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Research Article

THE TRANSFER FACTOR OF METALS IN SOIL-PLANT SYSTEM AROUND AN ABANDONED MINE IN ABAKALIKI, EBONYI STATE NIGERIA

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Abstract

This research assesses the concentration levels of heavy metals in parts of Abakaliki as a result of the lead-zinc mining in the area and its possible effects on human life. Heavy metals in soil and plant samples were analysed using Atomic Absorption Spectrometer (AAS). Physicochemical parameters were determined show that pH is generally low (3.65) resulting from the dissolution of the sulphide Ore. The heavy metal mean trend indicates that Fe > Zn >Pb> Cr >Cu > Ni > AS > Cd in the soil samples. Fe, Zn, Cu, Pb and Cr were observed to be high. The variations for the heavy metals suggest that mining operation is responsible for the distribution and redistribution of chemical elements. The values of contamination factor for the soil indicate moderate contamination for Cd, As and Ni while Fe, Zn, Pb, Cu and Cr show very high contamination. The result of enrichment factor (EF) using Fe concentration as normalizing value show that Ni, Cd, Cr, As, and Cu have depletion to mineral enrichment while Pb and Zn show moderate enrichment. The result of the Correlation analysis and principal component analysis (R- Mode and Q-mode) applied to the data analysis show that Zn, Pb, Cd, Cu, and Cr heavy metals originated from similar sources but may have been influenced by mining operation while Ni and As are attributed to a geogenic source. Proper sewage disposal practice and soil remediation are recommended.

Keywords: Metals, Soil, Plant, Abandon mine.

INTRODUCTION

The world's mining sector has played a very valuable role in the civilization of mankind as we explore nature's finest resources and harness them for our own good living. It has also contributed to the individual development of countries all over the world as the excavated or mined resources are chipped for international trade purpose (Oomen *et al.,* 2002). In as much as the mining sector is doing a great work, there are also lots of environmental problems caused by this processes worldwide and one of the major problem is environmental contamination by heavy metals. Metal contamination that occurs as a result of mining characterized by elevated toxic metal concentrations and acid rock and mine drainage, continue several years after the cessation of mining activities. Heavy metal effluents from the weathering of the mineral deposits and mine dumps affect both the surface and underground water quality and soil. These levels of contamination in the area lead to low agricultural production, and adversely affect the ecosystem if present at anomalously high level. Dissolved metals can be highly toxic, and become more readily absorbed by plants, animals and fish. Metals can also be bio-accumulated and biomagnified in the food chain. The search for potable and domestic water in Ebonyi State, Nigeria has made many rural dwellers to use any water at their disposal including water collected from mining sites (current mining sites and abandoned mining sites). Though human activities have substantially altered the natural environment, leading to potentially elevated concentrations of contaminants, mining has been described as a major contributor (Jenny and Carlo, 2007).

