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Phytoextraction and Risk Assessment Synergy of Three Edible Plants in Mining Area

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Authors' contributions

This work was carried out in collaboration between all authors. Authors CIAN, AUN and DOO designed the study, performed the statistical analysis and wrote the protocol. Authors LUO and PCN managed the analyses of the study and managed the literature searches and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The phytoextraction and risk assessment synergy of *Arachis hypogea* (groundnut), *Zea maize* (Corn) and *Citrullus colocynthis L.* (Melon) was investigated at a mining area contaminated with Cd, Cu, Pb and Zn heavy metals. The metal concentrations in plant matter and soil were determined using AAS. The average pH at 5.2 showed a slightly acidic soil while the total organic content and electrical conductivity were low. The studied metals exceeded the Nigerian FEPA guidelines as well as EU threshold values at the sites. Increase in Cd concentration in the North and South caused a corresponding decrease in plant yield. The maize appreciably accumulated more Pb than melon and groundnut. The phytoplants at the West sampling point accumulated more Zinc and melon grown at the west accumulated highest zinc concentrations of up to 1100 mg/kg. The Presence of Cu metal at low concentrations favoured an equivalent increase in weight of harvested groundnut seed. The Coefficient of Variation (CV) showed a correlation that hyperaccumulators had equivalent higher CV

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distribution. The values of Cd, Cu and Pb exceeded the Health Risk Index value of 1 in all the three edible phytoplants. The Cd demonstrated the lowest Bioconcentration Factor of (0.03) within the sampling area, among studied metals and the three edible plants. Thus Target Hazard Quotient (THQ) results agreed with the Daily Intake of Metals (DIM) results, that consumption of any of the three edible plants are unsafe and poses a health risk to locals; hence, the synergy of THQ and DIM in evaluating experimental data is detected in this study.

Keywords: Phytoextraction; risk assessment; edible plants; heavy metals.

1. INTRODUCTION

Phytoremediation and phytoextraction are well-established technology that utilizes natural plants to degrade or accumulate metal pollutants. Consequently, it can be used for contaminated soil cleanup and prevention of environmental pollution [1]. Among such plants are *Arachis hypogea* (groundnut), *Zea maize* (Corn) and *Citrullus colocynthis L.* (Melon). However, the implementation of these plants in soils at mining sites have remained largely unreported and herein will be studied.

Arachis hypogea phytoremediation ability was investigated when planted in controlled plastic bowls and exposed to Zn^{2+} and Pb^{2+} ions via their prepared salt solutions. The study showed that at 50 mg and 250 mg treatment of Pb salts, *Arachis hypogea* absorbed 27.47 mg and 201.49 mg of Pb respectively. Additionally, it absorbed 400 mg of Zn when treated with 700 mg of the zinc salt solution [2]. This was similarly observed by another study that confirmed the uptake of Pb in the plant seeds, stem, roots and leaves [3]. The uptake and distribution of some other heavy metals in *Arachis hypogea* were studied in the man-made contaminated soil. The result demonstrated that the plant showed high tolerance of Cd, Cu, Fe, Mg and Zn heavy metals even at high concentrations [4]. Another study confirmed that *Arachis hypogea* survived exposure to industrial effluent containing Fe, Co, Ni, Cu and Cr heavy metals [5]. Furthermore, in-situ studies of the plant at Pb contaminated site concluded that using peanut plants for phytoextraction was feasible and also economically viable even for biofuel generation [6].

Arachis hypogea commonly known peanut when planted alongside *Zea mays* at contaminated oil site showed more tolerable germination and seedling growth than Zea mays [7]. Interestingly, another study revealed that the growth rate of *Zea mays* is influenced by mixed pollutant interactions [8]. However, its phytoremediation ability can be improved when combined alongside chelants and resistant bacteria [9]. Thus *Zea mays* have been proposed as an alternative risk-reduction and income generating plant in agriculture but also a gradual pollutant reducing plant [10]. Similarly, successful application of maize for remediation of atrazine-contaminated soil and calcareous soils has been reported [11,12] as well as heavy metals (Cd, Cu, Co, Cr and Pb) contaminated soils [13]. Subsequently, *Zea mays* have been recommended as a tropical phytoremediation approach for developing nations [14,15].

