^{-3} to 6.76×10^{-2} for cobalt and 4.62×10^{-3} to 7.71×10^{-2} for zinc. Ecological Risk (ER) levels in the dry season ranged from 4.54×10^{-1} to 8.16×10^{-1} for cadmium, 6.00×10^{-3} to 9.14×10^{-3} for chromium, 1.15×10^{-2} to 4.07×10^{-2} for copper, 6.64×10^{-3} to 4.70×10^{-2} for lead, 5.03×10^{-2} to 9.73×10^{-2} for nickel, 3.10×10^{-3} to 6.76×10^{-2} for cobalt and 4.62×10^{-3} to 7.71×10^{-2} for zinc.
Geo-accumulation Index (I-geo) levels in the wet season ranged from 3.70×10^{-4} to 1.36×10^{-3} for copper, 1.04×10^{-3} to 2.01×10^{-3} for nickel, 2.76×10^{-4} to 1.31×10^{-3} for cobalt, 3.76×10^{-5} to 5.72×10^{-5} for manganese, 8.09×10^{-3} to 1.46×10^{-2} for cadmium, 1.13×10^{-3} to 8.02×10^{-3} for lead, 1.32×10^{-3} to 2.28×10^{-3} for zinc and 6.69×10^{-4} to 1.02×10^{-3} for chromium. Geo-accumulation Index (I-geo) levels in the dry season ranged from 8.29×10^{-4} to 3×10^{-3} for copper, 1.30×10^{-3} to 2.35×10^{-3} for nickel, 8.35×10^{-5} to 4.38×10^{-4} for cobalt, 4.15×10^{-5} to 6.74×10^{-5} for manganese 5.09×10^{-3} to 9.79×10^{-3} for cadmium, 1.09×10^{-3} to 7.58×10^{-3} for lead, 5×10^{-4} to 9.12×10^{-4} for zinc and 3.36×10^{-4} to 9.18×10^{-4} for chromium.

Table 3: The Contamination Factor (CF) and Pollution Load Index (PLI)

CONTAMINATION FACTOR/POLLUTION LOAD INDEX (PLI)							
WET SEASON	**Copper**	**Nickel**	**Cobalt**	**Cadmium**	**Lead**	**Zinc**	**Chromium**
			Contamination Factor				
STN1	2.52×10^{-3}	1.01×10^{-2}	1.96×10^{-3}	9.5×10^{-3}	2.23×10^{-3}	5.97×10^{-3}	2.99×10^{-3}
STN2	2.31×10^{-3}	1.01×10^{-2}	1.31×10^{-3}	1.68×10^{-3}	1.92×10^{-3}	5.28×10^{-3}	3.39×10^{-3}
STN3	2.97×10^{-3}	1.01×10^{-2}	6.20×10^{-3}	2.17×10^{-2}	1.34×10^{-3}	4.98×10^{-3}	4.57×10^{-3}
STN4	6.61×10^{-3}	1.40×10^{-2}	1.35×10^{-3}	2.35×10^{-2}	2.10×10^{-3}	4.62×10^{-3}	3.59×10^{-3}
STN5	8.13×10^{-3}	1.95×10^{-2}	2.92×10^{-3}	2.70×10^{-2}	9.40×10^{-3}	7.71×10^{-3}	4.20×10^{-3}
PLI	$\mathbf{3.92\times10^{-3}}$	$\mathbf{1.23\times10^{-2}}$	$\mathbf{2.29\times10^{-3}}$	$\mathbf{2.04\times10^{-2}}$	$\mathbf{2.57\times10^{-3}}$	$\mathbf{5.62\times10^{-3}}$	$\mathbf{3.71\times10^{-3}}$
DRY SEASON	**Copper**	**Nickel**	**Cobalt**	**Cadmium**	**Lead**	**Zinc**	**Chromium**
			Contamination Factor				
STN1	8.52×10^{-3}	1.43×10^{-3}	1.18×10^{-3}	1.73×10^{-2}	2.89×10^{-3}	1.89×10^{-3}	1.51×10^{-3}
STN2	7.01×10^{-3}	2.28×10^{-3}	1.81×10^{-3}	9.51×10^{-3}	2.74×10^{-3}	2.08×10^{-3}	6.55×10^{-3}
STN3	5.17×10^{-3}	1.26×10^{-3}	3.95×10^{-3}	1.83×10^{-3}	1.27×10^{-3}	3.08×10^{-3}	7.23×10^{-3}
STN4	6.38×10^{-2}	1.71×10^{-3}	1.38×10^{-3}	1.83×10^{-3}	1.58×10^{-3}	2.19×10^{-3}	5.24×10^{-3}
STN5	1.87×10^{-2}	1.68×10^{-3}	$2..07\times10^{-3}$	1.44×10^{-3}	8.89×10^{-3}	1.69×10^{-3}	4.14×10^{-3}
PLI	$\mathbf{8.18\times10^{-3}}$	$\mathbf{1.64\times10^{-2}}$	$\mathbf{1.19\times10^{-3}}$	$\mathbf{1.51\times10^{-2}}$	$\mathbf{2.69\times10^{-3}}$	$\mathbf{2.14\times10^{-3}}$	$\mathbf{4.34\times10^{-3}}$

