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Seasonal impact on phyto-accumulation potentials of selected edible vegetables grown in Ishiagu quarry mining effluent discharge soils

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Seasonal impact on soil trace metals and phytoaccumulation potentials of *Cucurbita pepo, Cucumis sativus* and *Taliferia occidentalis* grown in Ishiagu quarry mining effluent discharge soils were investigated. Soil samples were collected 200 m (sample C), 100 m (sample B) away from discharge point (sample A) in wet and dry seasons. Trace metals were analysed using atomic absorption spectrophotometer. Results reveal a significant decrease in levels of trace metals distance away from discharge points in the order A>B>C. Findings from the study show significant increase in level of soil trace metals in dry season compared to wet season. Phyto-accumulation potentials of the vegetables showed significant increase in level of trace metals in roots and shoots in dry season compared to wet season. Level of these metals were significantly higher compared to control. This is indicative of the potential risk associated with consumption of vegetables grown in these sites especially in dry seasons. The rural dwellers should be discouraged from planting edible vegetables around Ishiagu quarry mining effluent discharge soils in order to reduce excessive build-up of these metals in the human food chain.

Key words: Phyto-accumulation, trace metals, quarry mining, discharge soils, seasonal impact.

INTRODUCTION

Mining activities are well known for their deleterious effect on the environment due to deposition of large volume of waste on the soil. Adverse environmental consequences of open pit mining include land degradation arising from vegetation destruction, exposure of the soil to run-off water as well as dumps that have been confirmed as having harmful minerals and chemicals that contaminate the soil, plant, water and air quality (Osuocha et al., 2015). Mining activities generate a variety of wastes whose presence in soils have adverse effects on plant growth, such as low water infiltration rates, rough surfaces, poor aeration, high level of trace metals, low soil fertility, salinity and extremes of pH (Monty and Amiya, 2012). Ezeh (2007) and Nwaugo et al. (2009a) reported that mining activities are sources of environmental pollution and degradation through the introduction of chemicals above their threshold limit into the environment as wastes generated in the mining process are often discharged

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into the surrounding environment especially in developing countries. Environmental impacts of such mining operations are potentially long lasting due to destruction of vegetation, surface runoff of organic matter and the overall degradation of soil structure affecting plant and microbial growth.

According to Oluyemi et al. (2008), disruption of the existing balance in the soil usually leads to reduction in its productivity and quality of agricultural products as soil is a vital resource for sustaining two human needs of quality food supply and quality environment. The concentration of these trace elements in soils are associated with several factors such as biological and biogeochemical cycling, parent materials and mineralogy, soil age, organic matter, soil pH, redox concentration and microbial activities (Kabata-pendias, 2004; Obasi et al., 2013). Plants are one pathway for toxic metal mobilization into the human system. Elevated environmental concentration of these trace metals are a particular issue in mining areas because of their documented deleterious human health effect such as DNA, kidney and liver damage, skin and lung cancer caused by their mutagenic ability, neurotic effect and anaemia from lead poisoning, gingivitis as well as alteration of body metabolism (Duruibe et al., 2007). The determination of elemental status of cultivated land is necessary to identify yield limiting deficiencies of essential nutrients and level of polluted soils. This is important especially in Ishiagu because the inhabitants are essentially farmers and large quantities of crops and vegetables are produced not only for local consumption but also for food supplies to other parts of Nigeria.

MATERIALS AND METHODS

Study area

This study was carried out with mining effluents contaminated soil samples from Ishiagu in Ivo local Government Area of Ebonyi State. The rural settlers are mainly peasant farmers with most farm products as cassava, vegetables, yam, cocoyam and rice. Quarry sites of leads and zinc are the major industrial activities in Ishiagu. These ever increasing quarry industries dispose their wastes into nearby farm lands and these farms are cultivated by the rural settlers (Figure 1).

Three (3) different mining effluent contaminated soils in Ishiagu, Ivo Local Government Area of Ebonyi State were used for this study. The quarry sites include:

(i) Crush rock industries in Ano community,
(ii) Eza west Africa limited in Eziato community and
(iii) Crush stone industries in Amita village.

Soil sample collection

Three (3) different locations were used for the analysis from each quarry mining site. The soil samples were thoroughly mixed before collection at a depth of 0-50 cm. Points of collection were 100 m (sample B) 200 m (sample C) away from discharge point (sample A) along the flow of the mining effluent using metal auger. Soil samples were transferred into labeled polythene bags and transported to Biochemistry laboratory, Abia State University, Uturu, stored in a refrigerator at 4°C while the control soil were collected about 7 km away from an unimpacted area devoid of mining activities.

Determination of trace metals in soil samples

Trace elements were determined by the perchloric acid digestion method described in APHA (1998). Exactly 1.0 g of air dried soil sample was weighed into a digestion tube and 3 ml of concentrated HNO_3 was added. This was digested on electrically heated block for 1 h at 145°C. Then 4 ml of $HCLO_4$ was added and heated to 240°C for further 1 h, cooled and filtered through whatman #42 filter paper and made to 50 ml volume. The filtrate was analyzed for heavy metals using atomic absorption spectrophotometer (AAS) (Tables 1 to 3).

Determination of trace metals in plant samples

Trace metal content of plant roots and shoots were determined by Atomic Absorption Spectrophotometer as described by (James, 1995). Following the ashing of samples, the resulting ash was dissolved in 10 ml of Hydrochloric Acid (HCL). It was filtered with Whatman #42 filter paper. The extract was used for the analysis using atomic absorption spectrophotometer (AAS) (Tables 4 to 15).

Statistical analysis

Data collected were subjected to statistical analysis using one way analysis of variance (ANOVA) and t-test statistic. Values are mean of triplicate determination ± standard deviation. The mean of the samples were compared to the control using ANOVA while mean of the two seasons were compared using student t-test. The individual mean difference was ascertained using Least Significant Difference (LSD) as described by Onuh and Igwemma, (2000). The student package for social sciences (SPSS) version 20 computer software was used for the analysis.

