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Heavy Metals Assessment of Farmland Soil in Bagega Mining Community, Zamfara State, Northwestern Nigeria.

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ABSTRACT

The present study was conducted to examine the level of heavy metals pollution of farmland soil at Bagega community, Anka Zamfara State as a result of artisanal and illegal mining activities going on in the community. Soil samples were collected from farmland soil at the depth of 15cm, acid digestion was carried out and the solution was subjected to Atomic Absorption Spectrophotometer model Varian AA240FS for the metal analysis. The level of soil contamination were assessed by Geo-accumulation Index (Igeo) and Pollution Load Index (PLI). The Geo-accumulation studies show that the soil was moderately polluted by Pb (1.21 mg/kg), Fe (0.9 mg/kg), Zn (0.91 mg/kg) and Cu (1.46 mg/kg). The Pollution Load Index result shows that farmland soil was polluted, with PLI value of 2.1. Also, the geochemical distribution of the metals in the soil samples was revealed by sequential extraction procedures which show that 90 % of the metal concentrations were found in the residual fractions. This signified high level of heavy metals contamination of the farmland soil is associated with the anthropogenic activities such as the mining activities going on in the community.

Keywords*:* Bagega; Geo-accumulation Index; Pollution Load Index; Residual fractions; Zamfara State

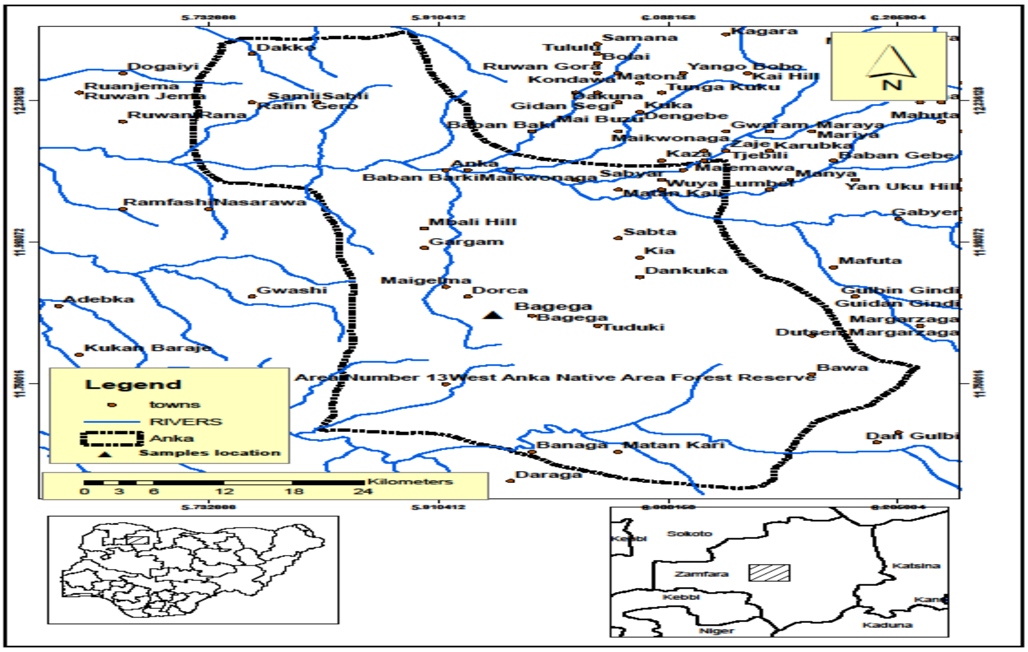
INTRODUCTION

Heavy metals are natural components of the environment; they are present in rocks, soil, plants and animals, bound to organic and inorganic molecules or bound to particles in air (Tan and Wong, 2000). Different definitions have been used to explain heavy metals. Some are based on density or atomic weight while some on chemical properties or toxicity. Recently, heavy metal is used as general term for those metals and metalloid with potential human and environmental toxicity (Samara and Richard, 2009). Mining and milling of metals ore together with industrial activities resulted into a wide distribution of metal contaminants in the soil (Devolder, *et. al*, 2003). Soil heavy metal environmental pose substantial risk to humans and is closely related to bioavailability and assimilation pathways which include the ingestion of plant materials grown through food chain or direct ingestion (Basta and Gradwohl, 1998). Monitoring the contamination of soil by heavy metals is a great concern due to their influence on ground and surface water as well as effect on plants, animals and humans (Sadhana, 2014). Several researchers (Jurgen *et al.*, 2010; Nuhu *et al.*, 2014; Sharhabil *et al.*, 2021) have carried out studies on effect of mining on soil sample close to mining sites in some villages such as Sunke, Abaare, Tunga and Bagega in Anka Local Government Area but not farmland soil. The present study is aimed at assessing the level of soil pollution by heavy metals in farmland of Bagega gold mining community in Anka Local Government Area of Zamfara State.

