Research Article

Assessment of heavy metal contents in farm produce around Ewekoro and its health implications on consumers

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Abstract

This study was conducted to assess the risk of exposure to thirteen (13) heavy metals from food products obtained from cassava tubers grown in the limestone mining area of Ewekoro, Ogun State in Nigeria. Four (4) samples each of soil and cassava tubers were collected at three different sites for this study. The first two sample collection sites were at 150 m and 300 m from the mining site while the third or the control samples were collected at a distance of 25 km far away from the mining activities. The collected samples were analyzed by the use of Inductively Coupled Plasma-Optical Emission Spectrometry. The concentration average of Fe, Mg, Na, Ag, As, Cd, Co, Cr, Cu, Mn, Ni, Pb and Zn ranged from 2.00–1284.96 to 0.0098–646.31 mg/kg for both soil and cassava tubers, respectively at site 1, which was far higher than 0.26–622.01 and 0.90–514.35 and 0.07–688.37 and 0.07–371.74 mg/kg reported in both soil and cassava tuber samples at the other 2 locations. The transfer factor from the soil to cassava tuber for Fe, Mg, Ag, As, Cd, Cu, Co, Mn and Pb were observed to be < 1. While Na, Cr, Ni and Zn had transfer factor > 1. The estimated average daily intake at site 1 for both adults and children were 0.46 and 1.69 mg kg^{-1} bw^{-1} d^{-1}, respectively. These values were far higher than the results noted at sites 2 and 3 for both adults and children. Similarly, the Risk Index for both adults and children at site 1 were reported to be 7.01 and 25.42, which were higher than the values noticed at the other 2 sites. Therefore, it can be concluded that although the concentrations of these heavy metals were higher than the internationally recommended standard, the EADI and RI revealed that children are at higher risk of exposure to the heavy metal contents from food products derived from cassava in the study area.

Article Highlights

- The risk of exposure to heavy metals in cassava food products was estimated in this study.
- The heavy metals were found to be higher in the cassava tubers than normal.
- Children were observed to be at the receiving end of the exposure.

Keywords Transfer factor · Risk Index · Cassava tubers · Spectrometry · Heavy metals

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1 Introduction

Food is one of the basic needs of man because it is required to sustain his living and it provides the needed energy to engage in other productive activities. Food items are grouped into various classifications depending on their function, such classifications include protein, carbohydrate, fats and oil and so on [1]. One of the food items that is very rich in carbohydrate is cassava. Cassava is a popular food crop in Nigeria because of the various ways it can be consumed. It can be boiled and eaten, and fried as chips [2, 3]. Cassava flakes popularly known as Garri is a delight in every home, also, Fufu (cassava starch) and Lafun (cassava flour) are all obtained from processed cassava tubers and they are among the most consumed foods in different parts of Nigeria and among different ethnic groups [1].

However, the conditions of land being used for agricultural practices contribute majorly to the condition of the farm produce harvested on it [4]. This is because water and nutrients from the soil are transferred into plants during cultivation for their growth [5]. Moreover, the application of fertilizers to farm land aids cultivation by supplying the lacking nutrients in the land. All of these processes have implications on the quality of farm produce [6]. Due to the transfer factor from soil to plants, the heavy metals and mineral contents in the soil leave their signature on the produce from the farm. It has also been noted that geologic features are registered in groundwater and other products that have their sources from nature [7].

Similarly, heavy metal concentrations in arable soil could be due largely to two factors, which are geologic and anthropogenic or influence of human activities. Geologic activities are largely as a result of weathering and leaching of rocks, while anthropogenic activities include smelting, application of pesticides, use of fertilizers, industrialization, cement-contamination, mining and so on [8]. All these activities contributed to the loads of heavy metals in the soil on which farm products are cultivated [9]. Especially in an environment like the area of study where both natural and manmade activities could contribute largely to the heavy metal concentration in farm products. The indifferent disposition of the regulatory bodies to the activities of miners in most developing nations allow them to operate without controls [10]. This unregulated activities endanger the lives of the people in the immediate environment of the mining activities in terms of air pollution and soil contamination.

Excess exposure to heavy metals especially when they are highly concentrated in foodstuff consumed or are contained in small proportion in food items popularly consumed by young and old can pose major health risk to consumers [11]. Studies have shown that heavy metals possess a characteristic of being non-biodegradable and they possess density, which is about 5 times greater than the density of water and a small amount of heavy metal can be very toxic to human. Yeboah in [12] revealed that cancer can occur in human organs as a result of undue exposure to lead (Pb). Other diseases such as kidney problems and symptoms such as vomiting have been traced to undue exposure to heavy metals in consumed foods.

