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EFFECTS OF QUARRYING ACTIVITIES ON SOIL QUALITY AND NUTRITIONAL COMPOSITION OF SELECTED VEGETABLES IN SOUTHEASTERN NIGERIA

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ABSTRACT

This research work assessed the effects of quarrying activities on soil quality and nutritional composition of fluted pumpkin *(Telferia occidentalis)* and smooth pigweed *(Amaranthus hybridus)*. Soil and vegetable samples were collected from three quarry and rock crushing sites. Soil samples were analyzed for various physicochemical parameters, soil nutrients and metals ($NO_{3,}$ PO_4, Nitrate, Sulphate, Cu, Zn, Cr, Ni, Pb, Cd, Mg, Fe, Ca, Mn, K, Na) using standard analytical methods. Proximate composition and trace metal content of *Telferia occidentalis* and *Amaranthus hybridus* were also evaluated using Atomic Absorption Spectrophometer (ASS). Results obtained revealed deterioration of soil quality near the quarries, with significantly high levels of Cu, Zn, Ni, Pb, Cd, Fe and Mn recorded. In general, the mean concentration of heavy metals in soils from the rock quarries decreased in the order of: Fe>Mn>Cr>Pb>Cu>Ni>Zn>Cd. Values for Iron (Fe) in the soil samples ranged between 1667.36 ± 1.15 mg/kg in Quarry 1, 1635.03 ± 1.15 mg/kg in Quarry 2 and 1734.79 ± 11.55 mg/kg in Quarry 3. The average concentrations of Nickel (Ni) in soil samples collected from Quarries 1, 2 and 3 were 9.22 ± 0.06, 8.68 ± 0.08 and 7.53 ± 0.12 respectively. Soil Ni content was found to be higher than the WHO (2017) recommended limit of <1 mg/kg. Soil levels of TOC, NO_3, PO_4, Nitrate, Mg, Ca, K and Na were below the guidelines for maximum limit in soils. Proximate analysis of the vegetables cultivated in the quarry environs showed high contents of protein and dietary fibre. While the concentration of Ni was within permissible limit in the vegetables, Cr values exceeded recommended levels. Findings from this study indicate that residents of the quarry areas are exposed to contaminated soil and health risks associated with consumption of accumulated toxic contaminants in edible vegetables.

Keywords: Quarrying; soil quality; pollutants; heavy metals; vegetables; nutrient composition; health risk.

INTRODUCTION

Quarrying is the process of removing rock, sand, gravel or other minerals from the ground in order to use them to produce materials for construction or other uses. It is a process that extracts non-metallic rocks and aggregates such as sandstone, limestone, perlite, marble, ironstone, slate, granite, rock salt and phosphate rock. The suitability of the stone for quarrying depends on its quality, the possibility of cheap and ready conveyance to a large market, and its inclination and depth below the surface [1-4].

The extraction of quarry resources is an important economic activity. However, it is a significant source of air pollutants [5,6]. Mining and quarrying can be very destructive to the environment [7]. The mechanical processes of crushing rocks into smaller sizes generate pollutants that are largely particulate in nature. These particulate contaminants have been known to adversely affect human health, soil and air quality, and vegetation in the surrounding environment [5,8-10]. Quarrying operations have been reported to release enormous amounts of heavy metals into the environment through waste emission. These heavy metals accumulate in land and water, and ultimately in the systems of organisms and subsequently reach injurious concentrations [11]. Previous reports established a vivid relationship between contamination of the surrounding by heavy metals and activities in quarry sites [12]. According to Hamza et al. [13], the current amount of some heavy metals in the soil could serve as a pointer to the effect of pollutants released into the surroundings.

The impacts of quarrying activities on plants are significant, as such activities have been reported to increase the heavy metal profile of soil and vegetables. Crops grown in areas near quarry sites take up heavy metals and upon consumption of these crops by man, there is accumulation of the heavy metals in the body system which may result in harmful effects. The level of heavy metals such as cadmium, lead, chromium, zinc and nickel in edible plants are of considerable concern as they constitute possible sources of toxicity [14]. Also, high concentrations of heavy metals such as Cu and Zn might lead to toxic symptoms and inhibition of growth in plants [15,16].

