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Impact of mining on heavy metal concentration and soil chemical properties in soils sorrounding a mining site in Ebonyi State, Nigeria

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ABSTRACT

This study was carried out to assess the impact of mining on heavy metal concentration in surrounding soils at a mining site in Ebonyi state, Nigeria. The soils were sampled from the east, west, north and south coordinates of the study area at two depths (0-20 cm and 20-40 cm), while the controls were set at 30 meters away from the mining site. The heavy metals investigated were copper, iron, lead and Zinc. soil chemical properties were also measured (pH in water, organic carbon, total nitrogen and available phosphorus, exchangeable potassium and exchangeable acidity). From the results obtained, the heavy metal contents decreased with depth; iron had the highest concentration at the two depths on the north, east, west and south flanks of the study area; the values were significantly ($p<0.05$) higher than what was obtained in the control in the order: Iron > copper > zinc > lead, and the values were significantly higher than the control. pH correlated significantly ($p<0.01$) positively with available phosphorus (r=0.747**), total nitrogen (r = 0.831**), organic carbon (r = 0.814**) and potassium (r = 0.629**) but correlated significantly ($p<0.01$) negatively with copper (r = -0.834**), lead (r= -0.832**), iron (-0.827**), and zinc (-0.830**) which implies that as the level of the heavy metals increased, soil pH decreased and consequently, phosphorus, nitrogen and organic carbon decreased. High concentration of the metals may exert phytotoxic effect which could drastically affect crop quality and yield¸ also their high concentrations could be detrimental to animals and humans.

1.0. Introduction

The term heavy metal refers to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations. Examples of heavy metals include mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Tl), and lead (Pb). Heavy metals are natural components of the earth's crust. They cannot be degraded or destroyed. To a small extent they enter our bodies via food, drinking water and air. As trace elements, some heavy metals (e.g. copper, selenium, zinc) are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning. Heavy metal poisoning could result from drinking-water contamination e.g. from lead pipes, high ambient air concentrations near emission sources, or intake via the food chain

Different studies have revealed that the presence of toxic heavy metals like iron (Fe), lead (Pb), and mercury (Hg) reduce soil fertility and agricultural output. Anthropogenic activities, such as mining and industrial processing were reported as the main sources of heavy metal contamination in the environment (Xilong *et al*., 2005). Under certain conditions, heavy metals may accumulate to a toxic concentration level which can lead to ecological damages. These metals enter the soils by different pathways, including: 1) aerial deposition (industries, vehicles and volcanoes), 2) paints, 3) pesticide and fertilizer application, 4) waste utilization, 5) disposal of degraded sediments, and 6) river and irrigation waters (Aguilar *et al*., 2013). Contaminated soil is a common environmental problem all over the world. The various countries confronted with contaminated soils differ significantly in awareness of the policies and the technologies to tackle it (Ashraf *et al.,* 2014).

However, intensive exchange of experiences gained with the management and remediation of polluted soils is taking place among various countries. Obviously, widespread pollution has caused vast areas of land to become non-arable and hazardous for both wildlife and human population. Contaminated lands generally result from past industrial activities when awareness of health and environmental effects connected with production, use and disposal of hazardous substance were less well recognized than today (Vidali, 2001).

These days, heavy metals originating from anthropologic activities are frequently detected in sediments, water columns of rivers /lakes, which cause a considerable number of the world's rivers/lakes severally contaminated (Susana *et al.,* 2005). Heavy metal pollution is gradually becoming a major concern worldwide. In aquatic environment for example, heavy metals are usually distributed as follows : water soluble species, colloids, suspended forms and sedimentary phases. Nevertheless, unlike organic pollutions, natural processes of decomposition do not remove heavy metals. Exposure to heavy metals at higher concentrations results in severe damage to various metabolic activities leading consequent death of plants. Heavy metals can migrate through the plasma membrane into the cytoplasm where they may affect the nutrient status of the plants. Photosynthesis is one of the most important physiological features of plant system. When plants are grown in metal enriched soils, the process of photosynthesis is adversely affected by heavy metals. Furthermore, the threat of heavy metals to the environment can be significantly reduced by fixation in the soil itself, so lowering bioavailability and risk of further mobility. Consequently, investigating the transformation and distribution mechanisms of heavy metals in sediment becomes very crucial.

To estimate levels of heavy metals in selected cultivated and industrially impacted soils in Afikpo Urban.

To determine the effects of heavy metals on soil physical and chemical properties.

2.0. Materials and Methods

2.1. Study Area

The study was carried out in Amasiri, in Afikpo North L. G. A of Ebonyi State. Amasiri is bordered to the north by the town of Akpoha, to the south by Unwana, to the south west by Edda in Afikpo South LGA, to the east by the Cross River.