Food crops such as cassava can be contaminated by heavy metals from the soil. This is due to the fact that cassava roots have the ability to absorb these metals from the soil in which they are planted [13, 14]. Further studies have confirmed that various species of plants accumulate toxic from soil at different rates. Therefore, it becomes very paramount to determine the level of heavy metals present in cassava crops cultivated on soils close to limestone mining activities at Ewekoro area, Ewekoro local government in Ogun State, Nigeria in order to determine the level of exposure to the consumers. In the next section, we considered the materials and methods, under which the geology of the area of study was first looked at. In addition, the laboratory analysis, transfer factor and consumption exposure and associated health implications were estimated. The third section presented the results of the findings in the study while the fourth section discussed the results. The section that followed focused on the statistical analysis of results while the final section presented the conclusion of the findings in the manuscript.

2 Materials and methods

2.1 Geology and geographical location of the study area

The study was conducted in Ota, Ogun state, which falls within the eastern part of the Dahomey (Benin) Basin in south-western Nigeria (Fig. 1). The basin stretches along the continental margin of the Gulf of Guinea. Rocks in the Dahomey basin are Late Cretaceous to Early Tertiary in age [15–17]. The general sequence of the rock unit from the top are the Coastal plain sands, Ilaro formation, Oshosun formation, Akinbo formation, Ewekoro formation, and Abeokuta Group lying on the Southwestern Basement Complex of Nigeria [16]. The Cretaceous Abeokuta Group consists of Ise, Afowo and Araromi Formations consisting of poorly sorted ferruginized grit, siltstone and mudstone with shale-clay layers [17].

The Dahomey is one of the sedimentary basins on the continental margin of the Gulf of Guinea, extending from

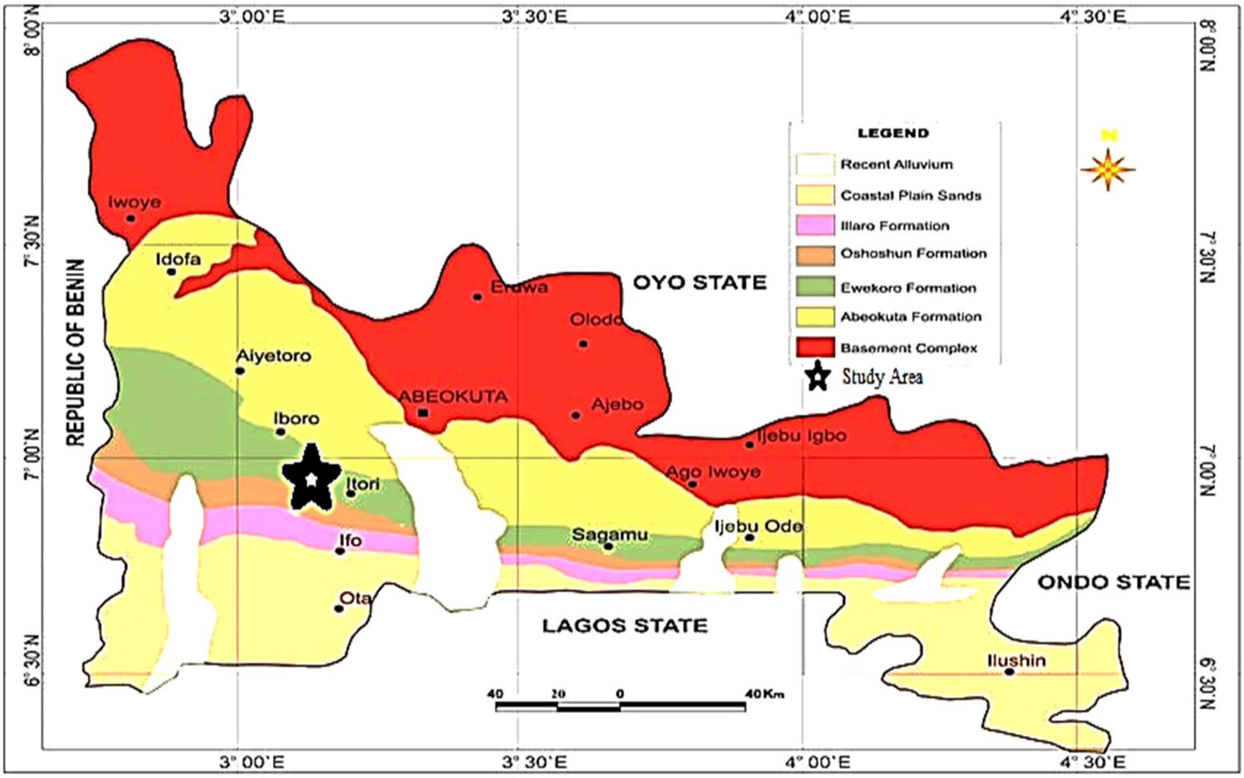

Fig. 1 Geological map of the area of study (modified after [15])

southeastern Ghana in the west to the western flank of the Niger Delta [15, 16]. The basin is bounded in the west by faults and other tectonic structures associated with the landward extension of the fracture zone. Its eastern limit is similarly marked by the Hinge line, a major fault structure marking the western limit of Niger Delta [16]. It is also bounded in the north by the Precambrian basement rock and the Bright of Benin in the south. Stratigraphic studies of Dahomey basin were conducted by various researchers among who are [16–18]. The population of the study area is about 700,000 people according to national population data of 2006.