RESULTS AND DISCUSSION

Trace metals can enter the food chain through a variety of sources. Elevated soil heavy metals have been reported to cause negative effects in soil such as reduction of soil microbial biomass level which are responsible for maintenance of soil fertility for optimum crop yield, affecting nitrogen- fixation and reduction in certain enzyme activities (Mathews et al., 2012). Soil trace metals content of mining effluent discharge soils as obtained from this study were significantly higher than the control. This may be attributed to mining activities in the area and indiscriminate discharge of mine water. The level of impaction decreased distance away from discharge points. Similar results have been reported by Akubugwo et al. (2013), Chinyere (2001), Nwaugo et al. (2004, 2009a, b, 2011), Onyeobi and Imeokparia (2014) and Smejkalova et al. (2003) that pollutants decrease distance away from discharge points or source of contamination. The high level of trace metals at the discharge points could be due to lower acidic pH

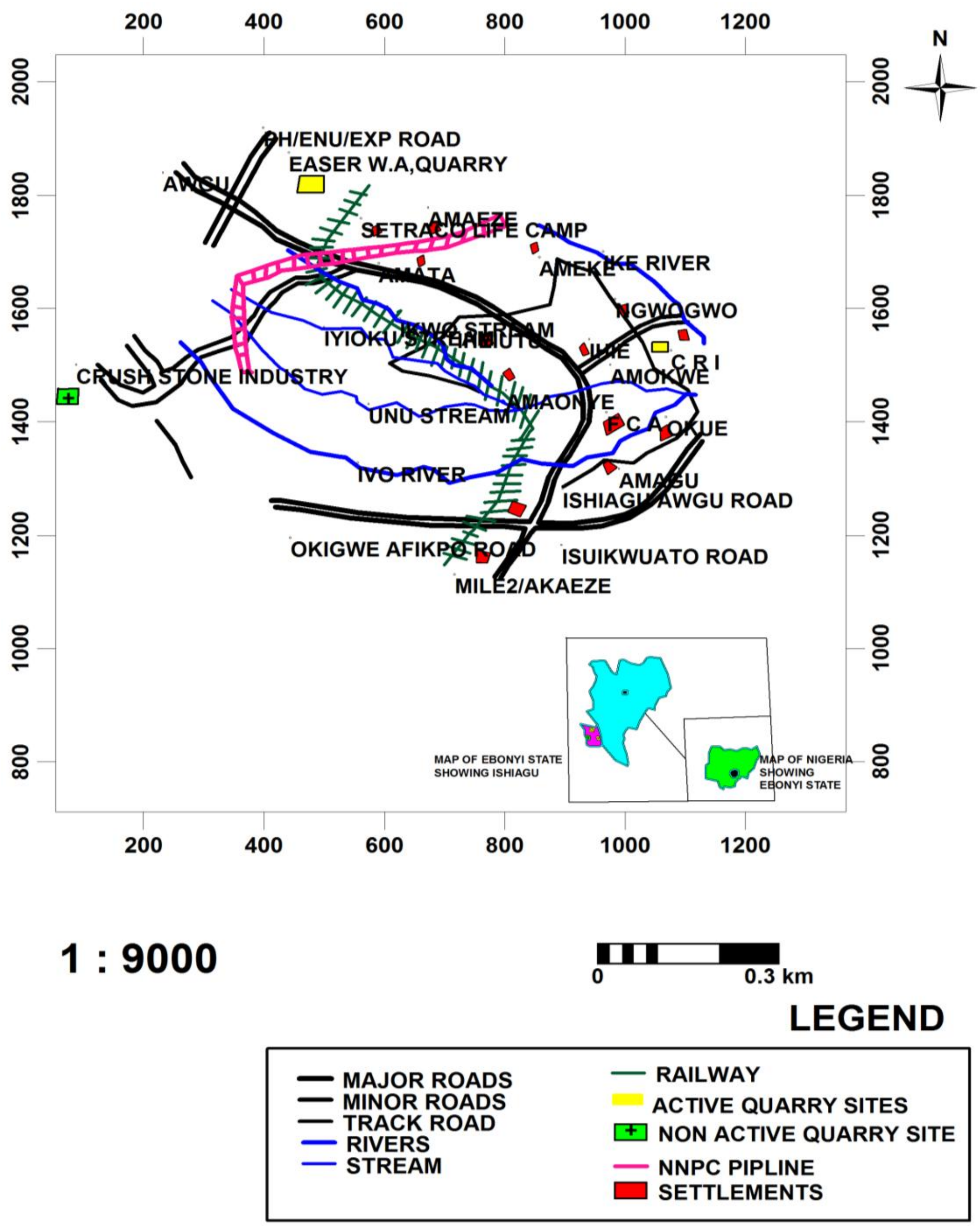

Figure 1. Map of Ishiagu quarry sites showing sampling location.

at the discharge points as reported by Osuocha et al. (2015) as this has been shown to increase retention capacity and stabilization of trace metals in soils (Ogbonna et al., 2013). The results indicated that the sequence of impaction was A > B > C. This implicated site C as the least polluted site followed by site B and site A which could be attributed to distance of these sites from the source of contamination. Levels of soil trace metal obtained from the study in wet season were significantly lower compared to dry season. This could be due to leaching and runoff effects of rainfall that are capable of removing toxic metals from soil in wet season. Water evaporation from soil is more intense during dry season leading to soil solution being concentrated with little or no leaching of nutrient from the top soil. Similar findings have been reported by Syed et al. (2012) who assessed implication of seasonal variation in heavy metal contamination of agricultural soil. Findings from this work

Table 1. level of trace metals in quarry mining effluent discharge soils in wet season(mg/kg).