Vegetables are the most important and widely cultivated and income generating crops in Southeastern Nigeria. *Telfairia occidentalis* and *Amaranthus spinosus* are important vegetables cultivated for food in the region. Most of these vegetable farms are located near quarry sites, thus increasing potentials for contaminant uptake by these crops and high risk of human intoxication.

The present study is therefore, aimed at assessing the impact of rock quarrying activities on soil quality and nutritional composition of fluted pumpkin and African spinach grown in Abakaliki, Southeastern Nigeria.

THE STUDY AREA

The study area is Abakaliki which lies between latitudes 06 14’ 32’ N to 060 24’ 32’’ N and longitudes 080 01’ 47’’ E to 080 11’ 14’’ E. It is located in southeastern Nigeria, 64 kilometres (40 mi) southeast of Enugu. The quarrying sites are located at Umuoghara Community (lat. 6^o 18’ 19” N, long. 8^o 2’ 31” E) where the geology formed during the lower cretaceous age gave rise to tectonic earth movements that resulted in minor folding, faulting, fracturing and fissuring, followed by igneous activity that deposited granite, limestone, lead, zinc, copper and cadmium mineralization in the area. It is estimated that the population of Abakaliki as at 2021 is about 1,179,280 [17-19].

MATERIALS AND METHODS

Collection of Soil and Vegetable Samples

Soil and vegetables samples were collected during the dry season. Soil samples were collected at different locations within the study area at a depth of 0.1-0.5m and a distance 30 to 50m away from the quarry sites while vegetables (*Telfaria occidentalis* and *Amaranthus hybridus)* were harvested from farm locations in close proximity to the quarry sites.

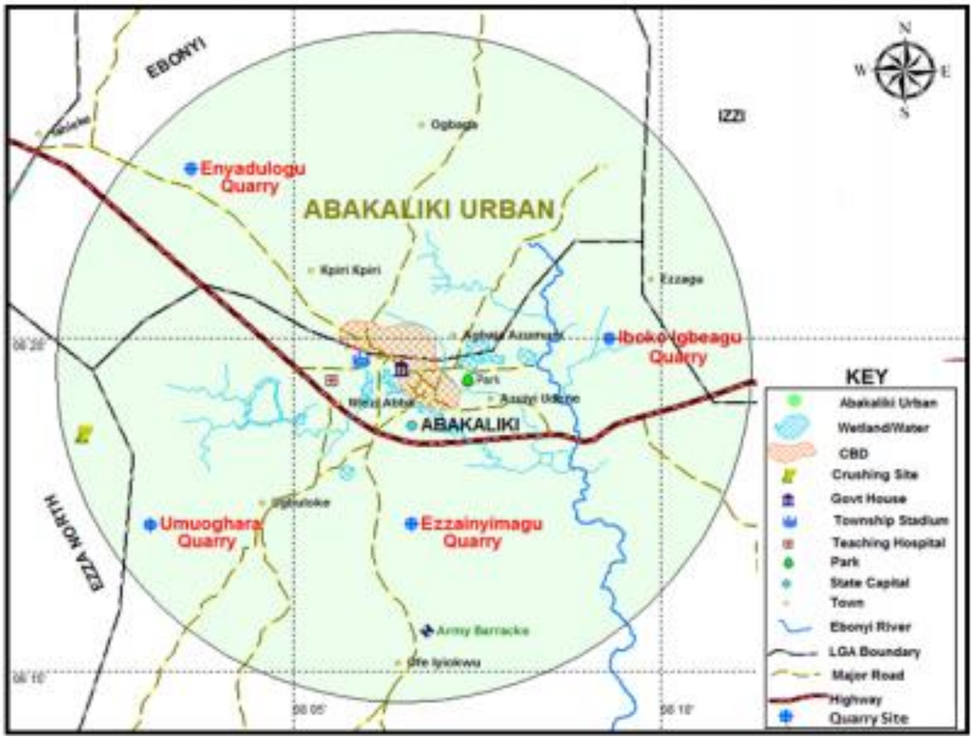

Fig. 1. Study area showing umuoghara quarry and similar crushing sites in Abakaliki

