Research Article / Review Article FUPRE JOURNAL 7(3): 122-134 (2023)

FUPRE Journal

of

Scientific and Industrial Research

ISSN: 2579-1184(Print) ISSN: 2578-1129 (Online)

http://fupre.edu.ng/journal

Geochemical Cycling of Metals in Plant – Soil System in Selected States of the Central Niger Delta Region of Nigeria

IBE, K. A.[1,*], *ETUK, E. A.*[2], *OKWUTE, M. C.*[3]

[1,3]*Department of Chemistry, Federal University of Petroleum Resources, Effurun, Delta State, Nigeria*
[2] *Arcon She'd 1, Clean Nigeria Associate Limited, Nigeria Ports Authority, Port Harcourt, Rivers State, Nigeria*

ARTICLE INFO

Received:10/04/2023
Accepted: 23/06/2022

Keywords

Geochemical cycling, Heavy Metals, MP-AES, Uptake ratio, Topsoil enrichment factor

ABSTRACT

T Heavy metal pollution is a global concern due to their toxic effects of some of them. The geochemical cycling of heavy metals within the soil- plant system is unavoidably necessary. It enables the distribution of these metals within the eco-system. However, where the metals predominantly reside, and the type of metal is of primary importance. The geochemical cycling of nine heavy metals were investigated in this study using fundamental parameters of metal concentration, uptake ratio and relative soil enrichment factors. Soil and plant samples were collected from locations within the vicinity of oil facilities in Delta, Bayelsa and Akwa Ibom states in Nigeria. The control samples were taken around the areas where there was no visible oil activity. The samples were appropriately pre-treated before the determination of their metal content using Agilient Microwave Plasma Atomic Emission Spectroscopy (MPAES) instrument, model 4200. Iron had the highest concentration in both the soils and plants (74.72mg/Kg and 11.98mg/Kg) respectively while arsenic and mercury had the lowest concentrations in the soils and plants (0.012mg/Kg and 0.034mg/Kg) respectively. The concentration of mercury was below detection level (<0.002mg/Kg) in the soils. The concentrations were within the permissible levels except chromium. The concentration of the metals varied in the following order in the soils; topsoil, 0-15cm: Fe> Ni>Cr>Pb>Sr>V> Cd> As. In the bottom soil, 15-30cm, the same order was observed though the metal concentrations were lower. The order of variation in the plant was different from that of the soil, Fe> Cr> Sr> V> Ni> Cd > Pb > As > Hg. The range of the mean values of uptake ratios was 0.296 – 43.177 indicating that most of the metals were more in the plant than in the soil. The range of the mean values of the relative soil enrichment factor was 1.107 -1.283, indicating that there was no metal pollution as the values were less than 2. Although there was no evident heavy metal pollution, prompt and adequate monitoring is necessary.

1. INTRODUCTION

Anthropogenic activities of humans globally are increasingly becoming inimical to the different compartments of the environment and all forms of lives that exist and depend on them. The terrestrial and aquatic

*Corresponding author, e-mail:ibe.kenneth@fupre.edu.ng
DIO

environment mostly support animals and plants that grow and live in them which in turn constitute nutritional resources to humans through the food chain. The cycling of trace metals both the essential and non-essential ones through the aforementioned transfer process could increase their concentrations several times higher than their natural background levels (Okafor et al., 2013).

The ability of a water body for example, to support aquatic life as well as its suitability for other uses depends on the presence of many trace elements. Trace concentrations of zinc are important for the physiological functions of living tissue for the regulation of many biochemical processes. Generally, essential trace metals are only used in trace amount by organisms and are usually found in small concentrations in the environment (Mgbemena et al., 2018). The number of heavy metals in the organism does not exceed the level which allows the enzyme system to function without interference. The excess amount of heavy metal in the organism can be regulated by homeostasis (Ahmad et al., 2010). But, if the heavy metal concentration at the source of supply such as water and food is too high, the homeostasis mechanism ceases to function and essential heavy metals act in either an acutely or chronically toxic manner (Wiener, 2006).

Dissolved oxygen, P^H , salinity, temperature and hardness of water have been shown to be factors that influence the physiology of an organism and the rate of uptake of heavy metals (Mgbemena et al., 2018).

Flood drains through the refuse in open dumps readily absorb many organic and inorganic compounds present in the refuse. Some of the absorbed inorganic elements such as Pb, Cu, Zn, Fe, Mn, Cr and Cd either drain laterally through adjoining soils contaminating the ground water (Awomeso et al., 2010).

The Niger Delta coastal environment with its rich and diverse ecosystems and natural resources has been under threat of geochemical cycling of these heavy metals perhaps due to increased urbanization, industrialization, legal and illegal crude oil exploitation. Therefore, there is the need to assess the cycling of these metals in some media of the environment and their accumulation. Three states within the central Niger Delta were selected for this study-Delta, Bayelsa and Akwa Ibom.

