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Studies on bioaccumulation of heavy metals and selected minerals from mining effluent contaminated soil treated with fertilizers into *Cucurbita pepo* vegetable

[1]Akubugwo E. I., [1]Osuocha K. U., [2]Nwaogu L. A. and [1]Chinyere G. C.

[1]Department of Biochemistry, Abia State University, Uturu
[2]Department of Biochemistry, Federal University of Technology, Owerri

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ABSTRACT

The present study evaluated bioaccumulation of heavy metals and selected minerals from mining effluent contaminated soil from Ishiagu, Ebonyi State South-East Nigeria treated with fertilizers into Cucurbita pepo vegetable. Effluents of Crush rock, Crush stone and Ezza quarry sites were used for the study. Heavy metals and selected minerals in both soil and vegetable were analysed using Atomic Absorption Spectrophotometer. Results showed that level of these heavy metals in the soil were more at the discharge points. Results also showed that Cucurbita pepo accumulated considerable amounts of these heavy metals. However, high levels of these heavy metals were found in pots without fertilizers (Sample D) than pots treated with urea (Sample E) and NPK 20.10.10 fertilizers (Sample F). The toxicity of these heavy metals at high levels of exposure is well known, but of a major concern is the possibility that continual exposure at relatively low levels of heavy metals through consumption of Cucurbita pepo vegetable may entail adverse health effects.

Key words: Bioaccumulation, mining effluent, heavy metals, contamination, quarry sites.

INTRODUCTION

Heavy metals have been known to act as biological poisons, due to their bioaccumulation abilities. Their levels are highly concentrated in soil and sediments which are readily taken up by plants during growth (Akinola *et al*., 2011). Soils are the major sink for heavy metals released into the environment by anthropogenic activities such as disposal of high metal waste, leaded gasoline and paints, application of fertilizers and deposition etc (Khan *et al.,* 2008). Heavy metal contamination of soil may pose risks and hazards to human and the ecosystem through indirect ingestion or contact with contaminated soil, the food chain (soil-plant-human or soil- plant-animal-human), reduction in food quality via phytotoxicity, reduction in land usability for agricultural production causing food insecurity (McLaughin *et al.,* 2000a; McLaughin *et al.,* 2000b). The most common heavy metals found at contaminated sites are lead (pb), chromium (Cr), cadmium (Cd), zinc (Zn), mercury (Hg) and arsenic (As). These metals are capable of decreasing crop production due to risk of bioaccumulation and biomagnifications in the food chain (USEPA, 1996). Plants take heavy metals from soil through different reactions such as absorption, ionic exchange, redox reaction and precipitation etc. Metal absorption and accumulation in plants depends on a few soil factors such as pH, clay content, organic matter content, cationic exchange capacity, nutrient balance, other trace element concentration in soil, physical and mechanical characteristics of soil (Ana-Irina *et al.,* 2008). *Cucurbita pepo* belongs to the group of family *Cucurbitacaea* and is an important vegetable in the south eastern part of Nigeria due to its nutritional composition. The present day study undertakes to evaluate and provide useful data on the level of heavy metal bioaccumulation of *Cucurbita pepo* grown in mining effluent contaminated soil treated with fertilizers.