Table 4: The Enrichment Factor (EF)

ENRICHMENT FACTOR						
WET SEASON	**Copper**	**Nickel**	**Cadmium**	**Lead**	**Zinc**	**Chromium**
STN1	2.10×10^{-4}	5.9×10^{-4}	3.16×10^{-3}	3.04×10-4	5.60×10^{-4}	5.10×10^{-4}
STN2	1.89×10^{-4}	5.80×10^{-4}	3.44×10^{-3}	2.57×10^{-4}	4.86×10^{-4}	5.67×10^{-4}
STN3	2.51×10^{-4}	5.96×10^{-4}	4.61×10^{-3}	1.84×10^{-4}	4.74×10^{-4}	7.89×10^{-4}
STN4	5.92×10^{-4}	8.92×10^{-4}	5.29×10^{-3}	3.08×10^{-4}	4.66×10^{-4}	6.58×10^{-4}
STN5	7.04×10^{-4}	1.18×10^{-3}	5.90×10^{-3}	1.33×10^{-3}	7.51×10^{-4}	7.42×10^{-4}
DRY SEASON	**Copper**	**Nickel**	**Cadmium**	**Lead**	**Zinc**	**Chromium**
STN1	6.70×10^{-4}	7.87×10^{-4}	3.40×10^{-3}	3.72×10^{-4}	1.68×10^{-4}	2.42×10^{-4}
STN2	6.37×10^{-4}	1.45×10^{-3}	2.17×10^{-3}	4.07×10^{-4}	2.12×10^{-4}	1.22×10^{-3}
STN3	4.67×10^{-4}	7.99×10^{-4}	4.15×10^{-3}	1.89×10^{-4}	3.14×10^{-4}	1.34×10^{-3}
STN4	4.91×10^{-4}	9.21×10^{-4}	3.52×10^{-3}	1.99×10^{-4}	1.90×10^{-4}	8.22×10^{-4}
STN5	1.48×10^{-3}	9.30×10^{-4}	2.86×10^{-3}	1.15×10^{-3}	1.51×10^{-4}	6.66×10^{-4}

Table 5: The Ecological Risk Factor (ER)

ECOLOGICAL RISK FACTOR							
WET SEASON	**Cadmium**	**Chromium**	**Copper**	**Lead**	**Nickel**	**Cobalt**	**Zinc**
STN1	4.54×10^{-1}	6.00×10^{-3}	1.26×10^{-2}	1.12×10^{-2}	5.06×10^{-2}	9.77×10^{-3}	5.98×10^{-3}
STN2	5.04×10^{-1}	6.79×10^{-3}	1.15×10^{-2}	9.61×10^{-3}	5.05×10^{-2}	6.52×10^{-3}	5.28×10^{-3}
STN3	6.52×10^{-1}	9.14×10^{-3}	1.48×10^{-2}	6.64×10^{-3}	5.03×10^{-2}	3.10×10^{-2}	4.98×10^{-3}
STN4	7.05×10^{-1}	7.20×10^{-3}	3.30×10^{-2}	1.05×10^{-2}	7.09×10^{-2}	6.76×10^{-3}	4.62×10^{-3}
STN5	8.16×10^{-1}	8.41×10^{-3}	4.07×10^{-2}	4.70×10^{-2}	9.73×10^{-2}	1.46×10^{-2}	7.71×10^{-3}
DRY SEASON	**Cadmium**	**Chromium**	**Copper**	**Lead**	**Nickel**	**Cobalt**	**Zinc**
STN1	5.18×10^{-1}	3.01×10^{-3}	4.26×10^{-2}	1.44×10^{-2}	7.14×10^{-2}	5.92×10^{-3}	1.90×10^{-3}
STN2	2.85×10^{-1}	1.31×10^{-2}	3.51×10^{-2}	1.37×10^{-2}	1.14×10^{-1}	9.03×10^{-3}	2.08×10^{-3}
STN3	5.49×10^{-1}	1.45×10^{-2}	2.58×10^{-2}	6.37×10^{-3}	6.30×10^{-2}	1.98×10^{-3}	3.08×10^{-3}
STN4	5.48×10^{-1}	1.05×10^{-2}	3.19×10^{-2}	7.91×10^{-3}	8.54×10^{-2}	6.92×10^{-3}	2.19×10^{-3}
STN5	4.33×10^{-1}	8.24×10^{-3}	9.33×10^{-2}	4.45×10^{-2}	8.37×10^{-2}	1.04×10^{-2}	1.69×10^{-3}

Table 6: The Geo-Accumulation Index (I-geo)