1.1 Description of the Study Area

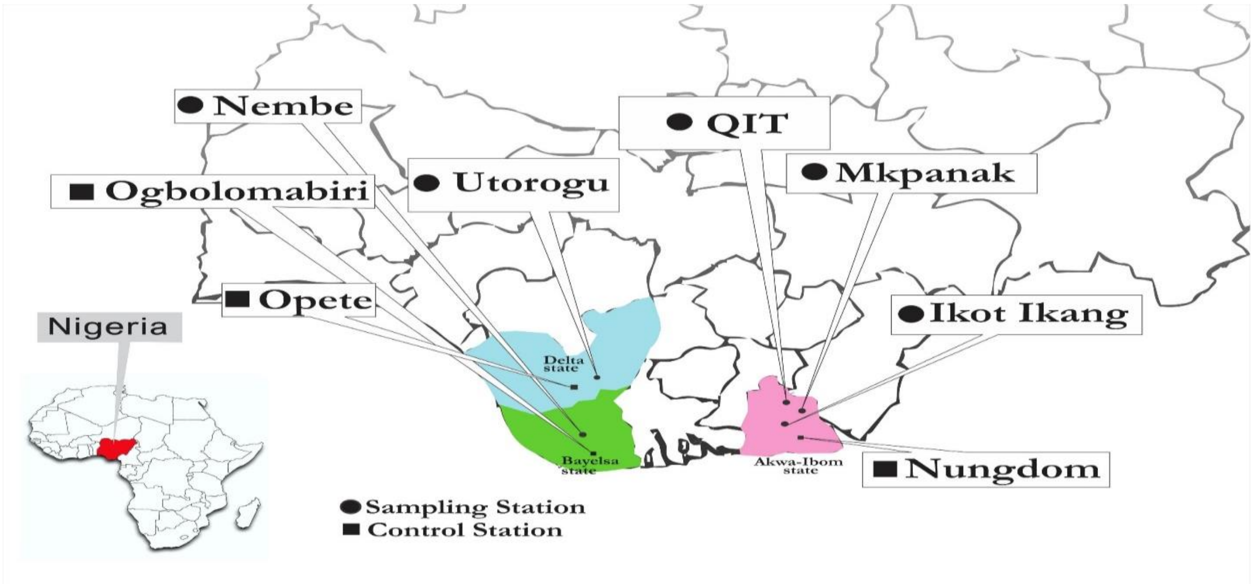

Fig. 1: Skeletal map of Nigeria showing the studied states and sample points

The Niger Delta region is situated at the apex of the Gulf of Guinea on the west coast of Africa (Haack et al., 2000; Doust, 1990). The Niger Delta, which is home to some 31 million people, occupies a total area of about 75,000 km^2 and makes up 7.5% of Nigeria's land mass (Young, 2012). The Niger Delta region consists of 9 oil–producing states (Abia, Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Ondo, Imo, and Rivers) and 185 local government areas. Only the studied states, Delta, Bayelsa and Akwa Ibom are shown on the map (Fig.1). This region cuts across over 800 oil–producing communities with an extensive network of over 900 producing oil wells and several petroleum productions–related facilities (Osuji and Onojake, 2004). The ecological zones in the Niger Delta region can be broadly grouped into tropical rainforest in the northern part of the Delta and mangrove forest in the warm coastlines of Nigeria. Mangrove forests and swamps, which are characterized by regular salt–water inundation, lie at the centre of a complex and sensitive ecosystem which is vital to the local economy and accommodates important flora and fauna (Ugochukwu and Ertel, 2008). The Niger Delta, which is the largest mangrove forests in Africa and the third largest in the world, is the richest part of Nigeria in terms of petroleum resources and diverse natural ecosystems supportive of numerous species of terrestrial and aquatic fauna. According to (Curtis, 1986), a large portion of the world's oil and gas reserves are in tertiary terrigenous fill on passive continental margins and the most significant hydrocarbon deposits of this type could be found in the U.S. Gulf of Mexico, Canadian Beaufort-Mackenzie Delta, and Nigeria's Niger Delta.

The stratigraphy of the Niger Delta consists of mainly three thick rock units (Evamy et al., 1978; Lambert-Aikhionbare and Ibe, 1984), which are from shallowest to the deepest, the Benin Formation, composed of sandstone in a fluvial and coastal environment; the Agbada Formation, composed of interbedded sandstones and shales deposited in a transitional to marine environment and the Akata Formation, composed of massive marine shales.

2. MATERIALS AND METHODS

Three states in the central part of Niger Delta (Delta, Bayelsa and Akwa Ibom) were selected for the study and therefore were sampled. In Delta State, Utorogu (UTG) was selected; in Bayelsa, Nembe (NMB) was selected while in Akwa Ibom, Qua Iboe (QIB), Nkpanak (NKK) and Ikot Itang (IKIT) were selected. These sample sites were close to one oil facility or the other. The control samples were taken far away from the main sample sites where there is no oil facility. They are Ogbolomabiri (OG) for Nembe; Opete (OP) for Utorogu and Nungdom (ND) for QIB, NKK and IKIT.

2.1 Flora Sampling

A branch from the different plant species was cut out from the stem and washed in de-ionised water before taking it to the Chemistry Laboratory of Federal University of Petroleum Resources, Effurun, Delta State, Nigeria. Four samples were taking from each state including the control sample. The plants sampled are shown on table 1. They are all edible plants frequently consumed by the natives.

2.1.1. Heavy Metal Analysis of Flora Samples

The dried and crushed whole plant samples were ashed in a furnace at 600^0C for 6 hours, and 2g of each sample mixed with 15mL of aqua regia, a mixture of hydrochloric acid and nitric acid (HCl : HNO_3) in ratio 3:1. The mixture was heated till the volume reduced to about 10 – 5mL, and allowed to cool. It was thereafter filtered into a volumetric flask and made up to 100mL with de-ionized water.