2.2 Sample collection and processing

The samples used for this study were collected at three different sites. Two of the sampling sites were located around Ewekoro mining station. Four samples were collected at each sample site. The first set of samples were gathered from two sites in the heart of Ewekoro while the third set of samples, which were used as the control, were taken at another community about 25 km away from the cement mining site. The reason for choosing a control site that is 25 km away is to confirm the influence of the geological formation of the study area on the concentrations of heavy metals in both soil and cassava plant samples and also to evaluate the trends in transfer factors of heavy metals from the soil to the plants at the three different sites. The distance between Ewekoro mining site and the first sample collection site was about 150 m while the distance between the first sample site and the second was about another 150 m as shown in Fig. 2. The local residents of the area were engaged and monitored for the sample collection exercise. At each location, soil samples, cassava tubers, stems and leaves were collected in large quantities so as to yield sizeable amount of samples required for analysis, after the samples have been processed. The collected samples were then transported to an open space at the College of Science and Technology building of Covenant University where they were first sun dried for five days. However, only the cassava leaves were dried at this temperature. Prior to sample processing, the cassava tubers were washed to remove every element of soil that could contaminate the result. Therefore, the samples of soil, cassava tuber and stem were oven dried at moderate temperatures of 50° and 20 °C, respectively in order to remove every moisture that could remain in the samples [19]. After oven drying, the samples were taken to the Mechanical Engineering departmental workshop of the same University for pulverization. The pulverized samples of soil and tuber were later sieved with 200 µm size sieve in order to attain uniformity of the samples [20]. However, adequate

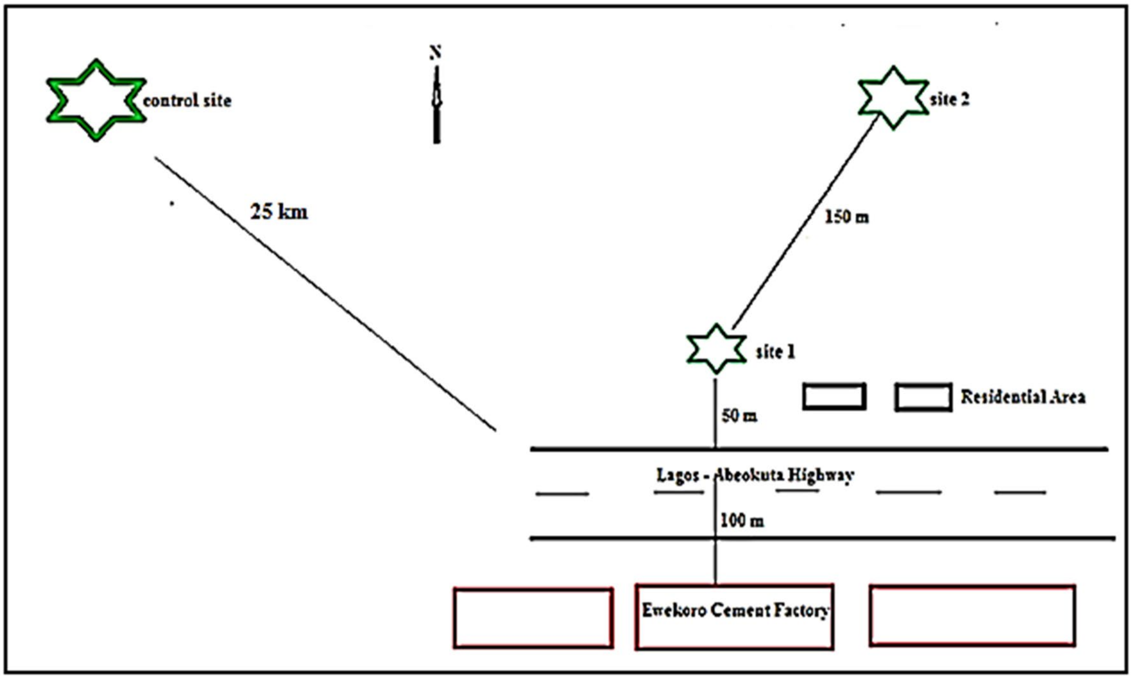

Fig. 2 Base map of the Study Area

precautions were taken to prevent cross contamination of the samples of soil and cassava tuber.

