

Heavy metal contamination of Cassava (*Manihot esculenta* Crantz) grown on quarry soils in Umunneochi Abia State and its health implications

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Abstract

Contamination of agricultural soils by quarry activities is posing serious challenges to food security in greater parts of the Sub-Saharan Africa. This study determined the heavy metals in soils and cassava (*Manihot esculenta* Crantz) tubers obtained from three different quarry sites in Umunneochi, Abia State Nigeria. Samples of soil and cassava tubers were collected in replicates following the direction of natural drainage, while control samples were obtained against the direction of natural drainage from the quarry pits. Soil and Cassava tuber samples were collected and subjected to standard physicochemical analyses. Heavy metal concentration in the quarry soil and cassava tubers varied significantly from the control except for Cd (mg/kg) at $P < 0.05$. All heavy metals identified in the soil were also present in the cassava tuber samples, with Al concentration in the quarry soils correlating positively (0.977**) with that of Cassava tubers. The quarry activities contributed to the heavy metal levels of quarry soils and responsible for the accumulation of heavy metals in cassava tubers that could lead to food insecurity and public health concerns. This further brings to fore the challenges and need to review and update mining and quarry regulations in Nigeria.

Keywords

Quarries, heavy metals, soil conservation, Cassava, food insecurity, public health

Introduction

Quarry and mining activities are identified as a major ecosystem and are largely responsible for growing cause of heavy metal contamination of the agro- amount of pollutants in soil. These mining activities

are well known for their deleterious effect on the environment due to the deposition of large volumes of wastes on soil (Nouri et al., 2009).

Soil is one of the repositories for anthropogenic wastes and soil being an important component of terrestrial ecosystem supports plant growth and biogeochemical cycling of nutrients, the waste from quarry activities end up interacting with the soil system thereby changing the physical and chemical properties. Akubugwo et al. (2013) reported that soil heavy metal contamination results in the uptake of metals by plants causing accumulation of these metals in plant tissues, reduced crop quality and increased phytotoxicity. Vousta et al. (1996) demonstrated that high level of heavy metals in soil could indicate similar concentration in plants by accumulation at high concentration causing serious risk to human health when consumed. Moreover, Fu et al. (2008) reported that accumulation of heavy metals in crops grown in metal - polluted soil may easily cause damaging effect on human health through food chain. Excessive concentration of these metals in food is associated with aetiology of a number of diseases (WHO, 1995). Some heavy metals like As, Cd and Pb have been reported to have no known bio-importance in human biochemistry and physiology and consumption even at very low concentrations can be toxic (Nolan, 2003).

Due to the non-biodegradable and persistent nature, heavy metals accumulates in vital organs in the human body such as the kidneys, bones and liver and are associated with numerous serious health disorders (Duruibe et al., 2007). Individual metals exhibit specific signs of their toxicity. Lead, As, Hg, Zn, Cu and Al poisoning have been implicated with gastrointestinal (GI) disorders (Nolan, 2003). Cassava (*Manihot esculenta*) is a major staple food in Abia State and beyond. This root crop is commercially cultivated for source of staple food (carbohydrate) in many African countries. Therefore, there is need to continuously assess the impact of quarry activities on arable soils since it can potentially cause public health problem.

Materials and Methods

Description of Study Area

The study area is Eziam, Lokpauku, Umuchieze community in Umunneochi Local Government area of Abia State, South-East Nigeria as shown in Figure 1. The area is characterized by sandy soil than clay soil as classified using (USDA, 1999). The two major climatic

conditions are rainy and dry seasons with average temperature of 20°C and annual rainfall of 25.8cm. Umunneochi is made up of the following communities: Ngodo, Lokpaukwu, Leru, Lomara Lokpanta, Lekwesi and Mbala. The major occupations of the Umunneochi people include agriculture, trading and mining of granite, quorite and laterite. The communities cultivate the following food crops: cassava, yam, black beans and cocoyam and cash crops like palm nuts and cashew nuts. Umunneochi has a land area of 368 km² and a population of 163,928 (National Population Commission, 2006).