Table 1: Collected Flora Samples and their Botanical Names

S/N	Sample Code	Common Name	Botanical Name
1	NMB1	GUAVA	*Prisidium guava*
2	NMB2	PAWPAW	*Carica papaya*
3	NMB3	CASSAVA	*Manihot esculentum*
4	0G (CONTROL)	PAWPAW	*Carica papaya*
5	UTG 1	MAIZE	*Zea mays*
6	UTG 2	PLANTAIN	*Musa paradisiaca*
7	UTG 3	MAIZE	*Zea mays*
8	OP(CONTROL)	MAIZE	*Zea mays*
9	QIB	GREENS	*Amaranthus hybridus*
10	NKK	OKRA	*Abelmoschsus execulentum*
11	IKIT	OKRA	*Abelmoschsus execulentum*
12	ND(CONTROL)	OKRA	*Abelmoschsus execulentum*

2.2 Soil Sampling

The soils were sampled in triplicate with calibrated soil auger. The samples were collected into a pre-cleaned plastic bags at depths of 0 -15 and 15- 30cm during the dry season like all the other samples. This is because heavy metals are likely to be more residual in soil during dry season when there is no run-off as is the case during rainy season (Yahaya et al., 2009; Amadi-Akobundu and Nwankwoala, 2013). The auger was rinsed with acetone in between sampling.

2.2.1. Heavy Metal Analysis of Soil Samples

1g of the dried, crushed, and sieved soil sample was placed in a kjeldahl flask, and 10mL of perchloric acid added to it. The mixture was refluxed on a hot plate inside the fume cupboard for 2 hours. After which de-ionised water was added to the digest and allowed to cool. The digest was filtered and made up to 100mL mark of the volumetric standard flask with distilled water.

The concentrations of the selected heavy metals were analyzed using Agilient Microwave Plasma Atomic Emission Spectroscopy (MP-AES) instrument, model 4200.

3.2 Discussion

3.2.1 Concentration of heavy metals

Contamination of agricultural soils by heavy metals has become an environmental concern due to the potential adverse ecological effects. Non-essential metals are considered as soil pollutants due to their acute and chronic toxic effect on plants grown on such soils (Nagajyoti and K.D.T.V.M., 2010).

The concentration of cadmium (Cd) in the main sample stations ranged from 0.0293 – 0.0461mg/Kg at depth, 0-15cm while the concentration of the control samples, ranged from 0.0035 -0.0315mg/Kg. At depth 15-30cm the concentration of cadmium ranged from 0.0221 – 0.0423mg/Kg while the control stations had concentration range of 0.0075 – 0.0212mg/Kg at the same depth. These values are below the permissible limit of 0.8mg/Kg for soils (Osmani et al., 2015). The range of cadmium concentration in plants is 0.0627 – 0.4561mg/Kg for the main sample stations and 0.0210 – 0.3555mg/Kg for the control stations. The concentration for the main sample stations is above the permissible limit of 0.02mg/Kg while the control samples have concentrations about the permissible limit of 0.02mg/Kg for plants. These results are in agreement with the results obtained by (Ogoke et al., 2014) for the soils of some parts of Eastern Niger Delta but contrary to the results obtained by (Nganje et al., 2013) on the soils of Okpoma, southeastern Niger Delta. Cadmium is toxic and high concentration of it is hazardous to animals, which depend on plants for survival, and to humans that depend on plant. Cadmium causes high blood pressure, kidney damage and destruction of red blood cells (Jung and Thornton, 1996).

The range of concentration of vanadium(V) in the soil at depth 0-15cm was 0.5262 - 5.4155mg/Kg for the main sample stations and 0.0453 – 0.2556mg/Kg for the control stations while at depth 15-30cm, the range of concentration of the main sample stations was 0.3484- 5.3650mg/Kg and 0.1345-1.1015mg/Kg for the control stations. These values are within the permissible limit of 20 -500mg/Kg for soil (Bowen, 1979). The range of cadmium concentration in plants was 0.4575 - 0.9732mg/Kg for the main sample stations but 0.4575 – 0.5950mg/Kg for the control stations. The values are within the tolerable limit of 6mg/Kg for land plants (Bowen, 1979; Brady and Weil, 1996). Vanadium is not an essential heavy metal and therefore not needed by plants for healthy growth.

The range of concentration of lead (Pb) at depth 0-15cm in the main stations was 0.2427- 1.0626 mg/Kg while the control stations had the range 0.1055- 0.3685ppm. At depth 15 – 30cm, the concentration range of lead for the main sample stations was 0.2110 – 1.0311mg/Kg, and 0.1135 –

0.3785mg/Kg for the control samples. These are below the World Health Organization (WHO) and Nigeria Environmental Standard Regulation and Enforcement Agency (NESREA) limits of 85mg/Kg and 100mg/Kg respectively (Amaechi and Onwuka, 2021).

Although lead occurs naturally in the environment, anthropogenic activities such as fossil fuels burning, mining, and manufacturing contribute to the release of high concentrations. Human exposure to lead remains a serious health problem (Pirkle et al., 1994; Pirkle et al., 1998). Lead is the most systemic toxicant that affects several organs in the body including the kidneys, liver, central nervous system, hematopoietic system, endocrine system, and reproductive system (ATSDR, 1999).

The range of concentration of arsenic (As) at depth 0-15 was 0.0035- 0.0226mg/Kg for the main sample stations; and 0.0040 – 0.0175mg/Kg for the control stations. At depth 15 -30cm the concentration range for arsenic is 0.0025 – 0.0225mg/Kg for the main station and 0.0035- 0.0112mg/Kg for the control stations. The range of concentration of arsenic in plant was 0.0059– 0.2545mg/Kg for main sample stations and 0.0040 -0.1356mg/Kg in control stations. The concentration of arsenic in the soil and plant are within the acceptable levels of 29mg/Kg and 0.2mg/Kg in soil and plant respectively (Bowen, 1979; Dutch Intervention values for standard soils and water, 2005). Arsenic is not an essential heavy metal and therefore not necessary for plant metabolism and growth.