Plate 1. *Telfaria occidentalis* (Fluted pumpkin)

Plate 2. ***Amaranthus hybridus*** **(African spinach)**

Table 1. Experimental sample grouping - soil and vegetable

Umuoghara Quarries	Quarry 1	Quarry 2	Quarry 3
Soil Samples	QR1s	QR2s	QR3s
Vegetable Samples	QR1v	QR2v	QR3v

Analytical Methods for Soil Samples

Determination of soil pH & electric conductivity

Measurement of soil pH & Electric conductivity was carried out using the Electrode Method [20].

Measurement of soil phosphate

Soil Phosphate was determined by ascorbic acid method [20].

Determination of soil sulphate

Soil Sulphate was determined using Turbidity Method [21].

Analysis for heavy metals

Digestion of soil samples

Sample digestion was done using the method described by Zhou et al. [22].

Sample analysis

Atomic absorption spectrophotometer (AAS) (Perkin–Elmer AAnalyst 400 model) was used to determine the content of heavy metals in digested soil samples.

Measurement of soil nitrate

Total Suspended Solids was determined using the cadmium reduction method [21].

Measurement of soil total nitrogen

Total Nitrogen was determined using Kjeldahl method [23].

Determination of chloride

TOC was determined using rapid oxidation method [24].

Analytical Methods for Vegetable Samples

Proximate analysis

Moisture, ash, crude fat and crude fibre were determined in accordance with the official methods of the association of official analytical chemists [25], while nitrogen was determined by the micro-kjeldahl method [26] and the percentage of nitrogen was converted to crude protein by multiplying by a factor of 6.25.

Mineral analysis

The conventional acid digestion method was used to analyze for minerals in the vegetable samples [27].

Statistical Analysis

Results in this study are expressed as Means ± Standard Error Mean (SEM) while one-way ANOVA was used to test for differences between treatment groups using SPSS version 20. The results were considered significant at p-values of less than 0.05, that is, at 95% confidence level (P=0.05).

RESULTS AND DISCUSSION

The results of physico-chemical and heavy metal levels in soil samples collected from the quarries under study are presented in Table 2. Results for soil samples collected from the quarries under study were compared with standards recommended by the World Health Organization (WHO), *United States Department of Agriculture* (*USDA*), the *Food & Agriculture Organization* (*FAO*) and the National Environmental Standards and Regulations Enforcement Agency (*NESREA*).

The mean concentrations of heavy metals and some physico-chemical parameters in the soil samples collected from Quarries 1, 2 and 3 are shown in Table 2. Soil collected from the Quarry sites recorded pH ranging from 7.0 (neutral) to 7.9 (slightly basic). Soil electrical conductivity values for the quarry sites were below regulatory standards for conductivity in soils. Data obtained revealed that Cu, Zn, Cr, Ni, Pb, Cd, Fe and Mn accumulated in the soil at different concentrations in Quarries 1, 2 and 3. The results further revealed high levels of Iron (Fe) in soil collected from the three quarry sites, with values ranging between 1667.36 ± 1.15 mg/kg in Quarry 1, 1635.03 ± 1.15 mg/kg in Quarry 2 and 1734.79 ± 11.55 mg/kg in Quarry 3. These results found were higher than standards set by FAO/WHO [28] and NESREA [29]. The high level of iron might be due its abundance in the environment because iron is the fourth most abundant element in the earth’s crust [30].

The concentration of zinc (Zn) ranged from 3.00 ± 0.29 to 21.42 ± 0.58 mg/kg. The lowest zinc content was reported in Quarry 2 soils while Quarry 3 recorded higher values. The concentration of zinc in this study is much higher than the standard limit of 1.0 mg/kg set by NESREA [29]. The high level of Zn in these quarry sites could probably be due to the widely used vegetable farming activities at these areas and usage of various types of pesticides and fertilizers.