Location	Site	Lead	Cadmium	Chromium	Nickel	Manganese	Zinc
Control		0.89±0.00^{a}	0.18±0.00^{a}	0.61±0.00^{a}	1.33±0.00^{a}	1.09±0.00^{a}	1.15±0.00^{a}
	A	2.87±0.53^{h}	2.57±0.25^{j}	1.29±0.08^{g}	3.70±0.52^{e}	3.05±0.69^{h}	3.39±0.31^{h}
Ezza	B	2.03±0.10^{d}	1.79±0.26^{g}	1.23±0.16^{d}	2.90±0.10^{d}	2.37±0.10^{g}	3.14±0.16^{f}
	C	2.03±0.01^{d}	1.56±0.30^{f}	0.99±0.06^{b}	1.69±0.06^{b}	2.13±0.15^{c}	3.04±0.36^{e}
	A	2.57±0.73^{g}	2.16±0.26^{i}	2.18±0.93^{h}	4.15±0.08^{h}	2.15±0.93^{d}	3.78±0.08^{j}
Crush rock	B	2.39±0.05^{f}	2.11±0.06^{h}	1.98±0.71^{a}	4.08±0.26^{g}	2.05±0.08^{b}	2.99±0.17^{d}
	C	2.14±0.12^{e}	1.09±0.06^{b}	1.98±0.71^{a}	4.08±0.26^{g}	2.05±0.80^{b}	1.68±0.08^{b}
	A	1.97±0.20^{c}	1.41±0.12^{e}	1.34±0.08^{g}	4.70±0.50^{i}	2.28±0.01^{f}	3.63±0.12^{i}
Crush stone	B	1.92±0.10^{b}	1.37±0.52^{d}	1.23±0.73^{d}	3.97±0.78^{f}	2.16±0.16^{e}	3.33±0.53^{g}
	C	1.93±0.55^{b}	1.29±0.16c	1.21±0.15^{c}	2.70±0.20^{c}	2.16±0.10^{e}	2.97±0.26^{c}
LSD		0.073	0.034	0.029	0.042	0.307	0.035

Means down the column having different superscript are significantly different (P<0.05) Site A= soil sample from discharge point, B= soil sample 100 m away from discharge point, C = soil sample 200 m away from discharge point

Table 2. Level of trace metals in quarry mining effluent discharge soil in dry season (mg/kg).

Location	Site	Lead	Cadmium	Chromium	Nickel	Manganese	Zinc
CONTROL		0.93±0.00^{a}	0.52±0.00^{a}	0.73±0.00^{a}	1.67±0.00^{a}	1.49±0.00^{a}	1.99±0.00^{a}
	A	4.78±0.51^{j}	4.63±0.57^{j}	4.13±0.02^{i}	6.09±0.16^{j}	3.50±0.15^{h}	4.33±0.58^{h}
Ezza	B	3.75±0.15^{f}	4.25±0.20^{h}	2.03±0.15^{d}	5.92±0.16^{h}	3.48±0.02^{g}	4.32±0.10^{g}
	C	3.71±0.10^{e}	2.08±0.10^{b}	2.10±0.71^{f}	5.93±0.52^{i}	3.39±0.10^{f}	4.27±0.21^{f}
	A	4.02±0.55^{i}	4.30±0.07^{i}	4.45±0.15^{j}	5.48±0.55^{g}	3.78±0.32^{b}	4.56±0.38^{j}
Crush rock	B	3.93±0.71^{h}	3.27±0.65^{g}	2.30±0.21^{g}	5.26±0.22^{f}	3.34±0.21^{e}	4.43±0.15^{i}
	C	3.92±0.53^{g}	2.26±0.15^{c}	2.07±0.64^{e}	5.21±0.20^{e}	2.99±0.10^{c}	3.29±0.15^{c}
	A	2.95±0.08^{d}	2.82±0.11^{f}	3.02±0.35^{h}	4.93±0.33^{d}	3.07±0.58^{d}	4.05±0.28^{e}
Crush stone	B	2.88±0.21^{c}	2.66±0.26^{e}	1.94±0.06^{c}	4.08±0.16^{c}	2.93±0.21^{c}	3.96±0.20^{d}
	C	2.57±0.20^{b}	2.37±0.06^{d}	1.83±0.50^{b}	3.88±0.15^{b}	2.54±0.10^{b}	2.95±0.57^{b}
LSD		0.031	0.029	0.105	0.143	0.042	0.042

Means down the column having different superscript are significantly different (P<0.05). Site A= soil sample from discharge point, B= soil sample 100 m away from discharge point, C = soil sample 200 m away from discharge point

also agrees with Ideriah et al. (2013) who reported high level of trace metals in dry season in crude oil contaminated soils from Niger Delta, Nigeria. This high level of soil trace metals recorded from this study in dry season may be attributed to low acidic pH in the soil. Kabata-Pendis (2004) reported that low soil acidity is a stabilizing factor for toxic metals in soil and increases metal solubility in soil. Elevated level of metals in soil may render the soil unsuitable for plant growth and destroy biodiversity (Obute et al., 2010), leading to low productivity of ecosystem (Matthews et al., 2012). According to Jung, (2008) metals dispersed from mine waste are likely retained in the lower plains used for agricultural purposes. Observation from the present study showed that the impaction of the soil by trace metals decreased during the wet season and distance away from points of discharge in both seasons. This could be attributed to reduction in soil acidity and level of pollutants in soil. The correlation between soil physicochemical parameters reported by Osuocha et al. (2015) and the level of trace metals obtained from this study in wet and dry season is in line with this explanation. Munoz-Melendez et al. (2000) noted that heavy metal concentrations in soil solution are generally reduced at neutral or alkaline pH.

Metal accumulation and distribution in plant roots and shoots are influenced by plant species and inherent soil quality. This study generally showed that vegetables cultivated in the quarry effluent discharge soils had significantly higher metal concentrations in roots and shoots than their control counterparts. This could be attributed to high metal content in the quarry mining

Table 3. Comparative assessment of trace metal content of quarry mining effluent discharge soils in wet and dry seasons (mg/kg).