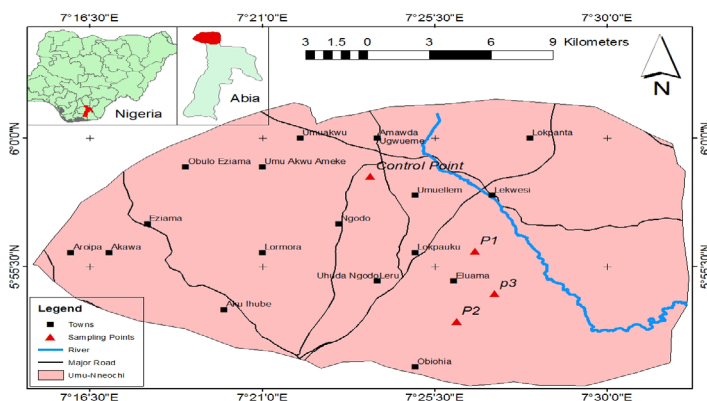


Figure 1. Map of Nigeria showing the sample locations.

Sample Collection

Soil Sample Collection. Soil samples were collected from farms 200m from Asphalt Quarry Company site in Ugbugdu (SQ₁), A-K-T Hard rock Quarries site in Ugwu (SQ₂) and Sino Quarrying Company in Iyiam, (SQ₃) and control soil sample was collected from farm land, 1km away from quarry activities, with the aid of a well calibrated hand dug soil auger at the depth of 0-30cm each. The soil samples were properly homogenized and packaged in a clean plastic container and immediately transported to the laboratory for standard physicochemical analysis.

Cassava samples collection. Cassava tubers (*Manihot esculenta*) were collected from the same sites as the soil samples (SQ₁, SQ₂, and SQ₃) and control farms with the aid of a clean spade, and separately peeled and washed with fresh running water to remove dirt, dust, and other contaminating agents.

Samples preparation and digestion

Soil samples preparation and digestion. The method of Soon and Hendershot (2006) was adopted in this analysis. 1 g of soil sample was digested in 250ml conical flask by adding 30ml of aqua regia and heated

on a hot plate until volume remains about 7-12ml. The digest was filtered using What-man filter paper and the volume made up to the mark in a 50ml volumetric flask, and stored in a plastic container for heavy metal analysis with Atomic Absorption Spectrophotometer (AAS). This was repeated three times and measurements standardized according the description of Vittori et al. (2014).

Cassava Samples Preparation and Digestion. The Cassava samples were rinsed with deionised water for more cleaning. The samples were sliced into separate clean plastic bowls using stainless steel knife and grounded with clean porcelain mortar and pestle. Each grounded tuber sample was kept in separate clean plastic bowl and labelled. A homogeneous solution of 650ml conc. HNO_3 , 80ml perchloric acid and 20ml conc. H_2SO_4 was prepared. 1g of the wet homogenized Cassava samples was weighed into digestion flask and 20ml of the prepared acid mixture was added. To increase the solubility, the sample solution was heated on hot plate at 130°C until the volume was reduced to 3 ml. Then, the solution was cooled and filtered into 25 ml volumetric flask using Whatman 42 filter paper. The filtrate was diluted up to the mark with distilled water (Khan et al., 2008).

Sample analysis

Physicochemical analysis of soil sample

Texture Classification. Fifty grams of dry screened soil (use 100g for sandy soils) was weighed into a 250ml beaker. 100ml Five percent (5%) calgon solution was added, stir and let stand overnight.

1. Transfer to a dispersion cup. Add 2 to 3 drops of oil place the dispersion cup on the hum bolt mixer and mix for 2 minutes.
2. Transfer graduated cylinder and bring to 1000ml mark with deionized water for sandy soils, dilute to 1120ml
3. Stir thoroughly using the weighted disc shaped bar. Alternatively, invert the cylinder 10 times. Immediately place the hydrometer and the thermometer into the slurry. Record the hydrometer reading and the temperature 40 seconds after the last mixing stroke or inversion
4. Let stand for 2hours and again record the hydrometer reading and the temperature.
5. Analyst a blank in the same manner using 100ml 5% calgon solution diluted to 980ml. for sandy soil the blank should consist of 100ml 5% calgon solution diluted to 1080ml.

Calculations:

A = Sample hydrometer reading + temperature correction*

B = Blank hydrometer reading + temperature correction*

*Temperature Correction: Add 0.2 units to the hydrometer reading for each degree above 67°f . Subtract 0.2 units to the hydrometer reading for each degree under 67°f .

- i) 40 second reading
 - (a) % silt + % clay = [(A-B):- wt. soil]* 100
 - (b) % sand = 100 - % (silt + clay)
- ii) 2hour reading
 - (a) % clay = [(A-B):- wt.soil]* 100
- iii) Determination of Silt
 - (a) % silt = 100 - % sand - % clay

Determination of pH and Conductivity. The pH of the soil sample were determined using a Jewniary digital pH meter in a sample to water ratio of 1:10 that is twenty grams (20g) of each sample was weighed in a beaker. Then two hundred millilitres (200ml) of distilled water was added to it. The pH electrode was dipped into the solution and the reading was accurately recorded. Also the conductivity electrode was dipped and its reading was recorded.