Citrullus Colocynthis L. commonly referred to as bitter gourd, bitter apple and Egusi has been rarely reported as a phyto remediating plant. Its chemical constituent, however, reveals the presence of some terpenoids, alkaloids, phenolics, saponins and tannins that can create surface active interactions for uptake of some heavy metals [16]. The plant has been described as stress-resistant and drought tolerance [17] with vast medicinal uses against infections, inflammations cardiovascular and immune-related diseases with anti-proliferation potential on human cancer cells [18]. Additionally, the plant has been reported to possess the ability for synergistic interaction and capability to neutralize side effects arising from combinations activities [19]. Such application has been explored to reduce hypatoprotective activity against CCl_4 induced hepatoxicity [20] and in storage insect management against *Callosobruchus maculatus* [21]. Albeit, one of the few published phytoremediation application demonstrated the successful application of *Citrullus colocynthis L.* for uptake of eight different heavy metals in polluted soil [22].

Hence, there is an information gap regarding its in-situ application around mining areas in Nigeria. In this regard, a team of researchers initiated the in-situ implementation of these three edible plants at a conservative mining area in Nigeria. The objective will study the synergy surrounding plants metal uptake and associated health risk that may arise as a result of consumption by locals within the community [23,24,25]. In addition, the selected edible "phytoremediating" plants are known to possess different phytoremediation ability under different ecological conditions. Therefore, this work will study the application of *Arachis hypogea* (groundnut), *Zea maize* (Corn) and *Citrullus colocynthis L*. (Melon) phytoextraction of Cu, Zn, Pb and Cd around Isiagu in Ebonyi State Nigeria, a conservative mining area.

2. MATERIALS AND METHODS

2.1 Site Location and Soil Properties

The study site is located at Ishiagu in Ivo LGA area of Ebonyi state of Nigeria (latitude 5°54' – 5°59' N and longitudes 7°30' – 7°35' E) with nearest communities such as Ngwogwa, Amonye, Amagu in Abia State, Iza-Ovim in Enugu state and Abakaliki in Ebonyi state. The area has experienced longtime conservative mining, industrial and quarrying activities at small and large scale due to rich mineral deposit [23, 24, 25]. This site is also part of a larger mining site in Ishiagu, Ebonyi state, Nigeria and hence selected for experimental analysis. For the purposes of the experiment, 5 plots were selected for the field study. Each plot was assumed to be 14 m x 7 m with 7 rows of plants grown at 1 m by 1 m spacing. At planting, three seedlings were sown in each hole and reduced to one plant after germination. The estimate was to give a plant population of 220-250 per plot tagged as North, South, East, West and central. Commercially purchased *Arachis hypogea* (groundnut*), Zea maize* (Corn) and *Citrullus colocynthis L*. (Melon) were sown on the plots. The phyto-plants were identified by Department of Crop Science Technology, Federal University of Technology Owerri and utilized based on the plant's output and adaptability to different ecological conditions. The crops were sown in April 2015 at the set of early rains after land tillage and harvested in October at the setting of dry season. Local weeding and use of traps were adopted for weed and pest control. The soil was regularly irrigated to forestall any scarcity of rainfall; the rains would oftentimes be irregular with varied distribution even within a specific site. The average pH test of 5.23 in 20 g soil mixed with 20 mL deionized water was often determined. Within each plot, plant and soil samples were taken at random sampling for plant and soil analyses [6,10].

2.2 Plant Analysis

Plant samples were selected at random from each site taken 20 full stem and peanut leaves, 10 full stem and corn leaves and 30 full steam and melon leaves. After the harvest, each plant was thoroughly washed with tap water and rewashed with deionized water to remove clogs, soil and dust particles. The initial weight of the harvested plants was taken before drying the whole plant at 105°C to obtain a constant weight. About 1g of dried sample was thoroughly mixed in 42 mL of concentrated HCl and 14 mL of Concentrated nitric acid. The Cu, Zn, Pb and Cd concentrations of the supernatant liquid were quantitatively determined using Atomic absorption spectroscopy model AA 500 Pg Instruments. The Average of two readings was reported for each analyte [6,10].