2.2. Geology

Two main soil types are found in Ebonyi State. These are the silty clayey hydromorphic soil and the grey sandy clay hydro morphic soils.

2.3 Climate

The tropical climate of the state is broadly of two seasons which are the rainy season between April and October and dry season between November and March. The temperature throughout the year ranges between 21°C to 29 °C and humidity is relatively high.

2.4. Vegetation and Land Use

Amasiri is primarily an agricultural area. It is a leading producer of rice, yam, potatoes, maize, Cassava in the state. As a keen observer, I observed that the predominant plants there were oil palm (*Elaeis guineensis*), elephant grass (*Pennisetum purpureum*). The socio-economic activities in the area are majorly hunting, fishing and trading.

2.5. Sample Collection

Soil (0-20 cm) samples were collected from the north, south, east and west of the quarry point at the following longitudes and latitudes:

Quarry Point East: Latitude (LAT) = 5.902478, Longitude (LONG) = 7.870950 and Signal accuracy (2m)

20m away from Quarry point: Latitude (LAT) = 5.902608, Longitude (LONG) = 7.870792 and Signal accuracy (8m)

Quarry Point South: Latitude (LAT) = 5.902608, Longitude (LONG) = 7.870792 and Signal accuracy (8m)

South 20m away: Latitude (LAT) = 5.902485, Longitude (LONG) = 7.870709 and Signal accuracy (10m)

Quarry Point West: Latitude (LAT) = 5.902595, Longitude (LONG) = 7.870781 and Signal accuracy (8m)

20 meters away: Latitude (LAT) = 5.902758, Longitude (LONG) = 7.870699 and Signal accuracy (13m)

Quarry Point North: Latitude (LAT) = 5.902569, Longitude (LONG) = 7.870834 and Signal accuracy (8m)

20 meters away: Latitude (LAT) = 5.902751, Longitude (LONG) = 7.870943 and Signal accuracy (7m)

In these selected places, leafy vegetables and vegetable crops were grown intensively for long period of time.

2.6 Soil Digestion

Soil pH, available N, exchangeable potassium, available phosphorous, cation exchange capacity and soil organic matter were determined as the basic soil properties. The total concentration of copper (Cu), lead (Pb), iron (Fe) and zinc (Zn) in soils were also determined.

2.7. Sample Analysis

2.7.1. Heavy Metal Determination

The following elements, cupper, iron, lead and zinc were determined using the digestive method of A.O.A.C (2002). One gram of air dried and processed soil sample was weighed into 100ml beaker and10ml of nitric acid was added. The mixture was reacted/heated by the addition of 3ml of Perchloric acid ($HClO_4$). The suspension was filtered and diluted with distilled water to 100ml mark. Standard solution of lead (Pb) and Zinc (Zn) were prepared. The concentrations of the heavy metals were determined using atomic absorption spectrophotometer (AAS).

3.0. Results and Discussion

3.1. Physical and Chemical Properties of the Soils of the Mining Site

Results of the physical and chemical properties of the soils not contaminated with mining activities (30 meters away from the mining site) is as shown in Table 1. The soil samples were measured at the North, South, West and East of the mining site (30 meters away from the mining site). The soils were sandy loam in all the points sampled the 0-20cm and 20-40cm depths of the soil. The pH (H_2O) values ranged from 5.6 –5.8 at the 0-20cm depth and 5.1–5.3 at the 20-40cm depth. This is an indication of strong acidity at both levels (Chude *et al.,* 2005). The values decreased down the profile. Same trend was recorded for other chemical properties of the soils such as Available phosphorus, Total nitrogen, Exchangeable cations, Base saturation and Organic carbon. The decrease in the values with the soil depth could be due to decreasing organic materials down the profile which according to Udo and Ibia (1993) influenced the availability and distribution of nitrogen, phosphorus and sulphur in the soils

Table 1: Physical and chemical properties of the soils not contaminated with mining activities (30 meters away from the mining site)