Determination of Total Nitrogen. Total Nitrogen concentration was determined by Kjehdahl digestion method using concentrated H_2SO_4 and a Sodium Copper Sulphate catalyst mixture (Brenner and Yeomans, 1988).

Determination of Cation Exchange Capacity. The method used by Burt (2004) was adopted.

Determination of Phosphate. Phosphate was extracted using 0 sample of sodium bicarbonate at soil water ratio of 1:25. The extracted phosphate was reacted with phosphate reagent/ Ammonium molybdate under reducing conditions in acidic solution to form a blue cultured complex. The intensity of the blue coloration is proportional to the phosphate level in the soil is determined by Amino acid method. The phosphate was then determined in the sample by using multi-parameter photometer.

Determination of Total Organic Carbon (TOC). One (1) grams of the sample can be weighed then 10mls of 0.5M $\text{K}_2\text{Cr}_2\text{O}_7$ added to it followed by 20ml of concentrated H_2SO_4 . The organic carbon was determined by the Walkley black method.

Determination of Heavy Metals. Atomic absorption spectrophotometer (AAS) model FS240AA was used for analyzing the aforementioned heavy metals.

Statistical analysis

Data collected were subjected to statistical analysis using one way analysis of variance (ANOVA) procedure by IBM SPSS (2012 Version).

Results

The result of the physicochemical characteristics of soil samples were as show in table1. Concentrations of heavy metals in the soil and the cassava samples were shown in table 2 and table 3 respectively. Correlation between the physicochemical and heavy metals, and concentrations of heavy metals in soil and cassava tuber were also shown in tables 4 and 5 respectively.

Variation in Physicochemical Characteristic. The variation in physicochemical characteristics was shown in table1. The pH, EC ($\mu\text{S}/\text{cm}$), TOC (mg/kg), PO_4^{2-} (mg/kg), TN (%), Clay (mg/kg) and Silt (mg/kg), showed significant variations ($P = 0.000$) at all the sampling points; SQ₁, SQ₂ and SQ₃ with CS. Control sample and SQ₁ were alkaline, while others samples SQ₂ and SQ₃ were slightly alkaline.

Note that a, b and c are the different Turkey groupings. Values with same superscripts along same row are not significantly different, while values with different superscripts along same row are significantly different at $P < 0.05$.

Table 1. Physicochemical properties of the soil samples.

Parameters	SQ1	SQ2	SQ3	CS	P-value
pH	8.62±0.017 ^b	7.30±0.01 ^d	7.65±0.01 ^c	9.53±0.04 ^a	0.000
EC ($\mu\text{S}/\text{cm}$)	80.00±5.77 ^c	110.00±5.77 ^b	113.33±3.33 ^b	326.67±3.33 ^a	0.000
CEC (mg/kg)	23.54±0.00 ^a	14.78±0.04 ^b	11.18±0.60 ^c	24.42±0.20 ^a	0.000
TOC (%)	45.13±1.05 ^c	75.31±0.68 ^a	43.33±1.32 ^c	0.57±0.75 ^b	0.000
PO_4^{2-} (mg/kg)	0.33±0.03 ^d	1.33±0.15 ^c	2.70±0.06 ^a	2.20±0.12 ^b	0.000
TN (%)	42.33±0.88 ^a	29.00±0.58 ^c	32.33±0.88 ^b	17.73±0.46 ^d	0.000
Clay (%)	26.74±0.89 ^a	20.56±0.73 ^b	18.66±1.03 ^b	0.00±0.00 ^c	0.000
Sand (%)	72.10±0.96 ^c	73.06±3.18 ^c	79.87±0.82 ^b	97.67±0.07 ^a	0.000
Silt (%)	1.15±0.10 ^c	3.05±0.02 ^a	1.47±0.22 ^c	2.33±0.07 ^b	0.000

Variations in concentration of heavy metals in soils across the sampling locations. The variations in concentration of heavy metals in soils across the sampling locations were shown in table 2. All heavy

metals showed significant variation ($p = 0.00$) at all the sampling points (SQ₁, SQ₂, SQ₃ and CS), excepting Cd that did not show variation ($p = 0.50$) from all the sampling points.