Location	Site	Lead W	Lead D	Cadmium W	Cadmium D	Chromium W	Chromium D	Nickel W	Nickel D	Manganese W	Manganese D	Zinc W	Zinc D
Control		0.89±0.00^{a}	0.93±0.00^{b}	0.18±0.00^{a}	0.52±0.00^{b}	0.61±0.00^{a}	0.73±0.00^{b}	1.33±0.00^{a}	1.67±0.00^{b}	1.09±0.00^{a}	1.49±0.00^{b}	1.15±0.00^{a}	1.99±0.00^{b}
	A	2.87±0.53^{a}	4.78±0.51^{b}	2.570±0.25^{a}	4.63±0.57^{b}	1.29±0.08^{a}	4.13±0.02^{b}	3.70±0.52^{a}	6.09±0.16^{b}	3.05±0.69^{a}	3.50±0.15^{b}	3.39±0.31^{a}	4.33±0.58^{b}
Ezza	B	2.03±0.10^{a}	3.75±0.15^{b}	1.79±0.26^{a}	4.25±0.20^{b}	1.23±0.16^{a}	2.03±0.15^{b}	2.90±0.10^{a}	5.92±0.16^{b}	2.37±0.10^{a}	3.48±0.02^{b}	3.14±0.16^{a}	4.32±0.10^{b}
	C	2.03±0.01^{a}	3.71±0.10^{b}	1.56±0.30^{a}	2.08±0.10^{b}	0.99±0.06^{a}	2.10±0.71^{b}	1.69±0.06^{a}	5.93±0.52^{b}	2.13±0.15^{a}	3.39±0.10^{b}	3.04±0.36^{a}	4.27±0.21^{b}
	A	2.57±0.73^{a}	4.02±0.55^{b}	2.16±0.26^{a}	4.30±0.07^{b}	2.18±0.93^{a}	4.45±0.15^{b}	4.15±0.08^{a}	5.48±0.55^{b}	2.15±0.93^{a}	3.78±0.32^{b}	3.78±0.08^{a}	4.56±0.38^{b}
Crush rock	B	2.39±0.05^{a}	3.93±0.71^{b}	2.11±0.06^{a}	3.27±0.65^{b}	1.98±0.71^{a}	2.30±0.21^{b}	4.08±0.26^{a}	5.26±0.22^{b}	2.05±0.08^{a}	3.34±0.21^{b}	2.99±0.17^{a}	4.43±0.15^{b}
	C	2.14±0.12^{a}	3.92±0.53^{b}	1.09±0.06^{a}	2.26±0.15^{b}	1.98±0.71^{a}	2.07±0.64^{b}	4.08±0.26^{a}	5.21±0.20^{b}	2.05±0.80^{a}	2.99±0.10^{b}	1.68±0.08^{a}	3.29±0.15^{b}
	A	1.97±0.20^{a}	2.95±0.08^{b}	1.41±0.12^{a}	2.82±0.11^{b}	1.34±0.08^{a}	3.02±0.35^{b}	4.70±0.50^{a}	4.93±0.33^{b}	2.28±0.01^{a}	3.07±0.58^{b}	3.63±0.12^{a}	4.05±0.28^{b}
Crush stone	B	1.92±0.10^{a}	2.88±0.21^{b}	1.37±0.52^{a}	2.66±0.26^{b}	1.23±0.73^{a}	1.94±0.06^{b}	3.97±0.78^{a}	4.08±0.16^{b}	2.16±0.16^{a}	2.93±0.21^{b}	3.33±0.53^{a}	3.96±0.20^{b}
	C	1.93±0.55^{a}	2.57±0.20^{b}	1.29±0.16^{a}	2.37±0.06^{b}	1.21±0.15^{a}	1.83±0.50^{b}	2.70±0.20^{a}	3.88±0.15^{b}	2.16±0.10^{a}	2.54±0.10^{b}	2.97±0.26^{a}	2.95±0.57^{b}

Means down the row having different superscript are significantly different (P<0.05). Site A = Soil sample from discharge point, B= soil sample 100m away from discharge point, C = soil sample 200 m away from discharge point. W= wet season, D = dry season.

Table 4. Level of trace metals in shoot of *Cucurbita pepo* vegetable grown in quarry mining effluent discharge soils (mg/kg).

Sample	Wet season						Dry season					
	Lead	Cadmium	Chromium	Nickel	Manganese	Zinc	Lead	Cadmium	Chromium	Nickel	Manganese	Zinc
Control	0.04±0.00^{a}	0.03±0.00^{a}	0.11±0.00^{a}	0.04±0.00^{a}	0.16±0.00^{a}	0.01±0.00^{a}	0.08±0.00^{a}	0.09±0.00^{a}	0.15±0.00^{a}	0.09±0.00^{a}	0.06±0.00^{a}	0.85±0.00^{a}
Ezza	0.16±0.12^{b}	0.07±0.06^{b}	0.20±0.10^{b}	0.42±0.15^{d}	0.19±0.10^{b}	0.29±0.01^{b}	0.97±0.06^{c}	0.76±0.00^{a}	0.85±0.14^{c}	0.99±0.12^{d}	0.65±0.17^{c}	1.10±0.31^{c}
Crush rock	0.82±0.25^{d}	0.19±0.12^{c}	0.50±0.07^{d}	0.32±0.06^{c}	0.53±0.05^{c}	0.23±0.02^{c}	1.07±0.47^{d}	0.64±0.07^{c}	0.90±0.06^{b}	0.79±0.06^{c}	0.82±0.07^{b}	1.50±0.21^{b}
Crushstone	0.44±0.26^{c}	0.25±0.15^{d}	0.39±0.15^{c}	0.20±0.06^{b}	0.75±0.03^{d}	0.53±0.06^{d}	0.88±0.11^{b}	0.49±0.05^{b}	0.85±0.19^{d}	0.75±0.03^{b}	1.05±0.17^{d}	1.28±0.34^{d}
LSD	0.361	0.190	0.185	0.166	0.195	0.054	0.462	0.097	0.233	0.124	0.363	0.478

Means down the column having different superscript are significantly different (P<0.05).

Table 5. Level of trace metals in shoot of *Cucumis sativus* grown in quarry mining effluent discharge soil (mg/kg).