Results for soil manganese (Mn) concentration were 187.08 ± 1.15, 284.45 ± 1.15 and 311.43 ± 1.15 mg/kg in the sampling sites for Quarries 1, 2 and 3 respectively. The concentrations of manganese observed in this study are higher than the FAO/WHO [28] recommended limits.

Table 2. Some soil quality parameters and heavy metal levels for the three quarries

SOIL	QR1s	QR2s	QR3s	FAO/WHO [28]; NESREA [29]
Conductivity (µs/cm)	$94.00 \pm 1.15^{a,e,h}$	$231.00 \pm 1.15^{b,d,h}$	$44.00 \pm 0.58^{b,e,g}$	1000
pH	$7.40 \pm 0.06^{a,d,g}$	$7.00 \pm 0.29^{a,d,h}$	$7.90 \pm 0.12^{a,e,g}$	6-9
TOC (%)	$0.82 \pm 0.01^{a,e,h}$	$0.43 \pm 0.01^{b,d,g}$	$0.51 \pm 0.03^{b,d,g}$	N.S
NO_3 (mg/kg)	$0.07 \pm 0.00^{a,e,h}$	$0.04 \pm 0.00^{b,d,h}$	$0.04 \pm 0.00^{b,e,g}$	10
PO_4 (mg/kg)	$0.23 \pm 0.01^{a,e,h}$	$0.33 \pm 0.01^{b,d,h}$	$0.54 \pm 0.01^{b,e,g}$	N.S
Nitrate (mg/kg)	$0.07 \pm 0.01^{a,e,h}$	$0.24 \pm 0.01^{b,d,h}$	$0.42 \pm 0.01^{b,e,g}$	20
Sulphate (mg/kg)	$5.00 \pm 0.29^{a,e,h}$	$17.94 \pm 0.58^{b,d,h}$	$24.74 \pm 1.15^{b,e,g}$	500
Cu (mg/kg)	$15.00 \pm 0.58^{a,e,h}$	$8.09 \pm 0.29^{b,d,h}$	$23.02 \pm 1.15^{b,e,g}$	1
Zn (mg/kg)	$3.00 \pm 0.29^{a,e,h}$	$7.72 \pm 0.06^{b,d,h}$	$21.42 \pm 0.58^{b,e,g}$	1
Cr (mg/kg)	$70.50 \pm 0.58^{a,e,h}$	$66.09 \pm 0.58^{b,d,h}$	$53.41 \pm 1.15^{b,e,g}$	0.05
N i(mg/kg)	$9.22 \pm 0.06^{a,e,h}$	$8.68 \pm 0.08^{b,d,h}$	$7.53 \pm 0.12^{b,e,g}$	<1
Pb (mg/kg)	$56.31 \pm 0.12^{a,e,h}$	$34.92 \pm 0.58^{b,d,g}$	$35.87 \pm 1.15^{b,d,g}$	1.0
Cd (mg/kg)	$0.27 \pm 0.01^{a,d,g}$	$0.35 \pm 0.01^{a,d,h}$	$0.20 \pm 0.03^{a,e,g}$	1.0
Mg (mg/kg)	$52.41 \pm 0.12^{a,d,g}$	$51.61 \pm 0.58^{a,d,g}$	$52.04 \pm 1.15^{a,d,g}$	N.S
Fe (mg/kg)	$1667.36 \pm 1.15^{a,e,h}$	$1635.03 \pm 1.15^{b,d,h}$	$1734.79 \pm 11.55^{b,e,g}$	20
Ca (mg/kg)	$310.82 \pm 0.58^{a,e,h}$	$263.98 \pm 1.15^{b,d,h}$	$234.28 \pm 1.73^{b,e,g}$	NS
Mn (mg/kg)	$187.08 \pm 1.15^{a,e,h}$	$284.45 \pm 1.15^{b,d,h}$	$311.43 \pm 1.15^{b,e,g}$	0.2
K (mg/kg)	$78.69 \pm 0.58^{a,e,h}$	$104.98 \pm 1.15^{b,d,h}$	$53.77 \pm 1.15^{b,e,g}$	N.S
Na (mg/kg)	$63.70 \pm 0.58^{a,d,g}$	$63.26 \pm 0.58^{a,d,g}$	$65.33 \pm 1.15^{a,d,g}$	N.S