GEO-ACCUMULATION INDEX								
WET SEASON	**Copper**	**Nickel**	**Cobalt**	**Manganese**	**Cadmium**	**Lead**	**Zinc**	**Chromium**
STN1	4.05×10^{-4}	1.05×10^{-3}	4.13×10^{-4}	4.36×10^{-5}	8.09×10^{-3}	1.90×10^{-3}	1.77×10^{-3}	6.69×10^{-4}
STN2	3.70×10^{-4}	1.04×10^{-3}	2.76×10^{-4}	3.76×10^{-5}	8.98×10^{-3}	1.64×10^{-3}	1.56×10^{-3}	7.57×10^{-4}
STN3	4.76×10^{-4}	1.04×10^{-3}	1.31×10^{-3}	3.92×10^{-5}	1.16×10^{-2}	1.13×10^{-3}	1.47×10^{-3}	1.02×10^{-3}
STN4	1.06×10^{-3}	1.47×10^{-3}	2.86×10^{-4}	4.22×10^{-5}	1.26×10^{-2}	1.73×10^{-2}	1.37×10^{-3}	8.03×10^{-4}
STN5	1.31×10^{-3}	2.01×10^{-3}	6.18×10^{-4}	5.72×10^{-5}	1.46×10^{-2}	8.02×10^{-3}	2.28×10^{-3}	9.37×10^{-4}
DRY SEASON	**Copper**	**Nickel**	**Cobalt**	**Manganese**	**Cadmium**	**Lead**	**Zinc**	**Chromium**
STN1	1.37×10^{-3}	1.47×10^{-3}	2.50×10^{-4}	4.93×10^{-5}	9.23×10^{-3}	2.46×10^{-3}	5.61×10^{-4}	3.36×10^{-3}
STN2	1.13×10^{-3}	2.35×10^{-3}	3.81×10^{-4}	6.45×10^{-5}	5.09×10^{-3}	2.34×10^{-3}	6.14×10^{-4}	1.46×10^{-3}
STN3	8.29×10^{-4}	1.30×10^{-3}	8.35×10^{-5}	6.74×10^{-5}	9.79×10^{-3}	1.09×10^{-3}	9.12×10^{-4}	1.61×10^{-3}
STN4	1.02×10^{-3}	1.76×10^{-3}	2.92×10^{-4}	4.15×10^{-5}	9.77×10^{-3}	1.35×10^{-3}	6.48×10^{-4}	1.17×10^{-3}
STN5	3.00×10^{-3}	1.73×10^{-3}	4.38×10^{-4}	5.33×10^{-5}	7.72×10^{-3}	7.58×10^{-3}	5.00×10^{-4}	9.18×10^{-4}

4.0 DISCUSSION

Heavy Metal Analysis

The levels of Cu, Ni, Co, Cd, Pb, Zn and Cr metals in the sediment samples were below their DPR (2002) target values of 36, 35, 20, 0.8, 85, 140 and 100 mg/kg respectively, in the wet and dry seasons. Inengite et al (2010) reported low levels of Pb, Cr and Ni concentrations in the Kolo creek sediment. The correlation results show that strong correlations at the 0.01 significance level were observed between Ni & Cu, and PB & Mn. At the 0.05 significance level, strong correlations were observed between Cd & Cu, Ni & Mn, Ni & Pb, Zn & Mn and Zn & Pb.

Sediment Pollution Indices

Results of the Contamination Factor (CF) for Cu, Ni, Co, Cd, Pb, Zn and Cr in sediment in the stations in both seasons were less than one, indicating low contamination. Moslen et al (2018) reported high Cf values for Zn, Cd and Pb, but similar value was reported for Cr. Chris and Anyanwu (2023) also reported higher Cf levels for Cu, Pb, Zn and Cu metals in sediments at Isaka–Bundu tidal mangrove creek. The sediment pollution index (PI) values for Cu, Ni, Co, Cd, Pb, Zn and Cr were all less than 1, which implies that the sediment have no or low pollution level with these elements. Elias *et al* (2014) reported degree of contamination values between <8 - 43.2 depicting low and very high degree of contamination respectively. Enrichment Factor (EF) values for Cu, Ni, Co, Cd, Pb, Zn and Cr were all less than 2, which implies that the sediment have deficient to minimal enrichment or low pollution level with these elements. A result of enrichment factor revealing depletion to moderate enrichment in sediment samples was reported by Moslen et al (2018). The ecological risk factor (ER) of the heavy metals in the sediment were below 40, indicating low potential risk to the ecological system. Kpee et al (2019) also recorded similar ecological risk levels in a study carried out at Andoni River. Geo-accumulation index (I-geo) values for Cu, Ni, Co, Cd, Mn, Pb, Zn and Cr were approximately zero, which implies that the sediments were uncontaminated with these elements. Moslen et al (2018), in a study at Azuabie creek, reported that Cr, Cd, Pb and Zn metals showed an Igeo less than 1, indicating that the sediment was uncontaminated to moderately contaminated.

5.0 CONCLUSION

Heavy metal levels and pollution indices in sediment samples from Anya-Ogolo River were examined in this study. The heavy metals analyzed were found to be below the DPR (2002) permissible limits. An assessment of the pollution levels using various indices (contamination factor, pollution load index, enrichment factor, ecological risk factor and geo-accumulation index) showed that the sediments had very lowly polluted/ contaminated by these heavy metals. This study proposes regular monitoring of these water bodies as pollution levels tend to increase with increase in deposits from anthropogenic activities in the study area.

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