The concentration of mercury (Hg) in the soil was below the detection limit of the instrument (0.002mg/Kg) but in plant it occurred above the detection limit, 0.0008-0.0540mg/Kg. The very low level of mercury in soil relative to the plant may be as a result of sequestration on plant leaves which is adjudged the most accumulating part of heavy metals (Nganje et al., 2013). It may also be due to the ability of plants to bio-accumulate mercury. A lot of caution has to be exercised in limiting the sources of mercury accumulation. Mercury is toxic and non- essential heavy metal. It is therefore not needed by plants.

The range of concentration of iron (Fe) for the main sample stations at depth 0-15cm was 22.321 – 191.15mg/Kg while the control had a concentration range of 10.3451 – 45.5351mg/kg. At depth 15- 30cm the range of concentration of iron for the main sample stations was 23.2451-192.145mg/Kg while the control stations had concentration range of 15.5756 – 192.1450mg/Kg. these values are within the permissible level of 10,000-100,000 mg/Kg (Brady and Weil, 2008). The flora samples had a concentration range of 6.3545 – 17.7596mg/Kg which is within the permissible limits ascribed to land plants (Bowen, 1979). Iron is an essential heavy metal. It helps in chlorophyll formation and enhances the activation of magnesium. Deficiency of iron in plants leads to yellowing of leaves and poor growth (Brady and Weil, 2008).

Strontium (Sr) had a concentration range of 0.0271 – 0.4019mg/Kg at the depth of 0-15cm while at the depth of 15-30cm the range of concentration was 0.0250 – 0.4014mg/Kg. In plant, the concentration range was 0.8275- 2.8526mg/Kg. Strontium mimics calcium at times as essential to bone formation but not significant always.

3. RESULTS AND DISCUSSION

3.1 Presentation of Results

Table1: Mean concentrations of heavy metals in selected soil samples at depth 0-15cm (mg/kg)

S/N	Sample Code	Cd	V	Fe	Sr	Ni	Pb	Cr	As	Hg
1	UTG SOIL 1	0.0371 ±0.001	0.5488 ±0.002	52.506 ±2.255	0.0271 ± 0.001	0.3362 ± 0.001	0.2427 ± 0.002	0.0743 ± 0.001	0.0143 ± 0.001	<0.002
2	UTG SOIL 2	0.0321 ±0.002	0.6211 ±0.001	30.341 ±1.355	0.0456 ± 0.001	0.3894 ± 0.003	0.3423 ±0.002	0.0635 ±0.001	0.0123 ±0.001	<0.002
3	UTG SOIL 3	0.0293 ±0.001	0.4982 ± 0.001	22.321 ±1.50	0.3051 ±0.002	0.4512 ±0.002	0.2651 ±0.001	0.9871 ±0.002	0.0035 ±0.001	<0.002
4	OP(CONTROL)	0.0056 ±0.00	0.2556 ±0.035	10.345 ±1.100	0.0256 ±0.001	0.2455 ±0.025	0.1055 ±0.036	0.0547 ±0.005	0.0040 ±0.001	<0.002
5	NMB SOIL1	0.0341 ±0.001	1.6065 ±0.003	54.865 ±4.565	0.1618 ±0.002	1.1083 ±0.001	0.4545 ±0.002	0.972 ±0.003	0.0148 ±0.001	<0.002
6	NMB SOIL2	0.0323 ±0.001	3.5296 ±0.850	110.22 ±5.65	0.1768 ±0.001	0.8948 ±0.002	0.6643 ±0.003	1.1305 0.015	0.0116 ±0.001	<0.002
7	NMB SOIL3	0.0349 ±0.001	5.4155 ±0.003	191.15 ±5.655	0.2504 ±0.001	1.0913 ±0.001	1.0626 ±0.003	1.6573 ±0.002	0.0088 ±0.001	<0.002
8	OG(CONTROL)	0.0315 ±0.002	2.9505 ±0.105	45.355 ±4.653	0.1010 ±0.006	0.7535 ±0.085	0.3685 ±0.002	0.8654 ±0.095	0.0095 ±0.001	<0.002
9	QIB SOIL	0.0461 ±0.001	0.5262 ± 0.003	85.903 ±6.150	0.4019 ±0.004	0.3610 ±0.025	0.3901 ±0.040	0.0414 ±0.003	0.0226 ±0.001	<0.002
10	NKK SOIL	0.0426 ±0.002	0.7035 ±0.003	123.18 6±4.35	0.3306 ±0.050	0.4383 ±0.025	0.5593 ±0.045	0.0156 ±0.001	0.0233 ±0.002	<0.002
11	IKIT SOIL	0.0432 ±0.001	0.6702 ±0.003	124.88 ±7.55	0.3611 ±0.045	0.4381 ±0.050	0.5386 ±0.062	0.0134 ±0.002	0.0233 ±0.001	<0.002
12	ND(CONTROL)	0.0035 ±0.001	0.0453 ±0.002	45.535 ±5.745	0.2755 ±0.033	0.3565 ±0.045	0.3455 ±0.035	0.0101 ±0.000	0.0175 ±0.002	<0.002
Sample Mean		**0.031**	**1.45**	**74.72**	**0.205**	**0.572**	**0.445**	**0.490**	**0.013**	

The range of concentration of nickel (Ni) at depth 0-15cm was 0.3362- 1.1083mg/Kg while range of concentration at the depth of 15 -30cm was 0.2656 – 1.0735mg/Kg which are within the permissible limit of 10 - 1000mg/Kg (Brady and Weil, 2008). The range of concentration of nickel in plants was 0.3643 - 0.6532mg/Kg, this is also within the tolerable limit of 3.0mg/Kg (Bowen 1979). Nickel (Ni) is an essential metal for plants and other living organisms and is a component of the enzyme urease, which is essential for its functioning and thus enhances animal health (Nagajyoti and K.D.T.V.M, 2010).