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Specifically, opencast mining activities have a serious environmental impact on soils and water streams, having generated millions of tons of sulfide-rich tailings (Rodrı´guez *et al.,* 2009). Moreover, acidic drainage resulting from the oxidation of sulphides from metalliferous mine spoils leads to the leaching of large quantities of cations including lead ions (Pb^{2+}) (Bhattacharya *et al.,* 2006). Thus, heavy metal (Pb) contaminations are very important human health and environmental concerns where open-pit mining has been carried out and abandoned. Unregulated open-pit mining commenced in Ebonyi State, Nigeria in 1952 (Chrysanthus, 1995). Soils constitute part of vital environmental, ecological and agricultural resource that has to be protected. The determination of elemental status of cultivated lands is necessary to identify yield limiting deficiencies of essential micronutrients and polluted soil as earlier reported by (Alloway, 1990; Osayande, 2018). This is especially important in Enyigba, Ameri and Ameka because the inhabitants are essentially farmers, and large quantities of yams, rice and okra are produced both for local consumption and also for food supplies to other parts of the world. Mining has also become important because of the existence of Pb-Zn lodes in the area. The study focuses on the heavy metals Pb, Zn, Cu, Cd, Ni, Cr and As. The potential for these heavy metals to constitute pollutants in the area is high. Availability of these metals and the presence of factors capable of mobilizing, distributing and storing them in pedologic system are critical. These metals are thus components of the existing rocks in the study area. Some may have been absorbed from the ancient depositional environments (Obiora and Umeji, 1995). Thus; Ni/Zn, Cu/Cd, Cd/Zn and Cu/Zn present a more hazardous effect than the individual metals (Down and Stocks, 1977). The Pb – Zn and pH concentrations of Enyigba top and sub-soils in Abakaliki and concluded that the soil recorded a pH mean value of 6.98 ± 0.02, and that the lead is relatively unavailable to plants when the soil pH is above 6.5, while availability of zinc decreases with increasing soil pH due to increased adsorptive capacity (Oti-Wilberforce *et al.,* 2012). The aim of this study is to use statistical tools and ecological factors to evaluate heavy metals in soil and plants from Pb-Zn mining areas and as a result of translocation processes.

Fig.1. Location Map of Enyigba, Ameri and Ameka at Abakaliki, Ebonyi State (Osayande and Opoke, 2018)

***Description of the Study Area*: ** The study area falls within Pb-Zn Ore mine area of Enyigba, Ameri and Ameka in Abakaliki district, Ebonyi State, Nigeria. It lies between latitudes 6^o8^l-6^o24^l N and longitude 8^o4^l-8^o16^l E. Enyigba, Ameri, Ameka and its surrounding villages is about 14km South East of Abakaliki town. The area is accessible through Ndufu-Alike Ikwo/Federal University Ndufu-Alike Ikwo road. The Enyigba, Ameka and Ameri region is marked by undulating range of shale outcrops, which serve as the host for Pb - Zn mineral deposits (Figure 1). The area forms part of the "Abakaliki antichrionium" and generally underlain by the Abakaliki shales of the Asu River Group. The Abakaliki shale of lower Cretaceous age is exposed in the area. The sedimentary rocks are predominantly black calcareous (calcite-cemented) shale with occasional intercalation of siltstone. The Asu River Group which consists of alternating sequence of shale, mudstone and siltstone with some occurrence of sandstone and limestone lenses in some places and attains an estimated thickness of 1500 meters (Farrington, 1952; Kogbe, 1979) described the sediments as consisting of rather poorly-bedded sandy limestone lenses. Extensive weathering and ferrogenization have generally converted the black shales to a bleached pale grey colour with mottles of red, yellow, pink and blue (Ukpong and Olade, 1979). The rocks are extensively fractured folded and faulted. The lead-zinc Ore is found in the Albian carbonaceous shale of the Asu River Group. The mineralization is structurally controlled and localized in fissures, fault zones and gently dipping veins. The veins are steeply dipping and have been proven to over 150m depth. They vary in width from less than a meter to 20m and in length from 30m to 120m. The dominant Ores in the area are observed from the fissures which contain lodes of sphalerite (ZnS), and /or galena (PbS) in association with smaller quantities of copper (Onyeobi and Imeokparia, 2011). The deposits have been mined on and off for several decades. In the Enyigba, Ameri and Ameka areas near Abakaliki, there is incontrovertible evidence of post-mineralization deformation that the lodes were developed at the end of Santonian folding as earlier reported by (Wright, 1968; Adaikpoh *et al.,* 2005). Pb – Zn Ore mine area of Abakaliki district have been implicated in various disease conditions as discussed by (Adaikpoh *et al.,* 2005; Onyeobi and Imeokparia, 2011). As, Cd, Co,Cu, Fe, Mn, Ni, Pb, Zn) as well as the pH of soils in the active areas of Enyigba Pb – Zn Mine were determined , and results show that total mean concentrations of the heavy metals decreased with depth in the order of Fe >Pb> Zn > Cu > Cd > Co > Ni > As.