Table 2. Variations in concentration of heavy metals in soils across the sampling locations. (<0.05)

Parameters (mg/kg)	SQ1	SQ2	SQ3	CS	P-value
Ni	1.39±0.04 ^b	2.21±0.02 ^a	1.30±0.02 ^b	0.06±0.04 ^c	0.00
Mn	12.04±0.17 ^c	35.25±0.18 ^a	29.88±0.15 ^b	0.72±0.01 ^d	0.00
Co	0.50±0.05 ^c	1.48±0.04 ^a	1.12±0.04 ^b	0.10±0.03 ^d	0.00
Pb	0.36±0.01 ^b	0.43±0.01 ^a	0.25±0.01 ^c	0.14±0.01 ^d	0.00
Cd	0.11±0.08 ^a	0.61±0.02 ^a	0.04±0.02 ^a	0.02±0.01 ^a	0.50
Cr	0.40±0.05 ^c	1.91±0.19 ^a	0.92±0.14 ^b	0.31±0.14 ^c	0.00
Fe	422.05±0.00 ^b	436.36±0.00 ^b	432.21±0.00 ^b	353.58±0.00 ^a	0.00
Al	14.65±0.25 ^a	12.87±0.43 ^{ab}	11.93±0.92 ^b	4.12±1.15 ^c	0.00

Variations in concentration of heavy metals in cassava tuber across the sampling locations. The variations in concentration of heavy metals in cassava across the sampling locations were shown in table 3. Manganese (Mn) showed significant variation ($p=0.042$) at all the

sampling points (SQ₁, SQ₂, SQ₃ and CS). Pb showed similar trend in variation with Mn at all sampling points. Fe and Al showed significant variation ($p=0.000$) at all the sampling points, while Ni, Co, Cd and Cr did not show significant variation at all the sampling points.

Table 3. Variation in concentrations of heavy metals in Cassava samples across the sampling locations ($P<0.05$).

Parameters (mg/kg)	SQ1	SQ2	SQ3	CS	P-value
Ni	0.05±0.51 ^a	0.04±0.03 ^a	0.12±0.05 ^a	0.83±0.03 ^a	0.305
Mn	0.16±0.01 ^a	0.91±0.01 ^b	0.15±0.02 ^b	0.14±0.01 ^{ab}	0.042
Co	0.07±0.01 ^{ab}	0.08±0.04 ^{ab}	0.13±0.04 ^a	0.02±0.02 ^a	0.184
Pb	0.09±0.02 ^a	0.04±0.01 ^{bc}	0.07±0.01 ^{ab}	0.01±0.02 ^d	0.006
Cd	0.02±0.01 ^a	0.05±0.19 ^a	0.05±0.01 ^a	0.07±0.02 ^a	0.262
Cr	0.39±0.20 ^a	0.16±0.02 ^a	0.11±0.05 ^a	0.19±0.19 ^a	0.352
Fe	0.00±0.00 ^b	0.00±0.00 ^b	9.48±0.37 ^b	0.00±0.00 ^a	0.000
Al	14.65±0.25 ^a	12.87±0.43 ^b	11.93±0.92 ^b	0.21±0.01 ^c	0.000

Note. SQ_{c1}, SQ_{c2}, SQ_{c3} are three cassava samples at different sampling points within the quarry sites and CS_c is the control site. Values with same superscripts along same row are not significantly different at $P<0.05$

Correlation between the physicochemical parameters and heavy metals. The correlation between the physicochemical parameters and heavy metals in the study were shown in table 4. The pH showed correlation with Fe, Mn, Co, Pb, Cr and Al except Cd. EC showed correlation with all the heavy metals except Cd and Cr. TOC showed correlation with Pb and Cr. Also TN showed correlation with Fe, Pb, Cr and Al. PO₄²⁻ showed correlation with Pb. Clay showed correlation

with Fe, Ni, Pb and Al. Sand Fe, Ni, Mn, Co, Pb and Al. Silt correlated with Cr. Porosity showed correlation with Fe, Ni, Mn, Co, Cr and Al.

The correlation coefficient between EC and Fe, Ni, Pb, and Al showed a negative correlation range $r=-0.795$ to -0.960 , while, the correlation coefficient between EC and Mn, and Co, shows a positive correlation range ($r=0.668$ to 0.667).

Table 4. Correlation between physicochemical parameters and heavy metals in the study.