	Depth	Sand %	Silt %	Clay %	TEX	pH H_20	pH KCl	A.V. P. Mg/ Kg	N %	OC %	OM %	Ca Cmol Kg^{-1}	Mg	K	NA	EA	CEC	BS %	AL^{3+}
Ctrl N	0-20	64.40	20.40	15.20	SL	5.70		19.40	0.142	1.76	3.03	4.90	2.00	0.40	0.30	1.08	8.68	87.54	0.12
Ctrl S	0-20	64.40	20.60	15.00	SL	5.80		18.80	0.17	1.83	3.15	5.20	2.20	0.38	0.30	1.04	9.12	88.59	0.12
Ctrl E	0-20	67.40	18.40	14.00	SL	5.70		19.20	0.16	1.80	3.10	4.80	1.80	0.38	0.31	1.06	8.35	87.30	0.08
Ctrl W	0-20	62.40	22.00	15.60	SL	5.60		18.60	0.16	1.78	3.07	5.10	2.00	0.40	0.29	1.06	8.85	88.02	0.08
Ctrl N	20-40	58.40	21.80	19.80	SL	5.20		15.60	0.11	1.02	1.76	3.00	0.80	0.28	0.20	1.28	5.56	76.97	0.16
Ctrl S	20-40	59.40	20.80	19.80	SL	5.30		14.90	0.10	0.94	1.62	3.20	0.80	0.28	0.21	1.32	5.81	77.28	0.18
Ctrl E	20-40	58.40	21.80	19.80	SL	5.10		15.30	0.01	0.90	1.55	3.40	1.80	0.28	0.19	1.30	6.18	78.96	0.16
Ctrl W	20-40	59.40	20.80	19.80	SL	5.20		15.10	0.10	1.03	1.78	3.00	1.20	0.28	0.21	1.32	6.01	77.97	0.14

Ctrl N – Control North
Ctrl S – Control South
Ctrl E – Control East
Ctrl W – Control West

3.2. Physical and Chemical Properties of the Soils of the Mining Site

Results of the physical and chemical properties of the soil of the mining site are as shown in the Table 2. The soil samples were measured at the North, South, West and East of the mining site. The table shows that pH at 0 – 20cm depth ranged from 4.65 – 4.75 and the 20 – 40cm ranged from 5.2 – 5.10 respectively. The low pH at 20 – 40 cm may be attributed to the excavation of the soil during mining activities. The pH (H_2O) ranged from 4.75 – 5.10 at 0 – 20cm and 5.05 – 5.10 for 20 – 40cm respectively which is a clear indication of strong acidity at both levels (Chude *et al.,* 2005).

Table 2: Physical and Chemical Properties of the Soils of the Mining Site

Chemical properties	**East flank**		**North Flank**		**South flank**		**West Flank**		**Control**		**%CV**	**SE**	**LSD (0.05)**
Depth	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40			
pH H_20	4.75	5.10	4.65	5.05	4.75	5.20	4.75	5.10	5.80	5.10	0.30	0.02	0.20
Av.P (mg/kg)	14.85	13.9	14.7	13.20	14.15	12.45	14.90	14.10	18.80	14.9	1.90	0.29	0.88
TN (%)	0.04	0.02	0.04	0.03	0.04	0.03	0.03	0.02	0.16	0.10	0.90	0.01	0.01
OC (%)	0.66	0.31	0.66	0.32	0.55	0.32	0.65	0.31	1.81	0.94	0.00	0.04	0.08
OM (%)	1.14	0.53	1.13	0.55	0.94	0.55	1.11	0.52	3.10	1.77	0.10	0.01	0.13
K Cmol/Kg	0.30	0.23	0.29	0.23	0.30	0.22	0.29	0.21	0.40	0.28	0.10	0.04	0.005
EA Cmol/Kg	1.60	1.37	1.59	1.35	1.57	1.37	1.58	1.35	0.99	1.31	1.70	0.02	0.13
Al^{3+}Cmol/kg	0.50	0.26	0.47	0.26	0.51	0.25	0.48	0.25	0.11	0.16	1.60	0.03	0.04

3.3. Selected Heavy Metal Concentration of the Soil of the Nining site

The results of heavy metal concentration of the soils of the mining site are as shown in Table 3. The selected heavy metals were: Copper (Cu), Iron (Fe), Lead (Pb) and Zinc (Zn). At 0-20 cm copper (Cu) ranged from 148.25-150.7 mg/kg and at 20-40cm, ranged from 112.6-11.8 mg/kg. Iron ranged from 238.18- 246.16 mg/kg at the depth of 0-20cm and at 20-40m ranged from 173.40 - 176.85 mg/kg respectively while lead (Pb) at the depth of 0-20cm ranged from 48.67-57.50 mg/kg and at 20-40cm it varied from 36.55 -40.62 mg/kg and finally Zinc at 0-20cm ranged from 19.49-215.7 mg/kg and at 20-40 cm ranged from 137.0-14.38 mg/kg.

Copper at this level of concentration has been reported to inhibit plant growth and interfere with several cellular process of plants (Devez *et al.*, 2003) and lead Zinc at these levels suppress homeostatic mechanism in microorganisms (Ernst, 1996).