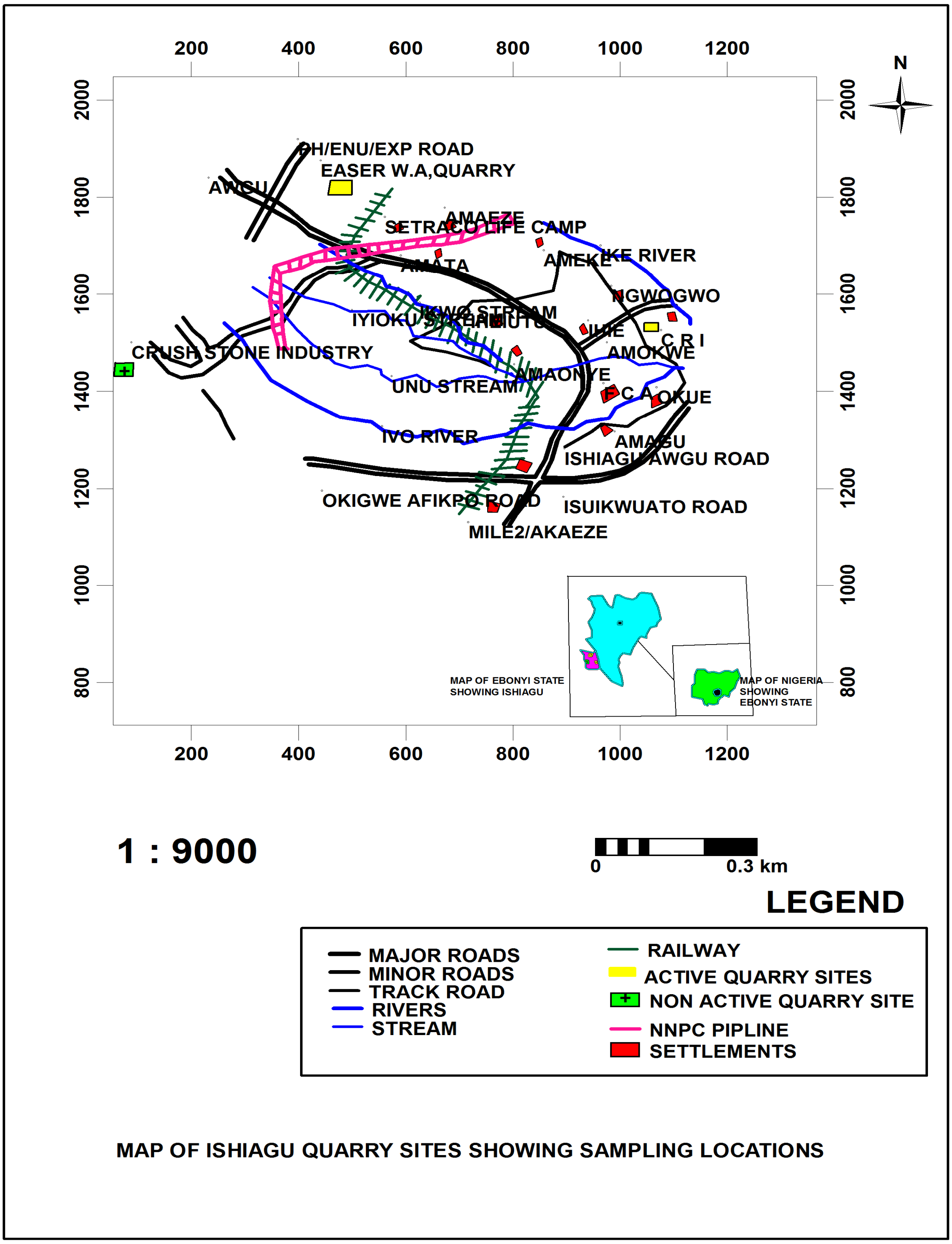

Fig 1: Map of Ishiagu showing sampling locations. (Source: Aroh *et al.*,2007)

MATERIALS AND METHODS

Study area
The study was carried out with mining effluent contaminated soil samples from Ishiagu in Ivo Local Government area of Ebonyi State, south-East Nigeria. Effluents of Crush rock, Ezza West Africa and Crush stone industries were used for the study. These ever increasing quarry, lead and zinc industries dispose their waste into nearby farms and these farms are cultivated by the rural settlers.

Soil and plant seedling collection
Soil samples were collected at a depth of 0-30cm and were homogenized before collection at 100m,(Sample B) 200m (Sample C) away from discharge points(Sample A) using auger. The soil samples from the three (3) spots in each mining sites were homogenized and divided into three (3) giving a total of twelve (12) soil samples for potted planting of *Cucurbita pepo* vegetable, While the control soil was collected from an unimpacted area devoid of mining activities. The plant seedlings were bought from Agricultural Development Program (ADP) Umuahia, Abia State.

Cultural conditions
The field was cleared of weeds and twelve (12) pots containing mining effluent contaminated soil and control soil were placed spaciously to avoid undue competitions among plants. In order to ensure optimum plant growth and yield, the weeds were removed at weekly intervals.