MATERIALS AND METHODS

Study Area

The study was carried out at Bagega community in Anka area of Zamfara State. Bagega is the largest vllage in Anka Local Government Area of Zamfara State. Geographically it is located on the coordinates of 11° 51' 47" N, 6° 0' 15" E as shown in Figure 1 and 2 with a population of about 3000 people who are mainly Hausa by tribe. The major occupation is farming and around 2009 artisnal mining becomes important socioeconomic activities of the people as a result of increases in the world gold prices (Alaba, 2018).



Source: Dept. of Geog. BUK (2020)

Figure 1: Map of Zamfara State showing the location of study Area in Anka LGA.

Figure 2: Gold Mining Site,Bagege village, Anka, Zamfara State.

Table 1: Identification of samples and Coding for soil samples

S/No	Samples	Code
1	Anka Soil Sample Zamfara	ASZ
2	Zamfara Background Soil Sample	ZBS

Collection of Soil Samples

Soil samples were collected from a depth of 0 - 15 cm after the removal of the top soil using stainless steel sharp egged spatula. The soil samples were transferred into a clean well labeled polythene bag container. Each soil sample was collected from five sampling spot at 30cm equal distance from each other, and then mixed thoroughly to obtain a representative sample (Uduma, 2014**).** The samples were then transferred to the Chemistry department laboratory Bayero University Kano for further treatment.

Pretreatment of soil samples

The Wet soil samples were collected in August, 2019 and were air dried under the room temperature in the laboratory. The samples were mixed frequently to expose fresh surface to dryness, then ground and sieved through 2 mm mesh sieve and stored in a clean and labeled plastic container for further analysis.

Digestion of soil samples

0.25 g of the dried soil samples were weighed into platinum crucibles. The digestions were carried out by mixtures of 6 cm^3 of concentrated HNO_3, 4 cm^3 of concentrated HF and 2 cm^3 of 50 % H_2O_2 solution. The digestion was carried out on a sand bath at a temperature of range 200 – 230 °C and the acid mixtures were evaporated to dryness. 20 cm^3 of 0.25M HNO_3 was added to dissolved the residue and warm for 10 minutes, filtered and transferred to 50 cm^3 plastic container and make up to 50 cm^3 volume with 0.25 M HNO_3 Solution. The digested samples were subjected to Atomic Absorption Spectrophotometer model Varian AA240FS for total metals (Pb , Fe, Zn, Cu and Cd) determinations (Cheng-Yung *et al.*, 2005).

Sequential extraction procedures

A seven step sequential extraction procedures was adopted viz: water soluble fraction, exchangeable fraction, carbonate fraction, amorphous metal oxide, crystalline metal oxide, bound to organic matter fraction and residual fraction (Cheng-Yung *et al.*, 2005).

Contamination factor (Cf)

Contamination factor is used to trace contamination sources and estimate the levels of soil /sediment contamination (Moore *et al.*, 2009)

Contamination factor (Cf) is expressed thus

$$Cf = \frac{C_{metal}}{C_{background}} \quad \text{Equation 1.}$$

Where C_{metal} is the metal concentration

$C_{background}$ is the background concentration.

Contamination factor is categorized into four classes:

Cf < 1 Low contamination**;**

$1 \leq$ Cf < 3 Moderate contamination

$3 \leq Cf < 6$ Considerable contamination

$Cf \geq 6$ Very high Contamination

Pollution Load Index (PLI)

The pollution load index is obtained as the n-root from the n-CFs (n- root is number of metals) that is obtained for all the metals. The PLI is expressed according to Adel *et al.* (2011).

PLI=$n\sqrt{}(CF1\ x\ CF2\ x\ CF3\ x\ CFn$

Equation 2

Where:

CF = contamination factors, n is the number of metals.

PLI values > 1 indicates Polluted.

PLI values of < 1 indicate no Pollution.