Values are means ± Standard Error Mean (SEM). Values with different superscript are statistically significant at (P=0.05). QR: Quarry; N.S: Not stated

Table 3. Proximate analysis of harvested vegetables

	QR1v (*Telfaria Occidentalis)*	QR2v (*Amaranthus hybridus*)	QR3v (*Telfaria Occidentalis)*	USDA [31]; WHO [32]
MOISTURE (%)	84.08 ± 0.32^{a,e,h}	86.15 ± 0.48^{b,d,h}	74.81 ± 0.22^{b,e,g}	72.4-95.2
ASH (%)	11.40 ± 0.26^{a,e,g}	23.08 ± 0.39^{b,d,h}	12.25 ± 0.03^{a,e,g}	0.2-1.9
LIPID (%)	7.40 ± 0.06^{a,e,h}	2.35 ± 0.09^{b,d,h}	3.10 ± 0.06^{b,e,g}	<2g/300g
CHO (%)	7.15 ± 0.07^{a,e,h}	4.30 ± 0.00^{b,d,h}	5.27 ± 0.04^{b,e,g}	2.3
PROTEIN (%)	25.15 ± 0.12^{a,d,h}	24.50 ± 0.25^{a,d,h}	22.31 ± 0.00^{b,e,g}	0.3-2.0
CRUDE FIBRE (%)	48.91 ± 0.15^{a,e,h}	45.81 ± 0.75^{b,d,h}	57.08 ± 0.07^{b,e,g}	8g/300g

Values are means ± Standard Error Mean (SEM). Values with different superscript are statistically significant at (P=0.05). QR: Quarry

Table 4. Heavy metal levels in harvested vegetables

	QR1v (*Telfaria Occidentalis)*	QR2v (*Amaranthus hybridus*)	QR3v (*Telfaria Occidentalis)*	WHO [32]
Mn(mg/kg)	65.60 ± 0.58^{a,e,h}	35.45 ± 0.58^{b,d,h}	74.20 ± 1.15^{b,e,g}	500
Zn(mg/kg)	89.55 ± 0.12^{a,e,h}	107.78 ± 1.15^{b,d,h}	81.80 ± 0.58^{b,e,g}	99.4
Ca(mg/kg)	1584.15 ± 5.78^{a,e,h}	2433.85 ± 57.74^{b,d,h}	2136.00 ± 11.55^{b,e,g}	0.2
Mg(mg/kg)	1353.95 ± 5.77^{a,e,g}	143.60 ± 0.64^{b,d,h}	1328.05 ± 11.55^{a,e,g}	N.S
K(mg/kg)	15.45 ± 0.58^{a,d,g}	15.65 ± 0.58^{a,d,g}	16.08 ± 0.58^{a,d,g}	N.S
Na(mg/kg)	272.78 ± 0.58^{a,d,g}	269.33 ± 0.58^{a,d,g}	270.38 ± 1.15^{a,d,g}	N.S
Pb (mg/kg)	BDL	BDL	BDL	0.3
As(mg/kg)	BDL	BDL	BDL	0.2
Cd(mg/kg)	BDL	BDL	BDL	0.2
P(mg/kg)	26.50 ± 0.29^{a,d,h}	25.82 ± 0.02^{a,d,h}	11.23 ± 0.00^{b,e,g}	N.S
Ni(mg/kg)	1.85 ± 0.06^{a,d,h}	1.93 ± 0.06^{a,d,h}	2.33 ± 0.06^{b,e,g}	67.9
Cr(mg/kg)	13.78 ± 0.12^{a,d,g}	8.48 ± 0.06^{a,d,g}	3.28 ± 0.06^{a,d,g}	2.3

Values are means ± Standard Error Mean (SEM). Values with different superscript are statistically significant at (P=0.05). QR: Quarry; N.S: Not stated; BDL: Below Detectable Levels

The concentration of copper (Cu) in the soil ranged between 8.09 ± 0.29 and 23.02 ± 1.15 mg/kg. The lowest concentration of copper was found in soil samples collected from Quarry 2 while the higher concentrations were observed in Quarry 3. The content of Cu reported in this study was generally higher than the permissible level recommended by NESREA [29].