Planting of seedlings and application of fertilizers
The plant seedlings were planted in the pots containing the soil samples. Two (2) out of the three pots from each site were applied 25g of N.P.K 20:10:10 and urea fertilizers while the other pots served as control. This was done, four (4) weeks from the date of planting using placement method.

Preparation of soil and plant samples for analysis
The soil samples were sieved and stored at 4^{oC} while the plant samples were oven dried at 60^{oC} before using them for analysis.

Soil heavy metal and selected mineral determination
Heavy metals and minerals such as lead (Pb), chromium (Cr), cadmium (Cd), Nikel (Ni), Zinc (Zn) and Manganese (Mg) were analysed in the soil by the Perchloric acid digestion method described in APHA (1998).

Exactly 1.0g of air dried soil samples were weighed into a digestion tube and 3ml of conc. HNO_3 was added. This was digested on electrically heated block for 1hr at 145^{0C}. Then 4ml of $HClO_4$ was added to whatman #42 filter paper and made to 50ml volume. The filtrate was analysed for heavy metal and selected minerals using atomic absorption spectrophotometer (AAS).

Plant heavy metal and selected mineral determination
This was determined using atomic absorption spectrophotometer (AAS) as described by James (1995). Following the ashing of plant materials, the resulting ash was dissolved in 10ml of hydrochloric acid. It was filtered with whatman #42 filter paper. The extract was used for the analysis using Atomic Absorption Spectrophotometer (AAS).

Statistical analysis
Data collected were subjected to statistical analysis using one way analysis of variance (ANOVA) procedure and difference in mean were separated using least significant difference as described by Onuh and Igwenma, (2000).

RESULTS

Soil heavy metals analyzed lead, zinc, cadmium, chromium, nickel showed significant increase in the contaminated soils when compared to control ($p<0.05$) The concentration of heavy metals were found to be more at the discharge points which tend to be lower distance away from discharge point. Result of the plant heavy metals and selected minerals were found to be more in pots without any form of fertilizer (sample D) while the pots with urea fertilizer absorbed lesser amount of these heavy metals which showed significant difference when compared to control($p<0.05$) .

Table 1 Selected heavy metal content of mining effluent contaminated soil (mg/kg)

LOCATION	SITE	LEAD (mg/kg)	ZINC (mg/kg)	CADMIUM (mg/kg)	NICKEL (mg/g)	CHROMIUM (mg/kg)	MANGANESE (mg/kg)
CONTROL		1.68^{j}	1.91^{j}	0.09^{i}	1.96^{l}	1.02^{h}	1.58^{j}
EZZA QUARRY	A	2.41^{f}	3.30^{h}	0.55^{f}	4.40^{g}	1.90^{a}	2.70^{d}
	B	2.10^{h}	3.70^{d}	0.45^{g}	3.71^{i}	1.70^{b}	2.45^{e}
	C	1.91^{i}	3.45^{f}	0.25^{h}	3.95^{h}	1.55^{d}	2.20^{g}
CRUSH ROCK QUARRY	A	2.65^{d}	3.65^{e}	1.21^{a}	5.30^{c}	1.65^{c}	2.35^{f}
	B	2.21^{g}	3.41^{g}	1.05^{b}	5.40^{b}	1.45^{e}	2.15^{h}
	C	2.45^{e}	3.25^{i}	0.75^{e}	4.65^{f}	1.15^{c}	1.95^{i}
CRUSH STONE QUARRY	A	3.75^{a}	4.31^{a}	0.95^{c}	5.65^{a}	1.30^{f}	3.40^{a}
	B	3.61^{b}	4.05^{b}	0.85^{d}	5.40^{b}	1.01^{h}	3.15^{b}
	C	3.40^{c}	3.95^{c}	0.75^{e}	5.25^{d}	0.85^{i}	2.90^{c}
LSD		0.017	0.016	0.013	0.017	0.014	0.015

Values are mean of triplicate determination.
Means in the same column, having the same letter(s) are not significantly different (P<0.05) using Least Significant Difference (LSD)
A = Soil sample from discharge point
B = Soil sample 100m away from discharge point.
C = Soil sample 200m away from discharge point.