From the heavy metal concentration recorded from the mining site are high, Copper - 150 mg/kg, Iron - 246 mg/kg, Lead - 54.55 mg/kg and zinc - 215.7 mg/kg. Zinc is higher when compared with the recommendation of Federal Ministry of Environment Nigeria, copper and zinc of 5.0 do not constitute hazard whereas the maximum in this work was 215.7 mg/kg. It therefore means that these concentrations is detrimental to plants, animals and humans living close to the mining site or coming in contact with the mining site.

Table 3: Mean value of selected heavy metal concentration of the soils of the mining site

Heavy metals	East flank		North Flank		South flank		West Flank		Control		%CV	SE	LSD (0.05)
Depth	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40			
Cu (mg/kg)	150.70	112.80	148.25	114.10	142.00	114.00	149.20	112.60	0.70	0.10	2.40	1.60	19.51
Fe (mg/kg)	244.05	170.60	238.18	176.37	246.16	173.40	241.81	176.85	22.05	7.32	1.40	1.52	6.26
Pb (mg/kg)	48.67	36.55	50.87	40.62	57.50	40.45	54.55	39.30	0.21	40.02	3.40	0.79	7.09
Zn (mg/kg)	194.49	137.00	200.40	143.80	215.7	140.40	199.00	142.90	13.30	4.20	0.90	0.81	18.41

3.4. Relationship Between Heavy Metal Concentration and Some Selected Soil Fertility Indices From the Mining Site

The correlation between heavy metal concentration and some selected soil fertility indices from the mining site is presented on Table 4. Soil pH correlated significantly ($P<0.01$) positively with available phosphorus ($r = 0.747^{**}$), Total nitrogen ($r=0.831^{**}$), Organic matter ($r=0.814^{**}$) and Potassium ($r = 0.629^{**}$) while pH correlated significantly ($P<0.01$) negatively with EA ($r=0.927^{**}$), Al ($r = 0.830^{**}$).

Positive correlation means that as soil pH increased, available phosphorus, nitrogen, organic matter and potassium also increased while the negative correlation with the heavy metal means that increase in Copper, Lead, Iron, and Zinc led to a decrease in pH, Available phosphorus, potassium and organic matter.

Table 4: Relationship between heavy metals and some selected soil fertility indices from the Mining site

	pH	Av.p	TN	OC	OM	K	EA	Al^{3+}	Cu	Pb	Fe	Zn
pH	1											
Av.p	0.747**	1										
TN	0.861**	0.892**	1									
OC	0.813**	0.956**	0.968**	1								
OM	0.814**	0.955**	0.968**	1.000**	1							
K	0.626**	0.933**	0.833**	0.933**	0.932**	1						
EA	-0.927**	-0.767**	-0.838**	-0.800**	-0.800**	-0.634**	1					
Al^{3+}	-0.883**	-0.551**	-0.758**	-0.630**	-0.631**	-0.354*	0.867**	1				
Cu	-0.834**	-0.656**	-0.894**	-0.765**	-0.766**	-0.525**	0.788**	0.889**	1			
Pb	-0.832**	-0.658**	-0.887**	-0.760**	-0.761**	-0.561**	0.789**	0.901**	0.986**	1		
Fe	-0.827**	-0.609**	-0.865**	-0.726**	-0.727**	-0.463**	0.777**	0.910**	0.991**	0.990**	1	
Zn	-0.830**	-0.611**	-0.863**	-0.725**	-0.726**	-0.465**	0.784**	0.913**	0.991**	0.988**	0.996**	1

** Correlation is significant at the 0.01 level.
* Correlation is significant at the 0.05 level.

4.0 Conclusion

The purpose of this study was to evaluate the impact of mining activities on some selected heavy metals (copper, lead, iron and zinc) concentration and some selected fertility indices of the soils of Amasiri in Afikpo LGA of Ebonyi state. The work revealed that there was a significant increase in the level of copper, lead, iron and zinc content of the soil as a result of mining activities going on within the area. The high level of heavy metals recorded on the mining site affected most of the chemical properties like pH, organic matter, potassium, phosphorus and total nitrogen negatively hence affecting the fertility and productivity of the soil. The heavy metal concentration of the mining site was significantly higher than what was found on the control site 30cm away from the mining site; this could affect agricultural activities around the mining area negatively.

5.0 Recommendation

it is therefore recommended to regularly monitor heavy metal loads in the environment, particularly within and around the mining site of developing areas like amasiri in afikpo lga of ebonyi state to minimize negative environmental impact on the plants and animals around the area. also, bioremediation measure and optimum land use plan for maximizing agricultural production should be developed by farmers in the area to ensure that the concentration of copper, lead, iron and zinc are kept under check.

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