	Fe	Ni	Mn	Co	Pb	Cd	Cr	Al
pH	-0.908**	-0.900**	-0.996**	-0.984**	-0.692*	-0.084	0.819**	-0.667*
EC (µS/cm)	-0.958**	-0.855**	0.697**	0.668*	-0.795**	-0.337	-0.417	-0.960**
TOC (%)	-0.239	-0.571	-0.498	-0.578	0.593*	-0.026	0.820**	0.104
TN (%)	0.728**	0.570	0.300	0.258	0.794**	0.260	0.609*	0.895**
PO ₄ ²⁻ (mg/kg)	-0.261	-0.393	0.108	0.067	-0.647*	-0.442	0.024	0.528
Clay (%)	0.897**	0.813**	0.575	0.544	0.816**	0.460	0.327	0.967**
Sand (%)	-0.905**	-0.886**	-0.655*	-0.635*	-0.872**	-0.462	-0.510	-0.949**
Silt (%)	0.124	0.206	0.267	0.350	0.198	-0.188	0.657*	-0.329

Correlation (r) between the concentrations of heavy metals in soil and Cassava tuber. The correlations (r) between levels of the heavy metals in soil and cassava tuber sampled are shown in table 5. Results show that, Al in soil correlated positively with Al in the Cassava tuber ($r = 0.977$). The concentrations of lead in the soils

and the cassava from all the sites ranged from (mg kg^{-1}) 0.14 ± 0.01 to 0.43 ± 0.01 and 0.01 ± 0.02 to 0.09 ± 0.0 respectively. The bioaccumulation of Fe in Cassava was only noticed in SQ₃ despite its high concentrations across the sampling points. Iron has the highest mean concentration among all the metals studied.

Table 5. Correlation (r) matrix between the concentrations of heavy metals in soil and Cassava tuber

	Fe _s	Mn _s	Ni _s	Co _s	Pb _s	Cd _s	Cr _s	Al _s
Fe _c	0.363							
Mn _c		-0.409						
Ni _c			-0.241					
Co _c				0.502				
Pb _c					0.382			
Cd _c						-0.290		
Cr _c							0.456	
Al _c								0.977**

c = cassava, s = soil, * = is poorly significant at $P < 0.05$, ** = is significant at $P < 0.01$

Discussion

The pH values recorded in the soil samples implied that the discharge from mining activities to the agricultural lands was acidic. This observation corresponded with the findings of Uba et al. (2008). The variation in the pH of the soil samples further implied that mining or quarry effluent and related wastes might have altered the pH of the soil, neutralizing its alkalinity as shown in the control soil sample. The correlation coefficient between pH and Fe, Ni, Mn, Co, Pb, and Al showed a negative correlation range. This implied that as the pH increases to alkalinity, the concentration of heavy metals decreases, and as the pH decreases in the study area, the concentrations of heavy metals increases. This alteration in pH may affect geochemical cycling and availability of soil nutrients. This was supported by the works of Arias et al. (2005). The variation recorded in EC in samples also indicated the influence of quarry waste on agricultural land. The range of values obtained in this study was higher than that reported by Egbenda et al. (2015), but lower than the values reported by Idugboe et al. (2014). These values indicated significant presence of trace metal ions or ionisable materials in the soil (Fuller et al., 1995).

The variation in total organic carbon content obtained in this study may be attributed to quarry effluent

discharge on the farm land. The positive correlation coefficient between TOC and Pb and Cr implied that heavy metal mobility could most likely be influenced at the study site by altering the soil TOC content.

Phosphate values recorded in this study were higher than those reported by Iwegbue et al. (2006) and Chaudhire (2013). The variation in concentration of phosphate indicated that quarry activities may be contributory to the increase in phosphate in the contaminated farm lands. The soil PO_4^{2-} and Pb showed a negative correlation ($r = -0.647$). This implied that increase in phosphate in the soil will reduce availability and accumulation of Pb in the soil and cassava tubers and other crops. Total Nitrogen (TN) (%) varied significantly among the samples and values were higher at the quarry site samples when compared with the control sample. This implied that quarry activities increased the total Nitrogen content of the farm land (Eddy et al., 2006).