2.3 Laboratory analysis

The samples of soil and tuber were first homogenized and 1 g of each sample was weighed. The measured samples were transferred into beakers in addition to 20 ml of Aqua Regia. The digestion was carried out on a heating block in a fume hood with the temperature not exceeding 90 ^{0}C for about an hour. The beakers were allowed to cool and 2 ml of Hydrogen peroxide was added to each beaker and heated for 10 min. After the digestion was completed, the digestate volume of each sample was measured. Digestate was then filtered and 0.5 ml was diluted to 10 ml using ultra-pure deionized water for ICP-OES analysis. Equation 1 was used to convert the unit from ml to mg/kg.

$$\text{Conc.(mg/kg)} = \frac{\text{Conc.(mg/L) x Final Volume (L) x Dilution Factor}}{\text{Weight of Sample (kg)}} \tag{1}$$

Where, Conc. (mg/L) = Instrument readout conc.

Final Volume = as recorded for each sample.

Dilution Factor = 20.

Weight of sample = 0.001 kg or as recorded.

The following materials were used Nitric Acid (Scharlau Spain), Whatman filter paper (125 mm), Ultra-pure reagent water (Merck US), Hydrogen Peroxide (Merck US) and Hydrochloric Acid (Merck US) [21–23].

2.4 Estimation of transfer factor (T_F)

The transfer factor (T_F) is a measure of the level of accumulation of toxic elements by the plants from the soil [24]. This was evaluated by dividing the concentration of heavy metals in the cassava tuber samples by the concentration of heavy metals in the soil samples. This is expressed mathematically as,

$$T_F = \frac{(Conc.\ of\ heavy\ metals)_{plant}}{(Conc.\ of\ heavy\ metals)_{soil}} \tag{2}$$

where, C_{plant} = Concentration of heavy metals in cassava tuber (mg/kg).

C_{soil} = Concentration of heavy metals in soil (mg/kg).

The significance of the result is that if T_F is greater than 1, it implies that the plants have accumulated elements. However, if T_F is less than 1, it connotes that the plant resists the uptake of the elements. However, if T_F is around 1, it simply shows that the plants are not affected by the element [24, 25].

2.5 Estimation of consumption exposure and associated health risk

The exposure and health hazards due to consumption of food items made of contaminated cassava produce were estimated using the estimated average daily intake (EADI) of the heavy metals contained in the cassava tubers and the associated hazard indices or risk indices (RI). The EADI was calculated using (3).

$$EADI = \frac{C \times F}{W \times D} \tag{3}$$

where, C = concentration of metal in cassava tuber (mg/kg),

F = yearly consumption of food made from cassava per person,

W = average body weight of 70 kg for adults and 15 kg for children.

D = number of days in a years (365 days).

The yearly intake of food made from cassava per person was assumed to be 154 and 120 kg per person per annum for adults and children, respectively [1]. Furthermore, the health implication, defined as the risk indices (RI) of consuming these food items was calculated using (4) [26] [43].

$$RI = \frac{EADI}{R_f Do} \tag{4}$$

where, R_fDo is the oral reference dose of the various metals considered.

3 Results and discussion

The concentrations of various elements in the cassava tubers depend on the level of heavy metals and other elements present in soil. As can be clearly seen in Table 1, the concentrations of heavy metals in soil samples at site 1 is far higher than in the sample of soil at site 2 for all the heavy metals tested, except zinc, which is much higher than in site 1. The observed high concentration in soil samples collected at site 1, could be attributed to the proximity of site 1 to the heart of mining activities. However, the soil samples in site 2, reported much lower heavy metal concentrations than site 1. This could be attributed to the distance between the mining site and site 2. The concentrations of heavy metals in soil recorded at site 2 showed the same trend as some of the heavy metals investigated in [27], this could be as a result of the distance of the sampling sites to the mining location. The minimum concentrations of heavy metals presented for Mn, Fe, Cu, Zn, Cr and Pb are 2.90, 184.71, 0.38, 2.57, 0.46 and 0.23, respectively, the slight differences in the result could be due to variations in the sensitivity of the analytical tools and level of depositions of cement dust in the study area. This also confirms the variation in the geology and lithological sequence of the study area from one sample location to another.

Similarly, the concentration of heavy metals in cassava tuber collected at site 1 were moderately higher than in site 2. This could be attributed to the concentration of heavy metal in the soil on which the cassava plant was cultivated. It can also be noted that some elements in cassava tubers collected at site 2, have higher concentrations than in cassava tubers collected at site 1. A case in point is cadmium in cassava tubers collected at site 2 with a concentration of 2.71 mg/kg when compared with the concentration of 0.98 mg/kg reported in cassava tubers collected at site 1. This could be as a result of the application of fertilizers rich in cadmium to cultivate the cassava. In addition, Pb and Zn reported higher concentrations of 6.01 and 2.17 mg/kg in cassava tubers collected at site 1 than in 2.21 and 2.70 mg/kg, respectively as noted in cassava tuber collected at site 2 as presented in Table 1. The variation in the heavy metal concentrations noted in cassava tuber picked at site 2 could be as a result of the water run-off from the mining region to the area where samples collected at site 2 were grown. The concentration of heavy metals in both soil and cassava tuber samples collected at site 3 were relatively lower than those collected at sites 1 and 2, respectively as presented in Table 1. Although, there are some of the elements that are at the same level when compared with concentrations obtained in site 2. This could be because the samples at site 3 or control samples, were collected about 25 km away from the mining area, where the influence of limestone and its constituents are not pronounce.