Sample	Wet season						Dry season					
	Lead	Cadmium	Chromium	Nickel	Manganese	Zinc	Lead	Cadmium	Chromium	Nickel	Manganese	Zinc
Control	0.08±0.00^{a}	0.01±0.00^{a}	0.07±0.00^{a}	0.06±0.00^{a}	0.02±0.00^{a}	0.04±0.00^{a}	0.12±0.00^{a}	0.13±0.00^{a}	0.07±0.00^{a}	0.11±0.00^{a}	0.20±0.00^{a}	0.77±0.00^{a}
Ezza	0.23±0.01^{b}	0.93±0.06^{c}	0.69±0.06^{b}	0.47±0.10^{b}	0.30±0.06^{c}	0.07±0.01^{a}	0.78±0.23^{d}	0.86±0.13^{c}	0.56±0.11^{d}	0.91±0.12^{c}	0.71±0.16^{c}	1.23±0.20^{c}
Crush rock	0.15±0.03^{c}	0.04±0.02^{b}	0.63±0.10^{c}	0.86±0.11^{c}	0.19±0.03^{b}	0.14±0.06^{b}	0.82±0.21^{c}	0.80±0.06^{b}	0.72±0.08^{c}	0.81±0.27^{d}	0.95±0.04^{b}	1.39±0.10^{d}
Crushstone	0.59±0.06^{d}	0.26±0.27^{d}	0.56±0.24^{d}	0.60±0.10^{b}	0.67±0.14^{d}	0.45±0.45^{c}	0.79±0.06^{b}	0.81±0.12^{d}	0.69±0.05^{b}	0.94±0.06^{d}	1.07±0.25^{d}	1.09±0.06^{b}
LSD	0.066	0.259	0.250	0.182	0.1483	0.429	0.299	0.175	0.0135	0.123	0.292	0.065

Means down the column having different superscript are significantly different (P<0.05).

Table 6. Level of trace metals in shoot of *Taliferia occidentalis* grown in quarry mining effluent discharge soil (mg/kg).

Location	Wet season						Dry season					
	Lead	Cadmium	Chromium	Nickel	Manganese	Zinc	Lead	Cadmium	Chromium	Nickel	Manganese	Zinc
Control	0.06±0.00^{a}	0.09±0.00^{a}	0.05±0.00^{a}	0.03±0.00^{a}	0.12±0.00^{a}	0.01±0.00^{a}	0.06±0.00^{a}	0.17±0.00^{a}	0.20±0.00^{a}	0.14±0.00^{a}	0.90±0.00^{a}	0.81±0.00^{a}
Ezza	0.17±0.03^{b}	0.49±0.01^{d}	0.24±0.05^{b}	0.32±0.10^{b}	0.40±0.18^{d}	0.11±0.10^{b}	0.97±0.49^{d}	0.54±0.30^{d}	0.65±0.06^{b}	0.81±0.13^{c}	0.75±0.02^{b}	1.33±0.50^{c}
Crush rock	0.61±0.12^{c}	0.43±0.06^{c}	0.51±0.76^{d}	0.63±0.12^{c}	0.34±0.06^{c}	0.39±0.09^{d}	0.87±0.16^{c}	0.87±0.16^{c}	0.77±0.21^{c}	0.56±0.06^{b}	0.66±0.22^{d}	1.25±0.35^{d}
Crushstone	0.21±0.18^{d}	0.14±0.02^{b}	0.47±0.21^{c}	0.57±0.73^{d}	0.25±0.03^{b}	0.55±0.52^{c}	0.67±0.15^{b}	0.33±0.10^{b}	0.82±0.06^{b}	0.90±0.06^{b}	0.85±0.03^{c}	1.21±0.16^{b}
LSD	0.202	0.058	0.261	0.213	0.298	0.995	0.509	0.331	0.211	0.144	0.209	0.0596

Means down the column having different superscript are significantly different (P<0.05).

Table 7. Comparative assessment of trace metal content in shoot of *Cucurbita pepo* vegetable in wet and dry season (mg/kg).

Location	Lead W	Lead D	Cadmium W	Cadmium D	Chromium W	Chromium D	Nickel W	Nickel D	Manganese W	Manganese D	Zinc W	Zinc D
Control	0.04±0.00^{a}	0.08±0.00^{b}	0.03±0.00^{a}	0.09±0.00^{b}	0.11±0.00^{a}	0.15±0.00^{b}	0.04±0.00^{a}	0.09±0.00^{b}	0.16±0.00^{a}	0.06±0.00^{b}	0.01±0.00^{a}	0.85±0.00^{b}
Ezza	0.16±0.12^{a}	0.97±0.06^{b}	0.07±0.06^{a}	0.76±0.00^{b}	0.20±0.10^{a}	0.85±0.14^{b}	0.42±0.15^{a}	0.99±0.12^{b}	0.19±0.10^{a}	0.65±0.17^{b}	0.02±0.01^{a}	1.10±0.31^{b}
Crushrock	0.82±0.25^{a}	1.07±0.47^{b}	0.19±0.12^{a}	0.64±0.07^{b}	0.50±0.07^{a}	0.90±0.06^{b}	0.32±0.06^{a}	0.79±0.06^{b}	0.53±0.05^{a}	0.82±0.07^{b}	0.23±0.02^{a}	1.50±0.21^{b}
Crushstone	0.44±0.26^{a}	0.88±0.11^{b}	0.25±0.15^{a}	0.49±0.05^{b}	0.39±0.15^{a}	0.85±0.19^{b}	0.20±0.06^{a}	0.75±0.03^{b}	0.76±0.34^{a}	1.05±0.17^{b}	0.53±0.06^{a}	1.28±0.34^{b}

Means in the same row having different superscript are significantly different (P<0.05). W= Wet season, D = dry season.

Table 8. Comparative assessment of trace metal content in shoot of *Cucumis sativus* in wet and dry season (mg/kg).