The range of concentration of chromium (Cr) at the depth of 0-15cm was 0.0101 – 1.6573mg/Kg while the depth of 15 -30cm the range of concentration was 0.0125 – 1.5735mg/Kg. The values are within the tolerable limit of 5-1000mg/Kg. The range of concentration of chromium in plants was 0.1105- 6.65 86mg/Kg. Some of the values are above the permissible limit of 0.23 mg/Kg for land plant (Bowen, 1979).

Generally, most of the metals had higher concentration at the soil top (0-15cm) with the exception of iron and chromium which were more at the bottom soil (15-30cm) than at the topsoil. The levels of the metals at the top and bottom of the soils were within

Table2: Mean concentrations of heavy metals in selected soil samples at depth 15-30cm (mg/kg)

S/N	Sample Code	Cd	V	Fe	Sr	Ni	Pb	Cr	As	Hg
1	UTG1 SOIL	0.0272 ±0.001	0.3484 ±0.001	30.504 ± 2.100	0.0250 ± 0.002	0.3211 ± 0.002	0.2110 ± 0.001	0.0443 ± 0.001	0.0123 ± 0.001	<0.002
2	UTG2 SOIL	0.0221 ±0.001	0.4321 ±0.001	28. 265 ± 1.210	0.0256 ± 0.001	0.2682 ± 0.001	0.2434 ±0.002	0.0325 ±0.001	0.0111 ±0.001	<0.002
3	UTG3 SOIL	0.0290 ±0.002	0.3511 ± 0.001	23.2451 ±1.535	0.2995 ±0.001	0.3425 ±0.003	0.2201 ±0.001	0.7531 ±0.003	0.0025 ±0.001	<0.002
4	OP(CONTROL)	0.0155 ±0.001	0.2175 ±0.023	15.5756 ±3.565	0.0357 ±0.015	0.1565 ±0.025	0.1856 ±0.015	0.0355 ±0.002	0.0112 ±0.001	<0.002
5	NMB1 SOIL	0.0245 ± 0.001	1.2650 ±0.002	47.7553 ±2.45	0.1305 ±0.002	0.9850 ±0.001	0.4123 ±0.003	0.8435 ±0.002	0.0126 ±0.001	<0.002
6	NMB2 SOIL	0.0423 ±0.002	3.2856 ±0.345	110.242 ±5.655	0.1356 ±0.001	0.7981 ±0.002	0.5533 ±0.002	0.9556 ± 0.015	0.0126 ±0.001	<0.002
7	NMB3 SOIL	0.0285 ±0.001	5.3650 ±0.004	192.145 ± 5.65	0.2355 ±0.002	1.0735 ±0.015	1.0311 ±0.025	1.5735 ±0.002	0.0068 ±0.001	<0.002
8	OG(CONTROL)	0.0212 ±0.002	1.1015 ±0.012	39.3453 ±4.350	0.1252 ±0.012	0.5655 ±0.035	0.3785 ±0.017	0.6555 ±0.035	0.0057 ±0.00	<0.002
9	QIB SOIL	0.0395 ±0.001	0.5243 ± 0.025	81.804 ±5.250	0.4014 ±0.004	0.3605 ±0.020	0.3603 ±0.035	0.0315 ±0.002	0.0210 ±0.001	<0.002
10	NKK SOIL	0.0415 ±0.002	0.7010 ±0.002	115.186 ±5.35	0.3215 ±0.050	0.3895 ±0.003	0.5755 ±0.055	0.0145 ±0.001	0.0225 ±0.002	<0.002
11	IKIT SOIL	0.0420 ±0.001	0.5450 ±0.025	120.765 ±6.89	0.3405 ±0.003	0.4265 ±0.045	0.5255 ±0.055	0.0125 ±0.002	0.0225 ±0.001	<0.002
12	NU(CONTROL)	0.0075 ±0.001	0.1345 ±0.015	29.1125 ±0.285	0.0854 ±0.004	0.3550 ±0.004	0.1135 ±0.035	0.0345 ±0.002	0.0035 ±0.00	<0.002
Sample Mean		**0.028**	**1.189**	**69.50**	**0.180**	**0.503**	**0.401**	**0.416**	**0.012**	