The values in Table 2 were used as the control for the results obtained at the mining site. From Table 1, it could be deduced that the concentrations of heavy metals in sample 1 were at least about twice the concentrations of heavy metals at site 3. Similarly, the concentrations of heavy metals in the tubers collected at the sample site 1 were about twice the concentrations of the tubers collected at site 3. This could largely be due to the variations in the geologic composition of the soil formation in the two areas. However, the results obtained at site 2 compares relatively with the results at site 3. This further confirmed the influence of the limestone on the results obtained at site 1.

The concentrations obtained at the site very close to the mining site in the present study was compared with the allowable standard limits for both soil and edible plants as recommended by the European Commission Director General Environment [26] and the study of [27]. The results for soil revealed that for most heavy metals compared, the result of the present study was far lower than the recommended limits from Germany, Ireland, USA and other countries presented in the study. However, the concentrations of cadmium was higher in the present study than what was recommended by [26]. The pattern observed

Table 1 Transfer factors of heavy metals and other elements from soil to tuber at sites 1, 2 and 3 (control)

Metal	Locations	Conc. in Soil (mg/kg)	Conc. in Tuber (mg/kg)	Transfer factor
Fe	Control	96.60 ± 5.12	70.77 ± 3.78	0.73
	1	256.37 ± 10.21	114.50 ± 8.52	0.45
	2	18.27 ± 2.35	102.33 ± 9.25	5.60
Mg	Control	688.37 ± 18.23	371.74 ± 12.25	0.54
	1	1284.96 ± 25.38	646.31 ± 13.73	0.50
	2	622.01 ± 12.47	514.35 ± 15.23	0.83
Na	Control	118.28 ± 9.45	99.36 ± 7.54	0.84
	1	108.85 ± 6.23	207.11 ± 10.08	1.90
	2	57.36 ± 3.29	272.21 ± 12.22	4.75
Ag	Control	1.48 ± 0.13	ND	ND
	1	7.41 ± 0.23	2.11 ± 0.12	0.29
	2	ND	1.07 ± 0.23	ND
As	Control	3.92 ± 0.24	1.81 ± 0.11	0.46
	1	7.71 ± 0.16	3.65 ± 0.13	0.47
	2	3.90 ± 0.28	1.64 ± 0.22	0.42
Cd	Control	3.33 ± 0.31	3.95 ± 0.21	1.19
	1	5.82 ± 0.12	0.98 ± 0.02	0.17
	2	2.76 ± 0.20	2.71 ± 0.30	0.98
Co	Control	2.26 ± 0.28	4.13 ± 0.28	1.83
	1	7.80 ± 0.16	6.58 ± 0.04	0.84
	2	3.53 ± 0.12	ND	ND
Cr	Control	0.81 ± 0.10	0.59 ± 0.21	0.73
	1	4.08 ± 0.14	4.24 ± 0.03	1.04
	2	1.34 ± 0.10	0.90 ± 0.02	0.67
Cu	Control	1.03 ± 0.04	ND	ND
	1	13.09 ± 0.10	1.19 ± 0.01	0.09
	2	1.20 ± 0.09	ND	ND
Mn	Control	11.16 ± 1.26	ND	ND
	1	20.91 ± 0.15	3.15 ± 0.02	0.15
	2	10.99 ± 1.25	1.14 ± 0.03	0.10
Ni	Control	2.18 ± 0.21	0.07 ± 0.01	0.03
	1	5.14 ± 0.18	6.54 ± 0.05	1.27
	2	0.47 ± 0.03	3.20 ± 0.24	6.74
Pb	Control	0.07 ± 0.00	5.73 ± 0.24	85.57
	1	6.15 ± 0.23	2.21 ± 0.03	0.36
	2	0.26 ± 0.02	6.01 ± 0.36	23.48
Zn	Control	2.00 ± 0.10	2.94 ± 0.18	1.47
	1	2.00 ± 0.11	2.70 ± 0.02	1.36
	2	5.36 ± 0.32	2.17 ± 0.15	0.40