Samples SQ₁, SQ₂, and SQ₃ of Sand, Clay, and Silt varied with the CS. In this study, all the quarry sampling points had higher sand and lower clay and silt contents. This was corroborated by Ideriah et al. (2006). According to Nyles and Ray (1999), soils with separate high sand and low clay content have high pollutant leaching potentials. This implied that soils affected by quarry effluent may not easily retain water, soil nutrients and organic matter

for the growth of crops including cassava. All the metals studied were detected in all the sites and corresponding cassava tuber samples. Generally the concentrations of the metals were higher at the quarry soils than the control soil. This implied that heavy metals contamination of the farm land led to their accumulation in Cassava tuber samples. This was expected since the quarry effluents were discharged on the nearby farmland. The variations recorded in the concentrations of Cd, Mn, Co, Pb, Fe and Al in the cassava tuber samples might be due to varying factor like bioavailability. This is similar to that reported by Pam et al. (2013). Airborne particles emitted by rocks and wears from heavy duty vehicle tyres can contain considerable amounts of nickel (Onder et al., 2007). This is a probable source of nickel in the recorded soils. Anthropogenic input of nickel in the study areas could also be from the diesel used in the automobiles (Iwegbue, 2013). Exposure to intake of large amount of nickel from plants, grown on nickel rich soil leads to higher chances of developing cancer of the lungs, nose, larynx and prostate as well as respiratory failures, birth defects and heart disorders (Lentech, 2009). The level of the accumulation of Mn in Cassava tuber might also be due to the age of the cassava. Manganese occurs principally as pyrolusite (MnO_2) and to a lesser extent as rhodochrosite ($MnCO_3$) (Essumang et al., 2007). Manganese is an essential element for all species. Manganese in the quarry sites was probably due to leaching effect of its sediments from waste rocks. The level of the accumulation of Co in cassava tuber might also be due to the age of the cassava. The level of the accumulation of Pb in cassava tuber might be due to the age of the cassava. Similar range of values for lead has been reported by Matthews-Amune (2013). Lead levels in quarry sites can be attributed to weathering of the rocks, which contains high levels of lead. Elevated levels of lead constitute serious health risk (Tuakuila et al., 2013). Chromium concentrations in soils and Cassava tuber corresponded with that reported by Ubwa et al. (2013). According to Al-Khashman (2007), chromium level in road side soil is associated with the chromic plating of some vehicle parts used for preservation of corrosion. Chromium is carcinogenic resulting in cancer of respiratory organs in workers exposed to chromium containing dust (Langard, 1980). High concentrations of iron in soils relative to other metals have been reported in various studies, confirming that natural soils contain significant levels of iron (Aluko

and Oluwande, 2003). The mean value of iron obtained in this study is within the range of those reported by Nwachukwu et al. (2011). Iron (Fe) is readily available in the soil through weathering of soil mineral of which mining is a major contributor (Jarsjö et al., 2017). According to U.S. EPA (2003), Al is the most commonly occurring metallic element on the earth's crust, and due to its ubiquitous nature, natural variability in the soil concentrations and the availability of conservative soil screening benchmarks, it is often identified for ecological risk assessments. U.S. EPA (2003) stated that the bioavailability of Al for toxicity and plant uptake increases with $pH < 5.5$. At acidic $pH < 5.5$, soluble Al is biologically available and causes toxicity in plants (Silva, 2003). In this study, the pH of the quarry sites' soil samples were all above acidic pH values which might limit the effects of Al on the soil quality, biota, plants accumulation and toxicity. According to U.S. EPA (2003), the toxicity on plant roots includes injury to root caps, root apex and vascular elements, with further effects in the decrease in the permeability of the roots to water and nutrients. The positive correlation of Al in soil with that of cassava tuber, implied that the quarry soils were the source of Al in the cassava tubers. However, its significant accumulation in the cassava (*Manihot esculenta*) tubers/ roots might be connected to its effects on plant roots, production and growth (Rengel and Zhang, 2003). The challenge therefore is the possible health effects of Al consumption in cassava tubers consumed by the increasing population of the rural dwellers, while the increasing accumulation of Al in human bodies remains a worrying health challenge. Uptake of Al in cassava tuber can lead to numerous human health risks. The effects are mainly targeted at many biological processes in the human body (Stahl et al., 2017). According to Stahl et al. (2017), Al is considered as cyto- and neurotoxic. In cytotoxicity, there is disruption of enzyme activity and alteration of mitochondrial functions. Other major effects may include production of oxidative stress (Kumer and Gill, 2009), effects on hemopoietic system, the nervous system and bones. It may also lead to breast cancer and Alzheimer's dementia.

Conclusion

Quarry activities have been established to contribute to heavy metal concentrations of cassava tubers in surrounding farm lands. This accumulation of metals in food sources may lead to destruction of soil health

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of farm lands, severe health challenges to farmers and consumers of food crops, lowering of agricultural produce, food insecurity and increased mortality and morbidity levels of consumers.

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