The average concentrations of nickel in soil in Quarries 1, 2 and 3 were 9.22 ± 0.06, 8.68 ± 0.08 and 7.53 ± 0.12. The contents of nickel found in this study were higher than the FAO/WHO [28] recommended limit of <1 mg/kg.

Cadmium (Cd) concentrations in the soil were 0.27 ± 0.01, 0.35 ± 0.01 and 0.20 ± 0.03 mg/kg in Quarries 1, 2 and 3 respectively. The levels of Cd in all the sampling sites were higher than the NESREA [29] recommended limit of 1.0 mg/kg.

The concentration of Chromium (Cr) in the soil ranged from 53.41 ± 1.15 to 70.50 ± 0.58 mg/kg. Soil Chromium level was generally higher than the permissible levels of 0.05 mg/kg set by NESREA [29] in soils.

In the studied soil samples, results for lead (Pb) concentrations were 56.31 ± 0.12, 34.92 ± 0.58 and 35.87 ± 1.15 mg/kg for Quarries 1, 2 and 3 respectively. The values of Pb obtained in this study were higher than NESREA [29] recommended maximum limit (1.0 mg/kg).

In general, results for soil quality parameters and selected metals present in the study areas showed that soil levels of TOC, NO_3, PO_4, Nitrate, Mg, Ca, K and Na were below the standard guidelines for maximum limit proposed for soils [28,29]. Though Calcium concentrations were below the critical permissible concentration level in soils, it seems that its persistence in soils within the study site led to increased uptake of this metal by vegetables cultivated within the quarry location.

Findings showed that soil concentrations of the heavy metals Cu, Zn, Ni, Pb, Cd, Fe and Mn were higher than recommended maximum limits while soil concentrations of Mg, Ca and K fell below standards set by FAO/WHO [28] and NESREA [29]. In general, the mean concentration of heavy metals in soils collected from all the Rock Quarries decreased in the order of: Fe>Mn>Cr>Pb>Cu>Ni>Zn>Cd.

Results for proximate analysis of fluted pumpkin leaves (*Telfairia occidentalis*) and African Spinach (*Amaranthus hybridus*) cultivated and consumed Quarries in the study area are presented in Table 3. Moisture content in both species of vegetables studied ranged from 74.81 to 86.15%. Moisture content of the vegetables were observed to be relatively high. *Amaranthus hybridus* recorded a higher moisture content than *Telfairia occidentalis*. Moisture content in both vegetables was within permissible range of 72.4-95.2%, set by WHO [32].

Total ash content ranged from 11.4% for *Telfairia occidentalis* in Quarry 1, 12.25% for *Telfairia occidentalis* in Quarry 3 to 23.08% for *Amaranthus hybridus* in Quarry 2. Total ash content for vegetables obtained from all three Quarries studied was higher than recommended values.

Lipid contents of vegetables studied ranged from 2.35 to 7.40%. *Telfairia occidentalis* obtained from Quarry 1 showed high fat contents. Protein contents the vegetables under study were higher than permissible values of 2g/300g. Protein content in the vegetables were 25.15% for *Telfairia occidentalis* in Quarry 1, 24.50% for *Telfairia occidentalis* in Quarry 3 and 22.31% *Amaranthus hybridus* in Quarry 2.

Crude fibre content was highest in *Telfairia occidentalis* cultivated around Quarry 3 (57.08 ± 0.07 mg/kg). *Telfairia occidentalis* in Quarry 1 and *Amaranthus hybridus* in Quarry 2 both recorded crude fibre content of 48.91 ± 0.15 and 45.81 ± 0.75 respectively. Total carbohydrate content ranged between 4.30 to 7.15%.