ND—Not Detected

in the concentrations obtained at the mining site is the same as in the concentrations in the control, although, the proportion in the control is lower by a factor of about 2 for some elements. The variations noticed in the results compared could be due to geological differences, variation in soil compositions and the kind of activities that are dominant in the study areas. Similarly, the concentrations of cassava tubers in this study was compared with the recommended safe limits by [27, 28] and [29], the results showed that the cassava tubers collected closest to the mining site have heavy metal concentrations higher than the recommended safe standards for most of the elements except for Copper and Zinc, which have lower concentrations of 1.19 and 2.70 mg/kg and were still lower than the recommended safe limits of 3.0 and 6.0 mg/kg, respectively. However, in the control study, Silver, Copper and Manganese were in the range of not detectable results while Nickel, Lead and Zinc have values of 0.07, 5.73 and

Table 2 Presents the estimated average dietary intake (EADI) and risk Index (RI) at Sites 1, 2 and 3 (control)

Elements	R_fDo	Site 1				Site 2				Site 3			
		EADI (adult)	EADI (children)	RI (adult)	RI (children)	EADI (adult)	EADI (children)	RI (adult)	RI (children)	EADI (adult)	EADI (children)	RI (adult)	RI (children)
Fe	0.7	0.69	2.51	0.99	3.59	0.62	2.24	0.88	3.20	0.43	1.55	0.61	2.22
Mg	–	3.90	14.17	–	–	3.10	11.27	–	–	2.24	8.15	–	–
Na	–	1.25	4.54	–	–	1.64	5.97	–	–	0.60	2.18	–	–
Ag	0.005	0.01	0.05	2.55	9.27	0.01	0.02	1.29	4.71				
As	0.0003	0.02	0.08	73.28	266.47	0.01	0.04	32.93	119.76	0.01	0.04	36.37	132.26
Cd	0.001	0.01	0.02	5.93	21.58	0.02	0.06	16.36	59.49	0.02	0.09	23.79	86.50
Co	0.02	0.04	0.14	1.98	7.21	ND	ND	ND	ND	0.02	0.09	1.24	4.52
Cr	1.5	0.03	0.09	0.02	0.06	0.01	0.02	0.00	0.01	0.00	0.01	0.00	0.01
Cu	0.04	0.01	0.03	0.18	0.65	ND	ND	ND	ND	–	–	–	–
Mn	0.14	0.02	0.07	0.14	0.49	0.01	0.03	0.05	0.18	–	–	–	–
Ni	0.02	0.04	0.14	1.97	7.17	0.02	0.07	0.96	3.51	0.00	0.00	0.02	0.08
Pb	0.0035	0.01	0.05	3.80	13.83	0.04	0.13	10.35	37.65	0.03	0.13	9.87	35.90
Zn	0.3	0.02	0.06	0.05	0.20	0.01	0.05	0.04	0.16	0.02	0.06	0.06	0.22
Total		6.04	21.95	–	–	5.47	19.90	–	–	3.38	12.30	–	–
Mean		0.46	1.69	7.01	25.42	0.42	1.53	4.84	17.59	0.26	0.95	5.54	20.13

EADI–mg kg^{-1} bw^{-1} d^{-1}, ND—Not Detected

2.94 mg/kg, which were lower than the safe limits of 1.63, 2.0 and 6.0 mg/kg, respectively [30].

Furthermore, the transfer factor estimated in the first sampling location revealed values less than 1 for Iron, Magnesium, Silver, Arsenic, Cadmium, Cobalt, Copper, Manganese, and Lead as seen in Table 1. While Sodium, Chromium, Nickel and Zinc revealed values more than 1. The elements whose transfer factors were less than 1 showed that the metals were excluded by the plants during the uptake of nutrients from the soil [30, 31]. This could be due largely to the nature of the plant and its selectivity for the listed heavy metals. This implies that the consumption of cassava at site 1 does not expose the consumers to metals such as such as Iron, Magnesium, Silver, Arsenic, Cadmium, Cobalt, Copper, Manganese and Lead. On the other hand, chromium has a transfer factor of 1.09, which indicated that the cassava plants are not affected by chromium [32]. This showed that the consumption of these cassava does not in any way expose the consumers to Chromium. However, Sodium, Nickel and Zinc having transfer factors of 1.90, 1.27 and 1.36, respectively, which revealed that the cassava tubers absorbed and accumulated these heavy metals during its growth. This further implies that consumption of these cassava tubers expose the consumers to the possible effects that may occur. Studies have revealed that too much exposure to Sodium can lead to high blood pressure, heart related diseases and eventually stroke. Similarly, undue exposure to Nickel can cause allergies, lung disorders, and cancer while exposure to Zinc can result in stomach pain and vomiting. The results observed for Cu, Pb, Zn, Cr, Co and Ni, in [33] for maximum concentrations of heavy metals in both soil and plant samples were much higher than the results obtained in the present study. However, the values of the minimum concentrations of heavy metals in their study were within the same range of values with the present study. This could be attributed to the differences in the depth of investigation considered in both studies. The present study investigated the concentration of heavy metal in the near surface from the topsoil to about 15 cm into the earth. Contrarily, the results of [34] in the same study area presented a lower average results for Mn, Fe, Cu, Zn, Cr and Pb, than the present study and this could be due to variation in the constituents of the geologic composition of the soil materials.