Geo-accumulation Index (Igeo)

Geo- accumulation Index (Igeo) is used to estimate the degree of anthropogenic pollution in the soil. It is the enrichment on geological substrates and is calculated using equation (3).

$$Igeo = \log \frac{C_n}{1.5Bn}$$

Equation 3 (Forstner *et al.,* 1993)

Where C_n is the concentration of the examined metal in the soil.
Bn is the geochemical background concentration in soil,
1.5 is the correction factor for variation in background values due to lithogenic effect.
Igeo consist of seven classes which are:
Igeo ≤ 0 Practically unpolluted;
1 < Igeo ≤ 1 Unpolluted to Moderately Polluted
2 < Igeo ≤ 3 Moderately Polluted;
3 < Igeo ≤ 4 Strongly Polluted
4 < Igeo ≤ 5Strongly to very strongly Polluted;
5 <I geo ≤ 6 Very strongly Polluted

RESULTS AND DISCUSSION

Table 1 and 2 below show the mean concentration of metals and distribution pattern of the lead in the soil respectively.

Table 1: Heavy metal concentration in the ASZ and ZBS soil samples.(mg/kg)

Samples	Pb	Fe	Cd	Zn	Cu
ASZ	295.8±0.28	36924±0.07	ND	84.80±0.007	466.2±0.14
ZBS	73.4±0.14	72924±0.64	ND	89.6±0.141	45.0±0.01
FAO/WHO (2022)	100	50000	3.0	300	100

ND = Not Detected, Mean ± SD

Table 2: Lead concentrations in the fractions (mg/kg)

Soil fractions	ASZ	ZBS
Amorphous	0.75±0.003	0.791±0.001
Crystalline	32.281±0.0014	32.815±0.007
Water soluble	0.073±0.003	0.095±0.001
Exchangeable	0.13±0.014	0.1405±0.002
Organic	24.11±0.014	8.27±0.021
Carbonate	11.087±0.002	0.376±0.003
Residual	6348.7±0.42	11103.5±0.98

Mean ± SD

The mean lead concentration in the soil samples ranges from 73.4 – 295.8 mg/kg. The sample ZBS had the least concentration while sample ASZ had the highest concentration. Sample ASZ is obtained from farmland area which might be polluted as a result of activities of artisanal miners while Sample ZBS is obtained from mining free environment, hence the low lead concentration. The distribution of lead in the fractions follows the trend, residual > metal oxide > organic > carbonate > exchangeable > water soluble fraction in all the samples. The Chemical fractions are presented in Table 2.

Water soluble and exchangeable fractions represent the most mobile and readily available metals (Zakir *et al.,* 2007). The result of exchangeable fractions was very low < 1 % of the total fractions concentration in the present study (Table 1). The exchangeable metal ions are those metal that are released readily into the environment, which are most available for plant uptake and organism and could be easily released by any alteration of ionic strength of the soil solution medium (Filguerias *et al.,* 2002). Among the principal factors that affect the behaviour of metals in the soils are amount of clays, associated oxides, organic matter and total metal concentration. This might explain low level of lead in the soluble and exchangeable fraction in this study moreover because the lead concentration in metal oxides (crystaline and amorphous oxide) was low, 1.03 %. The availability of metals in this fraction depends in adsorption of the metals with the Fe-Mn mineral surface which depend on the soil redox state. Low percentage of lead in this fraction indicates a less reductive state in the samples. Metal associated with oxide minerals are likely to be released under reducing condition (Zakir *et al.,* 2007).

Likewise, the concentration of lead in organic and carbonate fractions was 0.38 % and 0.17 % of total lead concentration in the fraction as shown in Table 2. The concentrations range from 8.27 -24.11mk/kg and 0.376 - 11.08 mg/kg respectively. Organic matter has high affinity for metal, forming stable complexes especially with divalent ion (Filguerias *et al.,* 2002). Metallic pollutant associate with organic fraction always remained in the soil for long period but after sometimes it may be demobilised by decomposition process (Kennedy *et al.,* 1997). Also, carbonate could be an alternative adsorbent for many metals when the metal oxides are less abundant (Stone and Droppo, 1996). The metal bound to carbonate is sensitive to pH and is mobilizable when the pH value is low. Lead concentrations in residual fractions ranges from 6348.7 to 11103.5 mg/kg. The residual fractions represent metal associated with silicate clay minerals (Halavay *et al.,* 2004).The relatively high percentage of the residual fractions in the soil samples indicate lithogenic origin of the metal contaminants. Residual fractions is a major carrier of metal in environmental system and the percentage of this fractions indicate the degree of non-availability of the metal to biota except over long period of time (Ma and Rao, 1997).