Table3: **Concentrations of heavy metals in selected flora samples (mg/kg)**

S/N	SAMPLE CODE	Cd	V	Fe	Sr	Ni	Pb	Cr	As	Hg
1	MAIZE UTG 1	0.0286 ±0.001	0.9732 ±0.255	17.7596 ±2.755	0.8275 ±0.001	0.5702 ±0.005	0.2994 ±0.001	0.1986 ±0.001	0.0059 ±0.001	0.0008 ±0.000
2	PLANTAIN UTG 2	0.0371 ±0.005	0.8849 ±0.075	9.5382 ±0.745	2.8526 ±0.453	0.3643 ±0.054	0.1203 ±0.025	0.1645 ±0.013	0.0132 ±0.001	0.0374 ±0.002
3	MAIZE UTG3	0.0443 ±0.006	0.7845 ±0.067	16.8751 ±0.675	0.9135 ±0.068	0.6532 ±0.056	0.1255 ±0.035	0.2153 ±0.023	0.0231 ±0.003	0.0485 ±0.066
4	MAIZE OP (CONTROL)	0.02452 ±0.003	O.5637 ±0.045	10.8956 ±1.255	0.6535 ±0.053	0.2356 ±0.015	0.0968 ±0.006	0.1105 ±0.021	0.0065 ±0.001	0.006 ±0.000
5	GUAVA NMB1	0.0386 ±0.001	0.5360 ±0.012	13.6292 ±1.211	1.1574 ±0.015	0.5166 ±0.115	0.1416 ±0.012	6.6586 ±1.225	0.0203 ±0.001	0.0378 ±0.001
6.	PAWPAW NMB2	0.0267 ±0.015	0.5047 ±0.010	10.1654 ± 2.105	1.0965 ±0.205	0.4241 ±0.125	0.0909 ±0.001	0.6990 ±0.105	0.0096 ±0.001	0.0490 ±110
7	CASSAVA NMB3	0.0315 ±0.110	0.6324 ±0.075	12.1159 ±1.255	0.9491 ±0.120	0.3989 ±0.015	0.1876 ±0.001	2.9474 ±0.355	0.0125 ±0.010	0.0503 ±0.015
8	PAWPAW OG (CONTROL)	0.0210 ±0.003	0.4575 ±0.074	6.3545 ±0.785	0.8564 ±0.056	O.3655 ±0.065	0.1055 ±0.021	0.5635 ±0.0623	0.0085 ±0.001	0.0452 ±0.011
9	GREEN QIB	0.4561 ±0.045	0.8563 ±0.055	18.3456 ±3.250	1.2562 ±0.125	0.6534 ±0.025	0.3524 ±0.043	2.4562 ±0.315	0.2456 ±0.001	0.0456 ±0.001
10	OKRA NKK	0.4123 ±0.035	0.8965 ±0.046	6.8965 ±0.254	1.9856 ±0.201	0.3985 ±0.025	0.1956 ±0.011	1.8561 ±0.035	0.2545 ±0.026	0.0456 ±0.015
11	OKRA IKIT	0.3465 ±0.040	0.6535 ±0.085	12.7545 ±2.055	2.3456 ±0.255	0.4565 ±0.025	0.2565 ±0.001	2.6535 ±0.035	0.2545 ±0.005	0.0540 ±0.001

12	OKRA ND(CONTROL)	0.3555 ±0.056	0.5950 ±0.045	8.4565 ±0.965	1.9856 ±0.856	0.3855 ±0.025	0.09856 ±0.009	1.2565 ±0.298	0.1356 ±0.035	0.0010 ±0.000
Sample Mean		0.149	0.695	11.982	1.407	0.452	0.173	1.648	0.082	0.034

TABLE 4: Values of plant uptake ratio (PUR) at 0-30cm

S/N	SAMPLE CODE	Cd	V	Fe	Sr	Ni	Pb	Cr	As	Hg
1	UTG1 SOIL - MAIZE	0.77	1.77	0.34	30.53	1.69	1.23	2.67	0.41	ND
2	UTG2 SOIL-PLANTAIN	1.16	1.42	0.31	62.56	0.94	0.35	2.59	1.07	ND
3	UTG3 SOIL - MAIZE	1.51	1.57	0.76	2.99	1.55	0.47	0.21	6.60	ND
4	OP(CONTROL) -MAIZE	4.37	2.21	1.05	25.52	0.96	0.92	2.02	1.63	ND
5	NMB1 SOIL-GUAVA	1.13	0.33	0.25	7.15	0.47	0.31	6.85	1.37	ND
6	NMB2 SOIL – PAW PAW	0.83	0.14	0.09	6.20	0.47	0.14	0.62	0.83	ND
7	NMB3 SOIL - CASSAVA	0.90	0.120	0.06	3.79	0.37	0.18	1.78	1.42	ND
8	OG(CONTROL) - PAW PAW	0.67	0.16	0.14	8.48	0.49	0.29	0.65	10.85	ND
9	QIB SOIL – GREEN	9.89	1.63	0.21	3.13	1.81	0.90	59.32	10.7	ND
10	NKK SOIL – OKRA	9.68	1.27	0.05	6.00	0.91	0.35	118.98	10.92	ND
11	IKIT SOIL – OKRA	8.02	0.98	0.10	6.49	1.04	0.48	198.02	10.92	ND
12	NU(CONTROL) OKRA	101.6	13.13	0.19	7.211	1.08	0.29	124.41	7.75	ND
Sample Mean		3.50	2.058	0.296	14.170	0.982	0.493	43.177	5.373	ND

TABLE 5: Values of relative topsoil enrichment factor (RTEF)

S/N	SAMPLE CODE	Cd	V	Fe	Sr	Ni	Pb	Cr	As	Hg
1	UTG1 SOIL	1.36	1.58	1.72	1.08	1.05	1.15	1.68	1.16	ND
2	UTG2 SOIL	1.45	1.44	1.07	1.78	1.45	1.41	1.95	1.11	ND
3	UTG3 SOIL	1.01	1.42	0.96	1.02	1.32	1.21	1.31	1.40	ND
4	OP(CONTROL)	0.36	1.18	0.66	0.84	1.57	0.57	1.54	0.36	ND
5	NMB1 SOIL	0.72	1.27	1.15	1.24	1.13	1.10	1.15	1.17	ND
6	NMB2 SOIL	1.31	1.07	1.00	1.30	1.12	1.20	1.18	0.92	ND
7	NMB3 SOIL	1.22	1.01	1.00	1.07	1.02	1.03	1.05	1.29	ND
8	OG(CONTROL)	1.49	2.68	1.15	0.81	1.33	0.97	1.32	1.67	ND
9	QIB SOIL	1.18	1.00	1.05	1.00	1.00	1.08	1.31	1.08	ND
10	NKK SOIL	1.03	1.00	1.07	1.03	1.13	0.97	1.08	1.04	ND
11	IKIT SOIL	1.03	1.23	1.03	1.06	1.03	1.02	0.99	1.04	ND
12	NU(CONTROL)	0.47	0.34	1.56	3.23	1.00	3.04	0.29	1.04	ND
SAMPLE MEAN		**1.053**	**1.268**	**1.118**	**1.283**	**1.179**	**1.229**	**1.238**	**1.107**	**ND**

acceptable levels established by some regulatory authorities. The same applies to the plants except for chromium. However, chromium plays a significant role in the enhancement of insulin action. A low molecular weight intracellular octapeptidide, known as chromomodulin, binds with the trivalent chromium (Cr) and increases the response of the insulin receptors (Vincent, 2004). This has been seen especially in non-insulin dependent diabetes mellitus patients (Anderson et al., 1997) but also in non-diabetic obese subjects with a family history of type 11 diabetes mellitus (Masayuki et al., 2014) as well as during long term total parental nutrition (TPN).