The results of the transfer factors at site 2, which is about 300 m away from the limestone mining site are also presented in Table 1. The results revealed Silver, Cobalt and Copper to be below the detectable limits. This could be that these elements are not available or available in very minute amount in the soil at the second station. Also, the values of transfer factor reported for Magnesium, Arsenic, Cadmium, Chromium, Manganese and Zinc varied between 0.10 and 0.98. Since these values are below 1, it implies that the cassava plant does not absorb these elements as part of the nutrients required for its growth. However, Iron, Sodium, Nickel and Lead are very prominent in the transfer factor of the second station with values of 5.60, 4.75, 6.74 and 23.48, respectively. This result showed that the cassava tuber acquired in this area, accumulated these elements. This further implies that the consumption of food products made from this cassava tubers can expose the consumers to the side effects of undue exposure to these elements [35]. Exposure to Iron can lead to stomach upset, nausea and vomiting while unnecessary exposure to lead can result in developmental delays in children, learning difficulties, irritability and loss of appetite among others.

The transfer factor at site 3 or control correlated with site 2 except for Iron, Sodium and Nickel, where the results are 5.60, 4.75 and 6.74, respectively compared with 0.73, 0.84 and 6.74. However there was an increase in the transfer factor for Lead at site 3 or control, which showed 85.37 compared to 23.48 noted in location 2. This variation in result could be due largely to the type of cassava plant or the influence of the environment on the plants. Moreover, consumption of cassava products that is highly infested with Lead (Pb) could result in loss of coordination and death in both children and adults.

The transfer factor at site 3 or control provided a contrast in result with transfer factor at site 1 because of the differences in the ratio of concentration proportions in both soil and cassava tuber samples. While site 1 was a mining site with higher concentration of the elements in both soil and plant, location 3 or control was a farm land that is not within the mining region and possessed lower concentrations of the elements in both tested samples and that is why this location was intended as a control for this study. Generally, it could be seen from the results obtained in this study that the concentrations of heavy metals in both cassava tubers and soil are higher at site 1 than at site 2 and site 3 (control). However, the transfer factors of the heavy metals from soil to the cassava tubers were noted to be in the order of site 1 < site 2 < site 3 (control). This could be as a result of the fact that the geological composition of the study area prevented the uptake of heavy metals from the soil by the plants. The transfer factor was noted to increase as we moved away from the epicenter of the mining station in the area of study and was at its highest at site 3 (control)..

The results of estimated average dietary intake and risk index for different age classifications are presented in Table 2. At site 1, the EADI for children is higher than adults in all the considered elements especially in Iron, Magnesium and Sodium, where in children, the values are 2.51, 14.17 and 4.54 mg kg^{-1} bw^{-1} d^{-1}, respectively while the values in adults are 0.69, 3.90 and 1.25 mg kg^{-1} bw^{-1} d^{-1}.

This result showed that children are at the receiving ends of the effects of these elements. Similarly, at site 2, the results of the EADI compared closely with location, which also confirmed that children are more prone to the risk of undue exposure to these heavy metals from their food. This could be as a result of their small body weight unlike in adults where the body weight gives room for proper dispersal of the exposure. Also, the average of EADI for adults at sites 1 and 2 ranged between 0.42 and 0.46 mg kg^{-1} bw^{-1} d^{-1}, while in children the EADI varied between 1.53 and 1.69 mg kg^{-1} bw^{-1} d^{-1}. Generally, the results of EADI at site 1 are slightly higher that the results at site 2 for both adults and children and this implies that the daily consumption of cassava produce from site 1 exposed both adults and children to the same level of risk. In Table 2, the average EADI for site 3 for both adults and children are 0.26 and 0.95 mg kg^{-1} bw^{-1} d^{-1}, respectively. This site was used as the control and it is lower than the average values of EADI at sites 1 and 2. This could be due to environmental conditions and the geological formation of site 3. The results obtained in the present study for site 3 fall within the same range of values obtained in [1, 12, 36].