Location	Lead W	Lead D	Cadmium W	Cadmium D	Chromium W	Chromium D	Nickel W	Nickel D	Manganese W	Manganese D	Zinc W	Zinc D
Control	0.08±0.00^{a}	0.12±0.00^{b}	0.01±0.00^{a}	0.13±0.00^{b}	0.07±0.00^{a}	0.07±0.00^{b}	0.06±0.00^{a}	0.11±0.00^{b}	0.02±0.00^{a}	0.20±0.00^{b}	0.04±0.00^{a}	0.77±0.00^{b}
Ezza	0.23±0.01^{a}	0.78±0.23^{b}	0.09±0.06^{a}	0.86±0.13^{b}	0.69±0.06^{a}	0.56±0.11^{b}	0.47±0.10^{a}	0.91±0.12^{b}	0.30±0.06^{a}	0.71±0.16^{b}	0.07±0.01^{a}	1.23±0.20^{b}
Crushrock	0.15±0.03^{a}	0.82±0.21^{b}	0.04±0.02^{a}	0.80±0.06^{b}	0.63±0.10^{a}	0.72±0.08^{b}	0.86±0.11^{a}	0.81±0.27^{b}	0.19±0.03^{a}	0.95±0.04^{b}	0.14±0.06^{a}	1.39±0.10^{b}
Crushstone	0.59±0.06^{a}	0.79±0.06^{b}	0.26±0.27^{a}	0.81±0.12^{b}	0.56±0.24^{a}	0.69±0.05^{b}	0.60±0.10^{a}	0.94±0.06^{b}	0.67±0.14^{a}	1.07±0.25^{b}	0.45±0.45^{a}	1.09±0.06^{b}

Means in the same row having different superscript are significantly different (P<0.05). W = wet season, D = dry season.

effluent discharge soil which was eventually taken up by these vegetables. This agrees with the findings of Oluyemi et al. (2008) who reported that plants grown on land polluted with industrial wastes can absorb high level of metals present in the soil solution through their root or through foliar absorption. Findings from the study showed that level of trace metals in roots and shoots of vegetables in dry season were generally higher compared to wet season. This could be attributed to increased amount of soil trace metals in dry season compared to wet season (Tables 1 to 3).

Table 9. Comparative assessment of trace metal content in shoot of *Taliferia occidentalis* vegetable in wet and dry season (mg/kg).

Location	Lead W	Lead D	Cadmium W	Cadmium D	Chromium W	Chromium D	Nickel W	Nickel D	Manganese W	Manganese D	Zinc W	Zinc D
Control	0.06 ± 0.00^{a}	0.06 ± 0.00^{b}	0.09 ± 0.00^{a}	0.17 ± 0.00^{b}	0.05 ± 0.00^{a}	0.20 ± 0.00^{b}	0.03 ± 0.00^{a}	0.14 ± 0.00^{b}	0.12 ± 0.00^{a}	0.90 ± 0.00^{b}	0.01 ± 0.00^{a}	0.81 ± 0.00^{b}
Ezza	0.17 ± 0.03^{a}	0.97 ± 0.49^{b}	$0.49^{a}\pm0.01^{a}$	0.54 ± 0.30^{b}	0.24 ± 0.05^{a}	0.65 ± 0.06^{b}	0.32 ± 0.10^{a}	0.81 ± 0.13^{b}	0.40 ± 0.18^{a}	0.75 ± 0.02^{b}	0.11 ± 0.10^{a}	1.33 ± 0.50^{b}
Crushrock	0.61 ± 0.12^{a}	0.87 ± 0.16^{b}	0.43 ± 0.06^{a}	0.87 ± 0.16^{b}	0.51 ± 0.176^{a}	0.77 ± 0.21^{b}	0.63 ± 0.12^{a}	0.56 ± 0.06^{b}	0.34 ± 0.06^{a}	0.66 ± 0.22^{b}	0.39 ± 0.09^{a}	1.25 ± 0.35^{b}
Crushstone	0.21 ± 0.18^{a}	0.67 ± 0.15^{b}	0.14 ± 0.02^{a}	0.33 ± 0.10^{b}	0.47 ± 0.21^{a}	0.82 ± 0.06^{b}	0.57 ± 0.73^{a}	0.90 ± 0.06^{b}	0.25 ± 0.03^{a}	0.85 ± 0.03^{b}	0.55 ± 0.52^{a}	1.21 ± 0.16^{b}

Means in the same row having different superscript are significantly different (P<0.05).W=wet season, D =dry season.

Table 10. Level of trace metals in root of *Cucurbita pepo* grown in quarry mining effluent discharge soils (mg/kg).

Location	Wet season						Dry season					
	Lead	Cadmium	Chromium	Nickel	Manganese	Zinc	Lead	Cadmium	Chromium	Nickel	Manganese	Zinc
control	0.23 ± 0.00^{b}	0.05 ± 0.00^{a}	0.21 ± 0.00^{a}	0.07 ± 0.00^{b}	1.02 ± 0.00^{c}	0.04 ± 0.00^{a}	0.63 ± 0.00^{a}	0.14 ± 0.00^{a}	0.61 ± 0.00^{a}	0.35 ± 0.00^{a}	0.12 ± 0.00^{a}	0.41 ± 0.00^{a}
Ezza	0.19 ± 0.00^{a}	0.23 ± 0.02^{b}	0.26 ± 0.10^{b}	0.06 ± 0.06^{a}	0.32 ± 0.10^{a}	0.06 ± 0.10^{b}	1.07 ± 0.06^{b}	1.72 ± 0.10^{d}	1.93 ± 0.10^{d}	1.89 ± 0.95^{d}	1.86 ± 0.01^{d}	0.95 ± 0.11^{c}
Crush rock	1.05 ± 0.06^{d}	0.27 ± 0.10^{c}	0.83 ± 0.01^{d}	0.57 ± 0.10^{d}	1.03 ± 0.16^{d}	0.32 ± 0.06^{c}	1.93 ± 0.10^{d}	1.60 ± 0.10^{c}	1.64 ± 0.38^{c}	1.05 ± 0.10^{b}	1.35 ± 0.06^{b}	1.22 ± 0.06^{d}
Crush stone	0.46 ± 0.10^{c}	0.28 ± 0.10^{d}	0.48 ± 0.31^{c}	0.48 ± 0.10^{c}	0.62 ± 0.13^{b}	0.78 ± 0.11^{d}	1.48 ± 0.10^{c}	1.03 ± 0.110^{b}	1.55 ± 0.10^{b}	1.63 ± 0.10^{c}	1.72 ± 0.15^{c}	0.88 ± 0.05^{b}
LSD	0.144	0.910	0.163	0.016	0.196	0.144	0.144	0.163	0.381	0.906	0.144	0.144

Means down the column having different superscripts are significantly different (P<0.05)

Table 11. Comparative evaluation of trace metals in root of *Cucurbita pepo* grown in quarry mining effluent discharge soils in wet and dry seasons (mg/kg).