Iron had the highest concentration both in the soils and plants, but arsenic had the lowest concentration in soil while mercury had the lowest concentration in plant. The order of variation of the metals was almost the same at the top soil and bottom soil; 0-15cm: Fe(74.72mg/Kg), V(1.45 mg/Kg)> Ni(0.572mg/Kg),>Cr(0.490mg/Kg) >Pb(0.445 mg/Kg)> Sr(0.205 mg/Kg)> Cd(0.031 mg/Kg)> As(0.013 mg/Kg) (Tables1& 2). The order of variation of the metal concentration in plants was different from that of the soil; Fe(11.982 mg/Kg)> Cr(1.648 mg/Kg)> Sr(1.407 mg/Kg)> V(0.695 mg/Kg)> Ni(0.0452)> Cd(0.149 mg/Kg)> Pb(0.173 mg/Kg)> As(0.0082 mg/Kg)> Hg(0.034 mg/Kg). The results are in agreement with the work of (Nganje et al., 2013) on the Southeastern Niger Delta but not in agreement with the work of (Ogoke et al., 2014) on the eastern Niger Delta.

3.2.2 Uptake Factor

One of the fundamental ways of determining human exposure to metals is uptake ratio or concentration factor (Smuc et al., 2011). It is the ratio of element or metal concentration in plant or plant tissue and soil, usually expressed as CP/CS where CP is the concentration of the metal in plant and CS is the concentration of the same metal in soil. The uptake of these metals by plants is influenced by several factors such as soil texture, plant species, plant part, age, climatic conditions, and concentration of the metals in soils, soil pH and organic matter content of soils (Smuc et al., 2011). Half of the metals studied were more in the plants than in the soil, having mean uptake values above one as shown on table 4; Cd (3.5), Sr (14.17), Cr (43.17) and As (5.37). The coefficient of correlation between the metal concentrations in the soil and in the plant, 0.99 shows the metal accumulation in plants originated primarily from the same soil. There is therefore a sufficient recycling of these metals between the soil- plant systems. This may be dangerous as Cd, As and perhaps Sr (toxicity not established yet) are very toxic and may affect human beings through the food chain.

3.2.3 Relative topsoil enrichment (RTEF)

The relative topsoil enrichment factor measures the ratio of the metal concentration in the topsoil and the bottom soil (Alloway, 1968). A value range of 1-2 implies no contamination or background value while values above it indicates contamination. The mean RTEF as shown on table 5 for all the metals were below 2 indicating background value or no contamination. This, could preliminarily predict their relative cycling ability or mobility within the top and bottom soil; Sr (1.283)> V(1.268) > Cr(1.238)> Pb(1.229)> Ni(1.179) >Fe(1.118) > As(1.107) > Cd(1.053) all other factors been equal.

4. CONCLUSION

The mean concentrations of both the essential and non- essential heavy metals in the soil and plants studied were within the acceptable limit of the regulatory authorities apart from chromium, an essential metal. The values of the metal uptake factor showed that the metals were more in the plant than in the soil while the values of the relative topsoil enrichment indicated that the metals were more in the topsoil (0-15cm) than in the bottom soil (15-30cm). Both the uptake factor and the relative topsoil enrichment showed active metal geochemical cycling; and there were higher levels of the heavy metals in the soil and plant samples of the main stations than those of control stations. Regular monitoring of the metal levels is essential.

Acknowledgement

The authors thank the Nigerian Tertiary Education Fund (TETFUND) for providing the financial support for the research in the Niger Delta which this publication is part of the results of the Research. We appreciate the Laboratory Technologist at Golden Year Laboratories, Port Harcourt, Mr. Ogehenekevwe who painstakingly did the instrumental analysis of the metals. We equally appreciate our field assistants and field guides who were part of the sampling team.

Reference

Agency for Toxic Substances and Disease Registry (ATSDR) (1999). Public Health Service. Atlanta: U.S. Department of Health and Human Services. Toxicological Profile for Lead.

Ahmad, M.K., Islam, S., Rahman, S., Haque, M.R. & Islam, M.M. (2010). Heavy metals in water sediment and some fishes of Buriganga River, Bangladesh. International Journal of Environmental Research, 4: 321-332.

Alloway, B. J. (1968). Agronomic control over the environmental cycling of elements. Advances Agronomy, 20: 235-274.

Amadi- Akobundu, N.I. and Nwankwoala, H.O., (2013). Evaluation of heavy metals in soils from Enyimba dumpsite in Aba, Southeastern Nigeria using contamination factor and geoaccumulation index. Energy and Environment Research, 3(1): 97-106.

Amaechi, M. and Onwuka, S.U., (2021). Determination of the presence and level of heavy metals in soils of automobile workshops in Awka, Anambra State (2021). European-American Journals, 9(3): 18-32

Anderson, R. N., Cheng, N. and Bryden, N. A. (1997). Elevated intakes of supplemental chromium improve glucose and insulin variables in individuals with type 2 diabetes. Diabetes, 46:1786-1791.

Awomeso, J.A., Taiwo, A.M., Gbadebo, A.M. and Arimoro, A.O., (2010). Waste disposal and pollution management in urban areas: A workable remedy for the environment in developing countries. American Journal Environmental Science, 6(1), 26-32.