The Risk Index at site 1 is higher than the results at site 2 for both adults and children in all the tested elements except for Cadmium and Lead, where the result at location 2 is far higher than site 1. Moreover, the average Risk Index for both adults and children at sites 1 and 2 are 7.01 and 25.42, 4.84 and 17.59, respectively [37–39]. However, at site 3, the average Risk Index for both adults and children were noted to be 5.54 and 20.13, respectively which are higher than the results observed at site 2 but lower than the results at site 1. The Risk Index for Cadmium are 5.93 and 21.58 for adults and children, respectively at site 1 while at site 2, the result is 16.36 for adults and 59.49 for children. At sites 1, 2 and 3, the Risk Index is higher in children than adults, this could be due largely to the smallness of their body weights. Thus, the results revealed that both children and adults are prone to the risk of heavy metal contamination, if they are uncontrollably exposed to the cassava products from this study area, which agrees with [1, 40] for unprocessed cassava. However, children are at higher risk of the effects of undue exposure to heavy metals from cassava food products in the area of study because of the smallness of their body size. The results of Cr, Co, Ni, Cu, Pb, Cd, Zn, Mn, As in the present study were compared with the results obtained by [42] around Pb–Zn mining site at Enyingba, southeastern, Nigeria. The result of their study was far higher than the result of the present study. This could be as a result of the high concentration of Pb–Zn in the area of their study, which influenced the concentrations of other metals available in the mining area. Similarly, the result of the present study is much lower than the safe limits recommended by the European Union, which are Cr (100), Co (50), Ni (50), Cu (100), Pb (100), Cd (1), Zn (300), Mn (2000), As (20) where all values are in mg/kg. The results of the present study are quite safer than in [42]. Furthermore, the heavy metal concentrations of Cr, Co, Ni, Cd, Zn, Mn, and As in cassava of the present study were noted to be far higher than in [42]. However, Cu and Pb in [42] reported higher concentrations than the present study. Moreover, the results of the heavy metal concentrations of cassava tubers in this study were compared with the European Union recommended safe limits and Co, Cu, Zn and Mn were found to be lower than the recommended standards while Cr, Pb and Cd reported greater concentrations than the safe limits. Similarly, the results of the transfer factor from soil to plants reported in [41] were much higher than the present study for Mn, Ni, Cu and Zn. However, the result of the transfer factor of Pb in the present study is far higher than in [41]. It can also be noted that the results of the transfer factor in [42] is lower than the present study. The variations in all these results could be largely due to the differences in the compositions of the geological formations in the areas and the different activities, such as mining, farming and so on, that take place in each area.

4 Statistical analysis of data

4.1 Kruskal–Wallis Test for variation between metals and locations

The Kruskal–Wallis statistical test was carried out to determine if the distribution of the metals was homogeneous with a significant value less than 0.05 across all the locations. The test showed no significant variation with heavy metal concentration as indicated by a significant value of 0.152 which is greater than 0.05. Further analysis to identify possible locations where variations could be significant would not be needed.

Furthermore, the Kruskal–Wallis test was also used to test if the deviation in the heavy metal content was significant across all metals analyzed (Table 3). The test revealed a significant value less than 0.05 which implies that one or more of the metals were significantly higher or lower in concentration compared to the others across all locations.

Table 3 Test statistics

	Values
Chi-square	3.765
df	2
Asymp. Sig	.152

Kruskal–Wallis test

Grouping variable: Location

Table 4 Test statistics

	Values
Chi-square	45.657
df	12
Asymp. Sig	.000

Kruskal–Wallis test

Grouping variable: Metals

To identify the metals with significant deviation in content, the Games–Howell post-hoc test was carried out (Table 4). From the result of the Games-Howell test, Mg was found to be the heavy metal with statistically significant deviation from the others with the exception for Na and Fe.

5 Conclusion

In this study, thirteen (13) heavy metals and elements were studied in both cassava tubers and arable soil in order to estimate their risk of exposure to man. Both samples of soil and cassava tubers were collected at three different sites. The samples were prepared and analyzed using Inductively Coupled Plasma Optical Emission Spectrometry. The mean concentrations of Fe, Mg, Na, Ag, As, Cd, Co, Cr, Cu, Mn, Ni, Pb and Zn in both soil and cassava samples varied between 2.00 and 1284.96 and between 0.98 and 646.31 mg/kg for both soil and cassava samples, respectively at site 1. However, the results at site I was far higher than 0.26–622.01 and 0.90–514.35 and 0.07–688.37 and 0.07–371.74 mg/kg measured in both soil and cassava samples collected at sites 2 and 3, respectively. Furthermore, the transfer factor from the soil to cassava tuber for Fe, Mg, Ag, As, Cd, Cu, Co, Mn and Pb were noted to be < 1. While the transfer factor for Na, Cr, Ni and Zn from soil to cassava recorded values > 1. The results of transfer factors from soil to cassava plants revealed a trend as follows, site 1 < site 2 < site 3 (control). Generally, the values of EADI and RI for both adults and children at site 1 were three (3) times higher in children than adults in most cases at sites 2 and 3. Furthermore, Games-Howell statistical test identified Mg as the only metal with obvious deviations from the others. Therefore, it can be concluded that children are at higher risk of exposure to heavy metals from cassava tubers cultivated in this limestone mining area than adults. Further study is recommended to analyze the radionuclide contents in the samples collected in the study area in order to define its health implications on consumers.

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Declarations

Conflict of interest The authors have no competing interests to declare that are relevant to the content of this article.

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