The result for contamination factor is presented in Table 7. The result shows that the soil is considerably contaminated by lead with Cf of 4.03. The pollution load index also revealed that the soil is polluted with PLI of 2.1 and geo accumulation index of 1.21 which signifies a moderately lead polluted soil.

Table 3: Iron concentrations in the soil fractions (mg/kg)

Soil fractions	ASZ	ZBS
Amorphous	53.71±0.00	102.96±0.04
Crystalline	40.865±0.021	33.172±0.003
Water soluble	ND	0.729±0.001
Exchangeable	0.153±0.003	0.079±0.00
Organic	168.40±0.65	126.75±0.064
Carbonate	0.172±0.000	0.0345±0.001
Residual	30080.5±0.71	17272.5±3.55

ND = below detection limit, Mean ± SD

Iron

The mean iron concentration in the soil samples ranges from 36924 – 72924 mg/kg. Samples ZBS had the highest concentration while sample ASZ had the least concentration of iron in the samples. The sequential extraction studies revealed the distribution pattern of iron in the fractions. The trends follow thus, residual > organic > metal oxide > carbonate > exchangeable > water soluble fraction in all the samples. The concentration of Fe ranges from not detected to 0.729 mg/kg (ZBS) in water soluble fraction and from 0.079 to 0.153 mg/kg in exchangeable fraction. The low proportion of iron in this fraction implies less availability of iron released into the environment.

Iron concentration in carbonate and organic fractions is presented in Table 3. The percentage of iron in the fractions is 0.065 % and 0.184 % respectively. The result agreed with Tianhung *et al.* (1998) which also reported a low iron content in both carbonate and organic fraction respectively. The concentrations of iron in crystalline and amorphous metal oxide were presented in Table 3. The percentage of iron in each fraction was 0.37 % for crystalline metal oxide and 0.009 % for amorphous metal oxide. The concentration of iron in this fraction is higher than concentrations of iron in other fractions except in residual fraction with about 99.36 % and this shows that the non-availability of the metal for plant up take and its association with primary minerals which can only be released to the environment over long period of time.

The result of iron soil contamination factor is presented in Table 7. The result indicated a low contamination of soil in Fe, with the Cf value of 0.51 while the geo accumulation index revealed a moderately polluted soil with Igeo value of 0.91.

Table 4: Zinc concentrations in the soil fractions mg/kg

Soil fractions	ASZ	ZBS
Amorphous	21.96±0.03	1.792±0.005
Crystalline	0.192±0.003	0.261±0.0014
Water soluble	ND	ND
Exchangeable	0.098±0.002	0.114±0.0003
Organic	0.662±0.002	1.326±0.002
Carbonate	0.711±0.0014	0.759±0.0014
Residual	30.50±0.141	56.50±0.14

ND = below detection limit, Mean ± SD

Zinc

The mean concentration of zinc in the samples ranges from 84.80 – 89.6 mg/kg. Sample ZBS had the highest concentration as compared to the sample ASZ. The distribution pattern of zinc in the soil fraction follows this trend, residual > metal oxide > organic carbonate> exchangeable > water soluble fraction in all the samples. The concentration of zinc in residual fraction was found to be highest about 75.74 % of total zinc in the soil fractions. Higher proportion of residual zinc indicates non- availability of the metal for plant up-take. This could be traced to lithogenic origin of the metal in the farmland soil of the studied areas. Shaheen *et al.* (2013) reported high concentration of zinc in the residual fraction in their study of Egytian soil. The result of zinc soil contamination factor is presented in Table 7. The result indicated a low contamination of soil by Zn, with the Cf value of 0.95 while the geo accumulation index revealed a moderately polluted soil with Igeo value of 0.91.

Table 5: Copper concentrations in the soil fractions (mg/kg)

Soil fractions	ASZ	ZBS
Amorphous	ND	ND
Crystalline	0.624±0.003	ND
Water soluble	ND	ND
Exchangeable	ND	ND
Organic	0.264±0.002	ND
Carbonate	0.051±0.0014	ND
Residual	67.45±0.071	ND

ND = below detection limit, Mean ± SD

Copper

The mean concentration of copper in the soil samples were presented in Table I. The concentrations of copper were found to be 466.2 mg/kg in sample ASZ and 45.0 mg/kg in sample ZBS respectively. The sequential extraction studied revealed that copper were below detection limits most of the fractions as shown in Table 5. The low concentration of copper in exchangeable fraction and water soluble fraction might be attributed to association of copper with primary minerals. Copper form strong complexes with ligands (Bika, 1994). In the absence of reactive soil components especially iron oxides, copper is complexed with organic matter like the total copper concentration in most soil samples are generally low which means copper is expected to be bioavailable. The result of contamination factor shows that the soil is highly contaminated with copper with Cf of 10.36 while the geo accumulation index (Igeo) shows that soil is moderately polluted with Igeo of 1.46.