Table 2. Selected mineral content of mining effluent contaminated soil

LOCATION	SITE	Magnesium (mg/kg)	Sodium (mg/kg)	Potassium (mg/kg)	Calcium (mg/kg)
CONTROL		2.65^{i}	212.30^{j}	649.50^{j}	0.440^{i}
EZZA QUARRY	A	2.40^{k}	313.50^{e}	722.10^{e}	0.95^{g}
	B	2.76^{f}	351.50^{b}	798.05^{a}	0.85^{h}
	C	2.26^{l}	247.10^{g}	750.50^{c}	1.05^{f}
CRUSH ROCK QUARRY	A	3.76^{a}	389.50^{a}	788.50^{b}	1.61^{b}
	B	3.55^{b}	294.50^{f}	712.50^{f}	1.69^{a}
	C	3.30^{c}	342.10^{c}	741.10^{d}	1.30^{e}
CRUSH STONE QUARRY	A	3.21^{d}	332.50^{d}	617.50^{k}	1.30^{e}
	B	2.55^{j}	226.10^{h}	655.50^{h}	1.45^{c}
	C	2.95^{e}	218.40^{i}	693.50^{g}	1.35^{d}
LSD		0.018	0.169	0.144	0.015

Values are mean of triplicate determination.
Means in the same column, having the same letter(s) are not significantly different (P<0.05) using Least Significant Difference (LSD).
A = Soil sample from discharge point
B = Soil sample 100m away from discharge point.
C = Soil sample 200m away from discharge point.

Table 3. Selected heavy metal content of *Cucurbita pepo* grown in mining effluent contaminated soil treated with fertilizers

LOCATION	SITE	LEAD (mg/kg)	ZINC (mg/kg)	CADMIUM (mg/kg)	NICKEL (mg/kg)	CHRONIUM (mg/kg)	MANGANESE (mg/kg)
CONTROL	D	0.0106^{f}	0.0385^{h}	0.00002^{d}	0.0065^{e}	0.0002^{i}	0.0216^{i}
	E	0.0102^{f}	0.0339^{gh}	0.00002^{d}	0.0065^{e}	0.0002^{i}	0.0217^{i}
	F	0.0134^{de}	0.0331^{h}	0.00003^{d}	0.0067^{d}	0.00018^{j}	0.0195^{j}
EZZA QUARRY	D	0.0142^{c}	0.0465^{fde}	0.00007^{ab}	0.0011^{f}	0.00057^{d}	0.0426^{b}
	E	0.0140^{de}	0.0415^{fg}	0.00006^{c}	0.0093^{b}	0.00056^{d}	0.0331^{g}
	F	0.0170^{d}	0.0538^{cab}	0.00005^{cb}	0.0098^{a}	0.00053^{e}	0.0370^{e}
CRUSH ROCK QUARRY	D	0.0245^{a}	0.0538^{cab}	0.00008^{a}	0.0011^{f}	0.00061^{c}	0.0355^{d}
	E	0.0195^{cb}	0.0577^{ab}	0.00002^{d}	0.0093^{b}	0.00043^{g}	0.0391^{f}
	F	0.0225^{a}	0.0505^{cde}	0.00006^{cb}	0.0089^{c}	0.00057^{d}	0.0415^{c}
CRUSH STONE QUARRY	D	0.0185^{c}	0.0580^{a}	0.00005^{e}	0.0011^{f}	0.00072^{a}	0.0371^{e}
	E	0.0115^{fe}	0.0515^{cdb}	0.00003^{d}	0.0094^{b}	0.00064^{b}	0.0341^{h}
	F	0.022^{ab}	0.0445^{fge}	0.00008^{a}	0.0093^{b}	0.00048^{f}	0.0441^{a}
LSD		0.003	0.006	0.0002	0.001	0.0003	0.002

Values are mean of triplicate determination.
Means in the same column having the same letter(s) are not significantly different (P<0.05)
Site D = Cucurbita Pepo grown in soil without fertilizer
Site E = Cucurbita Pepo grown in soil treated with Urea fertilizer
Site F = Cucurbita Pepo grown in soil treated with NPK 20.10.10 fertilizer.