Bowen, H. M., (1979). Environmental chemistry of the trace elements. Academic Press, New York, p. 333

Brady, N. C. and Weil, R. B. (1996). The Nature and Properties of Soils.

Macmillian Publishing. Co. Inc. New York. p. 639.

Brady, N.C. and Weil, R.R. (2008). The nature and properties of soils, 4th edition Prentice-Hall, Upper Saddle River, New Jersey, 111-130

Curtis, D. M., (1986). Comparative Tertiary petroleum geology of the Gulf Coast, Niger, and Beaufort-Mackenzie delta areas, Geological Journal, 21(3): 225-255.

Doust, H., (1990). Petroleum geology of the Niger Delta. Geological Society, London, Special Publications, 50 (1): 365-365.

Dutch Intervention Values for standard soils and water. Environmental Ltd. 2005

Evamy, B.D., Haremboure, J., Kamerling, P., Knaap, W.A., Molloy, F.A. and Rowlands, P.H., (1978). Hydrocarbon habitat of tertiary Niger Delta. American. Association. Petroleum Geologist Bulletin, 62: 1–39.

Haack, R. C.P., Sundararaman, J. O., Diedjomahor, H., Xiao, N. J., Gant, E. D.and Kelsch, K. (2000). "Chapter 16: Niger Delta Petroleum Systems, Nigeria, Petroleum Systems of South Atlantic Margins: AAPG Memoir 73, Mello, M. R. and Katz, B. J. eds., pp.213-231: American Association of Petroleum Geologists (AAPG)

Jung, J. C. and Thornton, I. (1996). Heavy metal contamination of soils and plants in the vicinity of a lead–zinc mine, Korea. Applied Geochemistry, 11: 53–59.

Lambert-Aikhionbare, D.O. and Ibe, A.C., (1984). Petroleum source-bed evaluation of the Tertiary Niger Delta: discussion. American. Association of Petroleum Geologist Bulletin, 68: 387–394.

Masayuki, K., Shoko, T., Yukio, I. and Shuto Y., (2014). Safety and efficacy of combination therapy with insulin glargine and oral hypoglycaemic agents including DPP- 4 inhibitors in Japanese T2DM patients. Journal of diabetes mellitus, 4(4): 120-131

Mgbemena, N.M., Amako, N.F. and Okoyeagu, A. (2018). Proximate analysis and bioaccumulation of heavy metals in some fishes in Elelenwo River, Rivers State. Journal Chemical Society of Nigeria, 43(3): 593-600.

Nagajyoti, P. C. and K. D. T. V. M. (2010). Heavy metal occurrence and toxicity for plants: a review. Environ Chem Lett, 8: 199-216.

Nganje, T. N., Adamu, C. I., Agbor, E. E., Besong, E. and Atanga, S. M.B., (2013). Accumulation of essential and non- essential metals in soil-plant system in parts of southeastern Nigeria. Journal of Earth Science Research, 11(2): 60-67.

Ogoke, E.C., Emeziem, D. and OSu-Charles, I., (2014). Geo accumulation index and contamination factor of heavy metals in soils of Aba dumpsites, Abia State, Nigeria. Journal Chemical Society of Nigeria, 39(2): 150-157.

Okafor, P.C., Okon, P.U., Daniel, E.F. Ikeuba, A.I. and Ekpe, U.J., (2013). Adsorption capacity of periwinkle (*Tympanotonus Fuscatus*) shell for lead, copper, cadmium, and arsenic from aqueous solutions. Journal Chemical Society of Nigeria, 38(1):77-84.

Osmani, M., Bani, A. and Belinda, H., (2015). Heavy metal and nickel phyto-extraction in the metallurgical area soils in Elbasan. Albanian Journal of Agricultural Science, 14(4):414- 419 .

Osuji, L. C. and Onojake, C. M., (2004). Trace heavy metals associated with crude oil: A case study of Ebocha-8 oil-spill-polluted site in Niger Delta, Nigeria. Chemistry & Biodiversity, 1(11): 1708-1715.

Pirkle, J.L., Brady, D.J., Gunter, E.W., Kramer, R.A., Paschal, D.C., Flegal, K.M. and Matte, T.D., (1994). The decline in blood lead levels in the United States: The National Health and Nutrition Examination Surveys (NHANES) Journal American Medical Association, 272: 284–291.

Pirkle J.L, Kaufmann, R.B., Brody, D.J., Hickman, T., Gunter, E.W., and Paschal, D.C., (1998). Exposure of the U.S. population to lead: 1991–1994. Environ Health Perspective, 106(11):745–750.

Smuc, N. R., Dolenec, T., Serafimovski, T., Dolenec, M. and Vrhovnik, P., (2011). Heavy metal characteristics in Kocani field plant system (Republic of Macedonia), Environmental Geochemistry and Health, 11: 9439-61.

Ugochukwu, C. N. C. and Ertel, J., (2008). Negative impacts of oil exploration on biodiversity management in the Niger Delta area of Nigeria. Impact Assessment and Project Appraisal, 26(2):139-147.

Vicent, J. B., (2004). Recent advances in the nutritional biochemistry of trivalent chromium. Proceedings Nutritional Society. pp. 6341-47.

Wiener, M.C., (2006). When world colloidal protein science. Wiley Online Library.

Yahaya, M.I., Mohammed, S. and Abdullahi, B.K., (2009). Seasonal variation of heavy metal concentration in abattoir dumpsite soil in Nigeria. Journal Applied Science and Environmental Management, 13(4): 9-13.

Young, E. M. M., (2012). Food and Development, Abingdon, Oxon: Routledge.