Location	Lead W	Lead D	Cadmium W	Cadmium D	Chromium W	Chromium D	Nickel W	Nickel D	Manganese W	Manganese D	Zinc W	Zinc D
Control	0.23 ± 0.00^{a}	0.63 ± 0.00^{b}	0.05 ± 0.00^{a}	0.14 ± 0.00^{b}	0.21 ± 0.00^{a}	0.61 ± 0.00^{b}	0.07 ± 0.00^{a}	0.35 ± 0.00^{b}	1.02 ± 0.00^{a}	0.12 ± 0.00^{b}	0.04 ± 0.00^{a}	0.41 ± 0.00^{b}
Ezza	0.19 ± 0.00^{a}	1.07 ± 0.06^{b}	0.23 ± 0.02^{a}	1.72 ± 0.10^{b}	0.26 ± 0.10^{a}	1.93 ± 0.10^{b}	0.06 ± 0.06^{a}	1.89 ± 0.95^{b}	0.32 ± 0.10^{a}	1.86 ± 0.01^{b}	0.06 ± 0.10^{a}	0.95 ± 0.11^{b}
Crush rock	1.05 ± 0.06^{a}	1.93 ± 0.10^{b}	0.27 ± 0.10^{a}	1.60 ± 0.10^{b}	0.83 ± 0.01^{a}	1.64 ± 0.38^{b}	0.57 ± 0.10^{a}	1.05 ± 0.10^{b}	1.03 ± 0.16^{a}	1.35 ± 0.06^{b}	0.32 ± 0.06^{a}	1.22 ± 0.06^{b}
Crush stone	0.46 ± 0.10^{a}	1.48 ± 0.10^{b}	0.28 ± 0.10^{a}	1.03 ± 0.10^{b}	0.48 ± 0.31^{a}	1.55 ± 0.10^{b}	0.48 ± 0.10^{a}	1.63 ± 0.10^{b}	0.62 ± 0.13^{a}	1.72 ± 0.15^{b}	0.78 ± 0.11^{a}	0.88 ± 0.05^{b}

Values in the same row having different superscript are significantly different (P<0.05). W= Wet season, D= Dry season.

This also agrees with the findings of Ayari et al. (2010) that concentration of metals in plant is dependent on their concentration in soil. The relationship between toxic metals and soil pH has been reported to influence the absorbability of the element from the soil solution which consequently interfere with their translocation into plants parts (Liu et al., 2005). Low acidic pH as observed from the study in dry season could affect metal solubility in soil and hence increased phyto-availability of these metals in plants parts. Low acidic pH has been reported to influence the

Table 12. Level of trace metals in root of *Cucumis sativus* grown in quarry mining effluent discharge soils (mg/kg).

Location	Wet season						Dry season					
	Lead	Cadmium	Chromium	Nickel	Manganese	Zinc	lead	Cadmium	Chromium	Nickel	Manganese	Zinc
Control	0.31±0.00^{b}	0.03±0.00^{a}	0.12±0.00^{a}	0.09±0.00^{a}	0.06±0.00^{a}	0.09±0.00^{a}	1.01±0.00^{a}	0.11±0.00^{a}	0.53±0.00^{a}	0.21±0.00^{a}	0.15±0.00^{a}	0.33±0.00^{a}
Ezza	0.21±0.11^{a}	0.18±0.10^{b}	0.28±0.06^{b}	0.12±0.06^{b}	0.41±0.20^{b}	0.11±0.10^{b}	2.03±0.10^{d}	1.25±0.21^{c}	1.71±0.10^{c}	1.18±0.10^{c}	1.98±0.10^{c}	1.78±0.10^{c}
Crushrock	0.38±0.31^{c}	0.53±0.06^{c}	1.14±0.16^{d}	0.93±0.10^{d}	0.48±0.10^{c}	0.21±0.16^{c}	1.96±0.35^{c}	1.98±0.05^{d}	1.8±0.07^{d}	1.12±0.07^{b}	1.13±0.06^{b}	1.32±0.07^{b}
Crush stone	0.73±0.01^{d}	0.87±0.10^{d}	0.76±0.44^{c}	0.88±0.10^{c}	1.07±0.05^{d}	0.64±0.10^{d}	1.13±0.10^{b}	1.19±0.23^{b}	1.69±0.03^{b}	1.83±0.10^{d}	1.77±0.21^{d}	1.91±0.09^{d}
LSD	0.163	0.193	0.439	0.144	0.144	0.196	0.357	0.163	0.163	0.163	0.225	0.164

Means down the column having different superscripts are significantly different (P<0.05).

Table 13. Comparative evaluation of trace metal in root of *Cucumis sativus* grown in quarry mining effluent discharge soils (mg/kg).

Sample	Lead W	Lead D	Cadmium W	Cadmium D	Chromium W	Chromium D	Nickel W	Nickel D	Manganese W	Manganese D	Zinc W	Zinc D
Control	0.31±0.00^{a}	1.01±0.00^{b}	0.03±0.00^{a}	0.11±0.00^{b}	0.12±0. 00^{a}	0.53±0.00^{b}	0.09±0.00^{a}	0.21±0.00^{b}	0.06±0.00^{a}	0.15±0.00^{b}	0.09±0.00^{a}	0.33±0.00^{b}
Ezza	0.21±0.11^{a}	2.03±0.10^{b}	0.18±0.10^{a}	1.25±0.21^{b}	0.28±0.06^{a}	1.71±0.10^{b}	0.12±0.06^{a}	1.18±0.10^{b}	0.41±0.20^{a}	1.98±0.10^{b}	0.11±0.10^{a}	1.78±0.10^{b}
Crush rock	0.38±0.31^{a}	1.96±0.35^{b}	0.53±0.06^{a}	1.98±0.05^{b}	1.14±0.16^{a}	1.8±0.07^{b}	0.93±0.10^{a}	1.12±0.07^{b}	0.48±0.10^{a}	1.13±0.06^{b}	0.21±0.16^{a}	1.32±0.07^{b}
Crush stone	0.73±0.01^{a}	1.13±0.10^{b}	0.87±0.10^{a}	1.19±0.23^{b}	0.76±0.44^{a}	1.69±0.03^{b}	0.88±0.10^{a}	1.83±0.10^{b}	1.07±0.05^{a}	1.77±21^{b}	0.64±0.10^{a}	1.91±0.09^{b}

Values in the same row having different superscript are significantly different (P<0.05). W= Wet season, D= Dry season.