MATERIALS AND METHODS

Samples Collection: A total of six (6) soil samples and three(3)plants samples were collected from Pb-Zn mine of Enyigba, Ameri and Ameka area of which two (2) samples were taken from areas (3 kilometers) away from the Pb-Zn mines as background values. Coordinate and elevation readings were taken with the aid of Global Positioning System (GPS) at the various sample collection points.

***Soil and plant samples Digestion and Analysis*:** The soil and plant samples were air – dried and soil clods and crumbs were removed. The dried soil samples was passed through a 2mm sieve to remove coarse particles; the soil and plant samples were then sub-sampled and ground to fine powder in a mortar in preparation for chemical analysis . A sample of 1.250g of air –dried ground soil and plants was digested in aqua regia, a mixture of 25% of HNO3 and 75% of HCl (Fisher Scientific, UK). The resulting solution were analyzed for total Fe, As, Cu, Pb, Cd, Ni, Cr and Zn using flame Atomic Absorption Spectrophotometer (AAS). The extraction and analytical efficiency of the AAS was validated using a standard reference material. pH was determined in a soil suspension of 10g in 25ml of deionised water using a pH-meter (Aqualytica Model pH 17). Other physico – chemical parameters were determined by titrimetric methods.

RESULTS AND DISCUSSION

The physico-chemical properties of the soil samples as shown in Table 1 below. The pH varies between 3.65 and 6.98 with the mean value of 6.78. Calcium and magnesium values range from 92.99-772.9 mg/kg and 1.722-20.92mg/kg with their mean values of 446.82mg/kg and 11.47mg/kg respectively. Sodium and potassium values ranges from 2.598 mg/k-93.306 and 4.746-9.522 mg/k with the mean value of 43.31mg/k and 7.62mg/k respectively. Electrical conductivity varies from 292-342 *us/cm* with a mean of 304 *us/cm*. Nitrogen and Total Organic Carbon 0.02-0.123% and 0.029-0.245 % with a mean values 0.04% and 0.098 % respectively. Heavy metal varies in soil ranges from Pb(16.638-286.98 mg/kg) with the mean value of 68.043 mg/kg; Zn(2144-40.460 mg/kg) with the mean value of 32.17 mg/kg; Cd(0.001 -5.400mg/kg) with the mean value of 1.796 mg/kg; Cu(0.01-0.438 mg/kg) with the mean value of 0.178 mg/kg; and Cr(20.694-86.484 mg/kg) with the mean value of 56.66 mg/kg (Table1). The above chart (Figure 2) gotten from our result (Table 1) shows that there is a very high level of Lead (Pb) concentration in location six (6) and also, a high level of Chromium (Cr) at location three (3). The zinc concentration seem to be slightly equal in location five (5), location six (6) and Location (4).

Table 1. Level of Physico-chemical parameters in soil samples from various locations

Sample	pH	% Total Organic Carbon	% Nitrogen	Conductivity (us/cm)	Nitrates mg/kg	Calcium (Ca) ppm	Sodium (Na) ppm	Potassium (K) ppm	Magnessium (Mg) ppm
L1	6.93	0.195	0.014	292	0.060	222.404	13.875	9.522	14.013
L2	6.67	0.245	0.123	316	0.161	772.951	73.698	4.746	20.923
L3	6.84	0.029	0.0015	278	0.007	708.969	93.306	6.908	9.468
L4	6.72	0.034	0.0017	342	0.008	713.704	34.458	5.944	4.296
L5	6.91	0.043	0.002	286	0.012	169.883	41.904	9.438	1.722
L6	6.59	0.039	0.002	310	0.011	92.987	2.598	9.166	18.366
Total	40.7	0.585	0.242	1824	0.259	2680.898	259.839	45.724	68.788
Mean	6.78	0.098	0.040	304	0.043	446.82	43.31	7.62	11.47
Max	6.93	0.245	0.123	342	0.161	772.951	93.306	9.522	20.923