Table 4: Selected mineral content of *Cucurbita pepo* grown in mining effluent contaminated soils

LOCATION	SITE	MAGNESIUM (mg/kg)	SODIUM (mg/kg)	POTASSIUM (mg/kg)	CALCIUM (mg/kg)
	D	0.034^{j}	3.41^{h}	6.12^{j}	0.0601^{h}
CONTROL	E	0.034^{i}	3.27^{j}	6.02^{k}	0.0599^{i}
	F	0.0322^{k}	3.39^{h}	6.17^{i}	0.0604^{a}
	D	0.0795^{c}	4.55^{d}	7.17^{i}	0.0705^{a}
EZZA QUARRY	E	0.0765^{e}	4.084^{e}	8.26^{c}	0.0645^{d}
	F	0.0771^{d}	4.05^{e}	7.63^{e}	0.0694^{b}
	D	0.0835^{a}	5.88^{a}	7.5^{f}	0.0655^{c}
CRUSHROCK QUARRY	E	0.077^{d}	5.22^{c}	8.93^{a}	0.0625^{e}
	F	0.0725^{h}	3.88^{e}	8.17^{d}	0.0645d
	D	0.0815^{b}	5.443^{b}	8.26^{b}	0.062^{f}
CRUSHSTONE QUARRY	E	0.0731^{g}	3.71^{g}	7.41^{g}	0.0605^{a}
	F	0.0753^{f}	3.31^{i}	8.36^{c}	0.0604^{g}
LSD		0.001	0.032	0.017	0.002

Values are mean of triplicate determination.
Means in the same column having the same letter(s) are not significantly different ($P<0.05$)
Site D = Cucurbita Pepo grown in soil without fertilizer
Site E = Cucurbita Pepo grown in soil treated with Urea fertilizer
Site F = Cucurbita Pepo grown in soil treated with NPK 20.10.10 fertilizer.

DISCUSSION

Table 1 and 2 shows the concentration of heavy metals and selected minerals in soil samples examined in mg/kg respectively. There is no doubt that soil samples contaminated with mining effluents have high level of heavy metal concentration. Results obtained showed that heavy metals analysed were higher at the discharge points. The significant high values of heavy metals recorded at the discharge points could be attributed to the mining operation within the area. This agreed with Chinyere (2001)., Nwaugo *et al.*, (2004) and Akubugwo *et al.*,(2010), that pollutants have highest concentration at the discharge points. Observation showed that the impaction of the soil showed decreased concentration of heavy metals away from the discharge point.

Tables 3 and 4 shows the concentration of heavy metals and selected minerals (mg/kg) of *Cucurbita pepo* grown in mining effluent contaminated soil treated with fertilizers. Result showed that heavy metals were more accumulated in plants without fertilizer application than in plants treated with urea fertilizer and NPK 20.10.10. This could be attributed to the fact that plants needs nutrients for survival and when these nutrients are not available due to heavy metal contamination they tend to absorb these metals more. This is in line with Ana-Irina *et al.,* (2008), who observed that heavy metal accumulation of zinc was higher in lettuce from pots with unfertilized soil than lettuce with fertilized soil. Results also showed that plants treated with urea fertilizer accumulated lower level of heavy metals. This could be attributed to urea's ability to release its nutrients faster than NPK 20.10.10. Results of the present study showed that *Cucurbita pepo* has the ability to accumulate all the heavy metals analysed and this could be attributed to the fact that mining effluent contaminated soil had relatively high electrical conductivity and low pH. These parameters were observed to increase solubility of heavy metals (Gabrilla and Anton, 2005).

CONCLUSION

The contamination of agricultural soil by mining effluents eventually contaminates the soil. However, its concentration is higher in soils from the discharge points while application of urea fertilizers is preferable to NPK 20.10.10 on vegetables and plants planted in and around the quarry area. This however, does suggest or encourage planting of vegetables around mining areas as these vegetables are likely to accumulate the heavy metals which may lead consumers of such of these vegetables to heavy metal toxicity if bioaccumulation results due to regular consumption.

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