Table 6: Cadmium concentrations in the soil fractions (mg/kg)

Soil fractions	ASZ	ZBS
Amorphous	ND	ND
Crystalline	ND	ND
Water soluble	ND	ND
Exchangeable	ND	ND
Organic	ND	ND
Carbonate	ND	0.0055±0.001
Residual	ND	ND

ND = below detection limit

Cadmium

The mean concentrations of cadmium in the studied areas were below the detection limit in all the samples. The result of chemical fractionation of the metal in the Table 6 revealed that cadmium was only determined in one fraction. The concentration was found to be 0.0055 mg/kg in carbonate fraction in samples ZBS. The low concentration in non-residual and residual fractions is an indication of non-availability of the metal in the environment or the biota and poses no threat. Also, the result of Contamination factor shows that the soil is uncontaminated by cadmium with Cf of 0.0 mg/kg while the result of geo accumulation index for cadmium below detection limit which shows that the soil unpolluted by cadmium.

Table 7: Contamination factor (Cf) mg/kg in the different sites

Samples	Pb	Fe	Cd	Zn	Cu
ASZ	4.03	0.51	0.00	0.95	10.36

ND = below detection limit, Mean ± SD

Table 8: Pollution Load Index (PLI) mg/kg

Samples	PLI
ASZ	2.1

Table 9: Geo-accumulation Index (Igeo) in ASZ sample mg/kg

Soil samples	Pb	Fe	Cd	Zn	Cu
ASZ	1.21	0.91	ND	0.91	1.46

ND = below detection limits

CONCLUSION

The results of the metals concentration in the soil shows the level of pollution ranges from low to moderate contamination and low to moderate pollution load index. Also, the behaviour of metal in soil using sequential extraction method revealed that metals were not bioavailable about 90% of the studied metals were associated with residual fractions which implies most of these metals naturally are not available. The pollution of the soil in the studied area is as result of anthropogenic activities going on in the environment such as mining activities.

REFERENCE

Alaba O. C. (2018): Evaluation of Occupational Therapy Practices for Artisanal Gold Mining in Bagega Community, Zamfara State, Nigeria. *Journal of Human, Environment and Health Promotion,* 3(2): 54-60.

Adel, M. R., Yaareub, F.A, Abd-Al-Hussain, N.A and Mustafa M, (2011): Using Pollution Load Index (PLI) and Geo Accumulation Index (I-Geo) For the Assessment of Heavy Metals. Pollution in Tigris River Sediment in Baghdad Region *Journal of Al-Nahrian University,* 14(4): 108 – 114.

Bibak, A.(1994): Cobalt, Copper and manganese Adsorption by Aluminum and Iron Oxides and Humic Acid. *Commun. Soil Sci Plant Anal.* 25: 3229-3239.

Basta, N. T, and Gradwohl, R. (1998). Remediation of Heavy Metal Contaminated Soil using Rock Phosphate, *Better Crops*. 82: 29–31.

Baizeme, D.and Sterckeman, T (2001): Natural Geochemical Background Content in the Evaluation of the Contamination of Soil by Trace Elements. *Sci.Total Environ* 2(64):127-139.

Cheng – Yuan, C, Hung – lung, C, Zhao – Ji, S, Chufang, W. (2005). A Sequential Extraction Method Measures the Toxic Metal Content in Fly Ash from a Municipal Solid Waste Incinerator. *J. of the Chin. Chem. Soc*. 52: 921 – 926.

DeVolder, P. S., Brown, S. L., Hesterberg D. and Pandya K., (2003).Metal Bioavailability and Speciation in a Wetland Tailings Repository Amended with Biosolids Compost, Wood Ash and Sulfate. *Journal of Environmental Quality,* 32(3): 851–864.

Fiuguerias, A. V, Lavilla, L and Bendicho, C.(2002): Chemical sequential extraction for Metals partioning in Environmental Solid Samples. *Journal of Environmental Monitoring,* 4:823-857. FAO/WHO.(2002):Codex Alimentarius. General Standard for Contaminants and Toxins in Food and Feed. Shedule 1 Maximum and Guideline Levels for Contaminants and Toxins in Food. Reference CX/FAC 02/16. Joint FAO/WHO Food Standards Programme, Codex Committee, Rotterdam, The Netherlands.