Table 2. The heavy metal concentration in soil

Sample	Chromium (Cr) ppm	Zinc (Zn) ppm	Cadmium (Cd) ppm	Lead (Pb) ppm	Copper (Cu) ppm
L1	13.668	21.144	<0.001	16.638	<0.001
L2	20.694	25.953	5.400	24.582	0.288
L3	86.484	28.806	1.188	38.635	<0.001
L4	82.161	38.54	1.111	21.963	0.438
L5	58.255	38.091	1.114	20.342	<0.001
L6	78.713	40.460	1.962	286.098	0.342
Total	339.975	192.994	10.775	408.258	1.068
Mean	56.66	32.17	1.796	68.043	0.178
Max	86.484	40.460	5.400	286.098	0.438
Min	20.694	21.144	0	16.638	0

**Note: <0.001 = No Detectable Limit (NDL)

Table 3. Level of concentration of Heavy Metals in plant tissues

Sample Identity	Arsenic (As) ppm	Zinc (Zn) ppm	Cadmium (Cd) ppm	Lead (Pb) ppm	Nickel (Ni) ppm
Cassava Leaf	0.0161	0.3684	0.0269	1.167	0.0020
Pumpkin Leaf	0.0019	1.1456	0.0156	1.0348	<0.001
Rice Husk/ Stem	0.0122	0.3139	0.0386	0.2064	0.0013
Total	0.0302	1.8279	0.0811	2.4082	0.0033
Mean	0.010	0.305	0.027	0.803	0.001

**Note: <0.001 = No Detectable Limit (NDL)

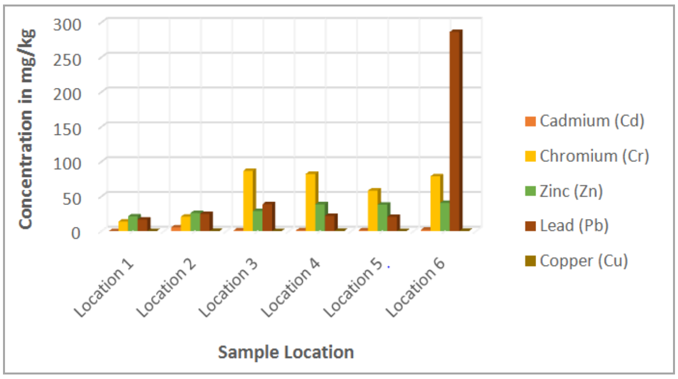

Figure 2. Heavy Metal concentration in soil samples from study locations

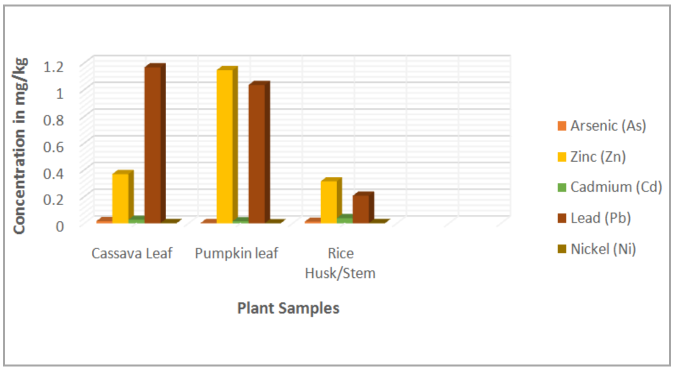

Figure 3. Heavy Metal concentration in plant samples

The three plants sample where all collected from a mining vicinity at Umuaghara mines. The cassava tissue sample show to have accumulated more Lead (Pb) than the rest tissue sample while the pumpkin leaf or tissue has a higher level of Zinc (Zn) concentration followed by a high level of Lead (Pb) concentration. The rice husk show a low heavy metal concentration but there is actually a visual heavy metal concentration with Zinc (Zn) as the highest followed by Lead (Pb), then Cadmium (Cd), Arsenic (As) and Nickel as the last.