Analytical results for mineral and heavy metal content are shown in Table 4. Results for heavy metals in *Telfaria Occidentalis* harvested from Quarries 1 and 3 indicated that Calcium and Chromium levels were above the maximum permissible limit set by WHO [32] for vegetables (0.2 and 2.3mg kg^{-1} respectively). The highest level of Chromium (13.78 ± 0.12 mg/kg) was recorded for *Telfaria Occidentalis* collected from Quarry 1. Calcium levels of 1584.15 ± 5.78 and 2136.00 ± 11.55 mg/kg were recorded for *Telfaria Occidentalis* grown in Quarries 1 and 3 respectively. However, results obtained for Mn, Zn, Mg, K, Na and Pb were below recommended permissible concentrations of these metals in vegetables.

Amaranthus hybridus cultivated *near Q*uarry 2 showed significantly high levels of zinc (107.78mg/kg), calcium (2433.85 ± 57.74 mg/kg and sodium (269.33 ± 0.58mg/kg) as compared to recommended standards (99.4 mg/kg and 0.2 mg/kg for Zn and Ca respectively). Calcium was observed to be significantly high in *Amaranthus hybridus* when compared with vegetables collected from Quarries 1 and 3.

Findings from this study indicate high levels of some of the heavy metals of concern in soils and vegetables as compared to recommended limits. These findings corroborate an earlier research by Osuocha et al. [33] where significant increases in the concentration of trace metals were recorded in well water samples collected from Ishiagu crush rock quarry mining sites in Southeastern Nigeria. Similarly, Akubugwo et al. [34] and Onwuemesi *et al.* [35] reported high levels of cadmium, lead, chromium, aluminium, copper, iron and zinc in well waters in Ishiagu crush rock quarry mining sites. Ojo et al., [36] studied seasonal concentrations of bioavailable heavy metals (Cr, Cu, Cd, Zn, Mn, Ni, Pb and Fe), along with some physicochemical properties of soil in vegetable farms around the rock quarry in Durumi, Abuja Nigeria and revealed that soil in farms around Durumi rock quarry contain heavy metals from both lithogenic and anthropogenic origins.

Leafy vegetables, and fruits are part of the daily diet in many Nigerian households. The consumer’s perception of the quality of vegetables is mostly based on leaf color and size. Hence, there is a general assumption that dark green vegetables with big leaves are of better quality. However, external morphology is inadequate for leafy vegetables qualitative assessment as heavy metals rank high amongst the major contaminants [37]. Consumption of vegetables and other foods containing high levels of heavy metals is detrimental and can result in acute or chronic intoxication. Shahid et al. [38] noted that ingestion of contaminated food accounts for more than ninety percent of human exposure routes to heavy metals. The present study has shown high concentrations of Cu, Zn, Ni, Pb,Cd, Fe in the soil around the quarry sites and also, high levels of Mn, Cr, Zn and Ca in vegetables cultivated near the rock quarry sites. A previous study on the impacts of quarrying activities on human health in Boki area of Cross River State Nigeria, reported high contents of Zn, and low contents of Cr and Ni in the soil investigated [39]. A similar assessment of heavy metal concentration in water around quarries and barite mine sites in part of Central Cross River State, Southeastern Nigeria revealed that the mean concentration of Ba, Cu, Mn, Pb and Zn in the water sources within the study area were above recommended standards [40].