Forstner, U., Ahif, W. and Calmono, W.(1993): Sediment Objectives and Criteria Development in Germany. *Water Science and Technology 28:307-316.*

Halavaya, J., Prohaska, T., Weisz, M., Wenzel, W.W and Stingeder, G.J.(2004):Determination of Trace Elements Bound to Soil and Sediment Fractions.(IUPAC Technical Report). *Pure Appl.Chem.* 76: 415-442.

Jurgen, B. Matthew, C. Gert-Jan, K. Edith, P and Ramon R. (2010): Lead pollution and poisoning crisis environmental emergency response mission Zamfara State, Nigeria. *Join UNEP/OCHA Environment Unit* Palais des Nations.

Kennedy, H.V., Sanchez, A.L., Oughton, D.H. and Rowland, A. P (1997): Use of Single and Sequential Chemical Extractants to Assess Radionuclide and Heavy Metal Availability from Soils for Root Uptake. *Analyst*. 122:89R-100R.

Moore. F, Forghani. G and Qishlaqi. A (2009): Assessment Of Heavy Metal Contamination in Water And Surface Sediment If The Maharlu Saline Lake, SW Iran, *Internationa Journal of Science And Technology, Transaction A*, 33(1): 44-54.

Ma, L. Q and Rao, G. N. (1997): Chemical Fractionation of Cd, Cu, Ni and Zn in Contaminated Soils. *Journal of Environmental Quality,* 26: 256-264.

Nuhu, A. A, Sallau, M. S and Majiya, M.H (2014): The Environmental Impact of Artisanal Gold Mining on Bagega Village of Zamfara State, Nigeria. *Research Journal of Pharmaceutical, Biological and Chemical Sciences,* 5(6):306.

Okoro, H. K., Fatoki, O. S., Adekola, F. N., Ximba, R. J. and Snyman, R. G. (2012): A review of Sequential Extraction Procedeure for Heavy Metals Speciation in Soil and Sediments, *Open Access Scientific Report* 1:181, Pages 6-9.

Samara, S. and Richard, H.S. (2009): Focus: Toxicity, Heavy Metals: Differential Diagnoses and Workup. Nov. 5, 5-10.

Shaheen, S. M., Rinklibe, J. and Tsadilas, C. (2013): Fractionation of Cd, Cu, Ni, Pb and Zn in Flood Plain Soils from Egypt, Germany and Greece. *E3S Web of Conference* 1:33003.

Sharhabil, M.Y, Fatima, A. and Nafiu, A.(2021): Ecological risk assessment of heavy metal-contaminated soils of selected villages in Zamfara State, Nigeria. *Springer Nature Journal of Applied Sciences*, 3:168.

Stone, M and Droppo, I.G. (1996): Distribution of Lead, Copper and Zinc in Size –fractionated River Bed Sediment in Two Agricutural Catchments of Southern Ontario,Canada. *Environmental Pollution,* 93(3): 353-362.

Tam, N.F.Y. and Wong, Y.S. (2000): Spatial Variation of heavy metals in surface Sediments of Hong Kong Mangroove Swamps. *Journal of Enviromental Pollution,* 110(2): 195-205.

Tianhong, Z., Xiaoquan, S and Fuliang, Li. (1998): Comparison of Two Sequential Extractions Procedures for Speciation Analysis of metals in Soil and Plants Availability. *Communication in Soil Science and Plant Analysis,* 29(9):1023-1034.

Vinod, J. Sapana, G. Rakesh, S. D., Natalija, M., Stanislaw, F. B. and Neda, D. (2013): Determination of Total Heavy Metal by Sequential Extraction from Soil International *Journal of Research in Environmental Science and Technology,* 3(1): 35-38.

Uduma, U.A (2014): Assessment of Metal Levels and Characteristics Farmland and Soils in the Vicinity of the Selected Mining and Dumping Sites in Nigeria. Ph.D Thesis, Chemistry Department, Bayero University, Kano-Nigeria. Pages17-19.

Zakir, H. M, Shikazone, N. and Otomm, K. (2007): Geochemical Distribution of Trace Metals and Assessment of Anthropogenic Pollution in Sediments of Old Nakagawa River, Tokyo, Japan. *America Journal Environmental Science,* 4(6): 654-655.