Transfer Factor from Soil to Vegetables: The heavy metal transfer factor for Zinc (Zn), Cadmium (Cd) and Lead (Pb) from soil in plant was established using the formula (Olănescu Georgiana *et al.,* 2007):

$$TF = \frac{Mp}{Ms} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 1$$

Where:
TF – transfer factor,
Mp – metal content in plant (mg kg -1),
Ms – metal content in soil (Total Average value) (mg kg -1).

The transfer factor which is the rate at which heavy metal is been transferred from soil to plants is been represented in Figure 4 below and from the chart it is seen that Zinc (Zn) has the total highest concentration in all plant tissues but its highest was in pumpkin with a concentration of ±5.9 which is way higher the WHO permissible limit which is 0.001. This shows that the soil found around this environment are actually not suitable for plant vegetation as the contaminated soil tend to contaminated the plants because plants derive their nutrients from the soil, and wind also deposit quarry dust on the plants and also the plants derive nutrients from water but because the water in this environments, these abandoned mines vicinities are contaminated, the plants have no choice but to survive with what they have that is getting contaminated too which makes the not suitable for human consumption.

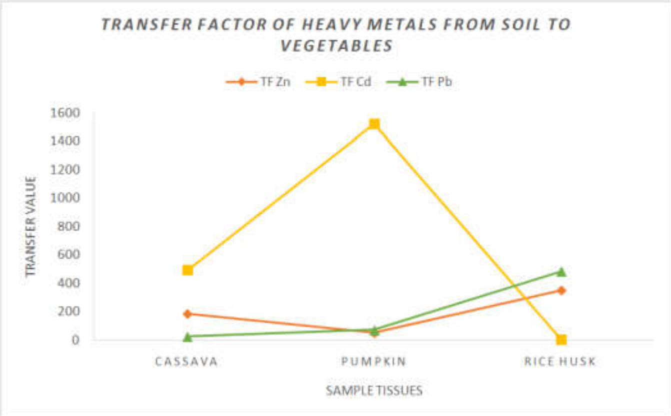

Figure 4. Transfer Factor of heavy metals from soil to vegetables

This study has shown that the soils in Abakaliki areas of Pb – Zn mines are contaminated due to many years of random dumping of waste from the mining and processing of Ores of zinc and lead. The results of the heavy metal analysis indicate that the soil is influenced by anthropogenic activities..The toxicological effect of heavy metals (Pb, As, Cd, Cr and Zn) includes hypertension, inhibition of haemoglobin formation, miscarriage, growth retardation and mental retardation to mention but a few. There is a need for soil remediation in the studied area. The results for all analysis shows that anthropogenic activities such as mining activities greatly influence the environment if not well established and monitored during closure. The Enyigba, Abakaliki mining province has resulted to a vast amount of environmental pollution of the immediate environment as most of the Lead (Pb) – Zinc (Zn) mines are artisanal therefore when abandoned led to the deposition of heavy metal as rain gradually washes these contaminated debris of soil in to the streams and also sinks these heavy metals into the soil which is then passed on to plants and other living organisms in the environment.

Recommendation: Government agencies such as National Environmental Standards and Regulations Enforcement Agency (NESREA) must be up and doing in evaluating all proposals or mining right of any miner before the mining begin work at site. Environmental impact Assessment should also be assessed and approved by government agencies before mining activities commences. Prospective miners must be regulated by Council of Mining Engineering and Geoscientists (COMEG) so as to be monitored in carrying out the mining activities in best known practices. All illegal or artisanal mines must be prevented and when perpetrators are caught severe punishment should be melted to them so as to serve and deterrence to others. All Abandoned site must be carefully turned to an Environment friendly site to prevent outbreak of epidemic.

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