Table 14. Level of trace metals in root of *Taliferia occidentalis* grown in quarry mining effluent discharge soils (mg/kg).

	Wet season						Dry season					
Location	Lead	Cadmium	Chromium	Nickel	Manganese	Zinc	lead	Cadmium	Chromium	Nickel	Manganese	Zinc
Control	0.09±0.00^{a}	0.19±0.00^{a}	0.09±0.00^{a}	0.01±0.00^{a}	0.07±0.00^{a}	0.03±0.00^{a}	0.17±0.00^{a}	0.67±0.10^{a}	0.44±0.00^{a}	0.16±0.00^{a}	0.10±0.00^{a}	0.29±0.00^{a}
Ezza	0.26±0.10^{b}	1.31±0.05^{c}	1.23±0.06^{d}	0.09±0.01^{b}	0.20±0.76^{b}	0.18 0.01^{b}	1.02±0.10^{b}	1.87±0.25^{d}	1.44±0.15^{c}	1.28±0.09^{b}	1.55±0.10^{b}	1.57±0.16^{c}
Crush rock	0.77±0.10^{d}	1.34±0.01^{d}	0.42±0.51^{b}	0.77±0.23^{d}	1.25±0.32^{c}	1.18±0.01^{d}	1.94±0.12^{d}	1.05±0.00^{b}	1.12±0.10^{b}	1.4±0.10^{c}	1.64±0.06^{c}	1.77±0.06^{d}
Crush stone	0.32±0.00^{c}	1.00±0.10^{b}	0.61±0.10^{c}	0.73±0.15^{c}	1.52±0.10^{d}	0.46±0.21^{c}	1.22±0.09^{c}	1.77±0.01^{c}	1.67±0.15^{d}	1.94±0.35^{d}	1.88 0.10^{d}	1.05±0.05^{b}
LSD	0.163	0.144	0.144	0.196	0.503	0.163	0.163	0.037	0.225	0.357	0.163	0.163

Means down the column having different superscripts are significantly different (P<0.05).

translocation of metals into plant tissues (Oluyemi et al., 2008; Sherene, 2012). This increase in phytoavailability of metals in low acidic pH has been reported to be due to the fact that protons have high affinity for negative charges present on colloids which come into competition with metal ions inducing ion exchange of metals ions in soil pore water (Tshibangu et al., 2014). The increase in metal concentration of vegetables in dry season could also be due to the fact that during dry season, dust particles generated due to blasting of rock are deposited on plants leaves which

Table 15. Comparative evaluation of trace metals in root of *Teliferia occidentalis* grown in quarry mining effluent discharge soils in wet and dry season (mg/kg).

Location	Lead W	Lead D	Cadmium W	Cadmium D	Chromium W	Chromium D	Nickel W	Nickel D	Manganese W	Manganese D	Zinc W	Zinc D
Control	0.09±0.00[a]	0.17±0.00[a]	0.19±0.00[a]	0.67±0.10[a]	0.09±0.00[a]	0.44±0.00[a]	0.01±0.00[a]	0.16±0.00[a]	0.07±0.00[a]	0.10±0.00[a]	0.03±0.00[a]	0.29±0.00[a]
Ezza	0.26±0.10[b]	1.02±0.10[b]	1.31±0.05[c]	1.87±0.25[d]	1.23±0.06[d]	1.44±0.15[c]	0.09±0.01[b]	1.28±0.09[b]	0.20±0.76[b]	1.55±0.10[b]	0.18 ±0.01[b]	1.57±0.16[c]
Crush rock	0.77±0.10[d]	1.94±0.12[d]	1.34±0.01[d]	1.05±0.00[b]	0.42±0.51[b]	1.12±0.10[b]	0.77±0.23[d]	1.4±0.10[c]	1.25±0.32[c]	1.64±0.06[c]	1.18±0.01[d]	1.77±0.06[d]
Crush stone	0.32±0.00[c]	1.22±0.09[c]	1.00±0.10[b]	1.77±0.01[c]	0.61±0.10[c]	1.67±0.15[d]	0.73±0.15[c]	1.94±0.35[d]	1.52±0.10[d]	1.88± 0.10[d]	0.46±0.21[c]	1.05±005[b]

Values in the same row having different superscript are significantly different (P<0.05). W= Wet season, D= Dry season.

might get translocated into the plants system through foliar absorption and increase metal load of these vegetables. This process of foliar absorption may be more pronounced in dry season due to the persistence of these dust particles on plants leaves. This is however absent in wet season due to constant washing of the leaves by rainfall. Water evaporation from soil during dry season together with dehydration of plant leaves has been reported to increase metal concentration in plants root and leaves (Fatoki, 2000). Farm irrigation with metal contaminated water as observed from the study may also contribute to high metal concentration of these vegetables. This finding is in conformity with the reported of Sherene (2012) that farms irrigated with contaminated water are likely to absorb high level of metals. This study revealed that level of the studied trace metals in roots of these vegetables was higher than their level in shoots in wet and dry seasons (Tables 4 to 15). This demonstrate that the vegetables retained the studied metals in their roots but limits their mobility from roots to shoots once absorbed from the soil by the roots of the plants. This study in general showed that the vegetables grown in quarry mining sites accumulated high level of metals in plants parts than their counterparts in control sites. Similar findings were reported by Ebong et al. (2007, 2008) and Akubugwo et al. (2013) who undertook similar studies.

Conclusion

The study revealed that vegetables grown in mining effluent discharge soils accumulated high levels of trace metals compared to those from the control site. The level of accumulation was more in dry season than wet season. This indicates potential health risk associated with prolonged consumption of edible vegetables grown in these soils. Therefore planting of vegetables close to these mining sites should be discouraged.

Conflict of Interests

The authors did not declare any conflict of interest.

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