Nkwunonwo et al. [37] noted that of all the heavy metals found in literature, Pb, Cd, Hg, and Mn have the highest health risk index (HRI) in Nigeria because of their bioavailability. These heavy metals are present in most staple foods in the southern and southeastern parts of Nigeria. This is a risky situation for people who live in these areas where the consumption of such foods is part of the endeared human culture. Wide application of various types of pesticides, cadmium-containing phosphate fertilizers and contamination from cadmium-containing dusts may have contributed to the increased availability of Ni and Cd in the soil. Also, the relatively high levels of lead might have resulted from accumulation of lead caused by use of heavy machines that emit gases during quarrying activities [41]. This finding corroborated results obtained in the risk assessment of heavy metals in vegetables grown around quarry sites in Okigwe, Southeastern Nigeria, where it was observed that eggplant and pumpkin accumulated lead beyond tolerable limits for human consumption [42]. Lead (Pb) is a severe cumulative body toxin which enters the body through food, air and water and cannot be eliminated by washing vegetables [43,44]. Lead (Pb) induces reduced cognitive development, increased blood pressure, cardiovascular diseases and intellectual performance in children. High concentrations of lead in human body can cause nephrotoxicity, neurotoxicity and damage to liver, lungs and spleen [45,46]. Higher amount of Pb in soil may cause the availability of Pb in vegetables [47]. Accumulation of Cd has been reported to induce kidney dysfunction, skeletal damage and reproductive deficiencies. Intranasal exposure to Cd has also been attributed to olfactory dysfunction. Severe diseases like tubular growth, kidney damage, cancer, diarrhea and incurable vomiting may be caused by higher concentration of cadmium. Zinc (Zn) is a major essential element in human physiological system. Zn is necessary for normal functioning of the cell including protein synthesis, carbohydrate metabolism, cell growth and cell division [48]. Zinc is also important for enzymatic function. It takes part in the synthesis of DNA, protein and insulin. However, Zn is toxic to humans when its concentration exceeds tolerable limit. Chronic exposure to Zn and/or Copper (Cu) is associated with Parkinson’s disease [49]. Nickel (Ni), though essential for growth and reproduction, could be carcinogenic in high amount in the body. At minimal levels, Ni act as a cofactor for the enzyme, Urease, but at very high concentration can be deleterious to health. Ni interferes in calcium metabolism which can cause carcinogenic effect in human body. It has also been suggested that high levels of Ni may impair absorption or utilization of iron when iron status is low [50]. Trace amount of Cu is essential for normal biological activities of aminoxide and tyrosinase enzymes. On the other hand, its excessive intake may cause hemolysis, hepatotoxic and nephrotoxic effects [48]. Chromium (III) is an essential nutrient that helps the body utilize sugar, protein and fat, though it might be detrimental to health at high doses. Studies have shown that chromium (VI) is cytotoxic and able to induce DNA damaging effects [51,52].

Findings of high ash and fibre content in vegetables grown in the quarry sites in the present study are similar to reports by Osuocha et al. [33] where they reported significant increase in ash and fibre content of vegetables grown in quarry mining effluent discharge soils. This finding could be as a result of rapid metal uptake and accumulation in the vegetables, and development of woody texture in the vegetables due to enhanced lignin synthesis. Dietary fibre helps to prevent constipation, bowel problems and piles. The high values of ash content observed in this study is an indication that the vegetables contained so much minerals. This finding is comparable to that reported in similar studies for *A. hybridus*, *C. peps* and *G. africana* [53]. High % protein recorded in this study might be as a result of increased protein synthesis in the vegetable plants or increased availability of essential components of amino acids to the site of protein synthesis. It has been reported that plant materials or foods that provide more than 12% of their calorific value from protein are good sources of protein [54]. The results for protein content (%) is an indication that the vegetables studied are good sources of protein. The high moisture content recorded for the two vegetables in this study provides for greater activity of water soluble enzymes and coenzymes needed for metabolic activities of these vegetables [55,56].

CONCLUSION

This study revealed that soils around Umuoghara Quarry sites have significantly high levels of Cu, Zn, Ni, Pb, Cd, Fe, Mn and may serve as potential source of these heavy metals in the environment at large. Findings from the study also suggest negative impact on nutritional composition of vegetables grown on soils that are in close proximity to the rock quarry sites. This implies that rock mining in the study area have negative impacts on different environmental media including plants. The results obtained for proximate analysis of fluted pumpkin leaves (*Telfairia occidentalis*) and African Spinach (*Amaranthus hybridus*) cultivated and consumed within the environs of the quarries in the study area showed that they are good sources of nutrients such as protein, dietary fibre and therefore can be ranked as protein rich food due to their relatively high protein content. Therefore, it can be concluded that these vegetable species are good source of nutrients. However, attention should be given to the high ash content of the vegetable species as this could be as a result of prolonged exposure to soil heavy metals even at low concentrations.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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