2.3 Soil Analysis

Using a previously reported method, the modified soil analysis could be stated concisely as follows. All soil samples were taken at harvest at the depth of 30 cm and placed in different sterile black polythene bags to minimize degradation and afterwards transferred to an insulated box to avoid irradiation. The soils were air dried for three days, ground and sieved through a 2.5 mm sieve. Then 1 g of the sample from each of the 5 plots were taken and dissolved in 16 mL concentrated HCl and 4 mL of Concentrated nitric acid. The mixture was heated over a hot plate with hood extractor until no dense white fumes were seen. Afterwards, the equilibrated mixture was cooled to room temperature (28ºC) and 40 cm^3 of deionised water added and mixture reheated before filtrations for atomic absorption spectrometry analyses [2,5,14].

2.4 Statistical Analysis

The heavy metals in the harvested phytoplants will be evaluated using the Coefficient of Variation (CV). The significance of CV will demonstrate the distribution patterns of the heavy metals within the harvested edible parts. Hence, the CV would be calculated using the stated formula below.

$$CV = \left(\frac{STDEV}{Mean}\right) \times 100$$

The Daily Intake of Metals (DIM) will provide the health risk assessment as per consumption and related health risk among the locals. The obtained values will be compared with their respective Oral Reference Dose (RfD) using the formula stated below

$$DIM = \left(\frac{C_{metal} \times D_{intake}}{B_{average}}\right)$$

Where,

C_{metal} is the heavy metal concentration in the edible maize cobs, melon and groundnut pods
D_{intake} is the intake of metals (average of 1% of harvested cobs and pods in a plot)
$B_{average}$ is the average body mass of an adult (65 kg)

The health risk index (HRI) provides a guide for acceptability grading of associated health risk. Wherein the HRI is > 1, the existing health risk is unaccepted whereas if the HRI is < 1 the health risk exposed to the population is acceptable. The formula is written as.

$$HRI = \left(\frac{DIM}{RfD}\right)$$

Lastly, to estimate the hazard related to the probability of the population that has an adverse effect from consumption of the harvested pods and cobs which utilized Target Hazard Quotient (THQ). This will provide a platform to compare risk levels and pollutant exposure and the common formula is shown below as follows.

$$THQ = \frac{Ef \times ED \times CR \times Mc \times 10^{-3}}{RfD \times BW \times AET}$$

The exposure frequency *(Ef)* is the exposure frequency for 365 days/year' the exposure duration *(ED)* is 70 days while the consumption rate of g/day for an adult (being the average amount consumed by the adult = 50 seeds per day). The *Mc* is the metal concentration in mg/kg; *RfD* gives the reference oral dose by ATSD index (Cd is 0.001; Cu is 0.040; Pb is 0.0035; Zn is 0.300) while the body weight *(BW)* of 65kg is assumed for an average adult. The *AET* is the average time of exposure which is 365 days/year multiplied by *ED* and 10^{-3} is the conversion factor. The guideline for *THQ* is as follows. If the *THQ* value is > 1 then it means the state of risks in the environment. If *THQ* is < 0.1 it confirms the existence of nominal hazard; *THQ* value of 0.1-1.0 shows that low level of hazard exists; *THQ* value of 1.1 – 10 confirms moderate hazard whereas *THQ* > 10 depicts a high hazard level [26]. Also, CR is the consumption rate of 50 seedlings per day.

The Bioconcentration factor (BCF) for the metals in the three edible plants will be calculated using the equation below [12,27].

$$BCF = \frac{C_p}{C_s}$$

Where C_P is the concentration of metal in plant tissues (mg/kg) and C_S is the total concentration of metals in the soil (mg/kg).

3. RESULTS AND DISCUSSION

3.1 Soil Characteristics

The results of the soil analyses are shown in Table 1 below. The pH of the soils were all slightly acidic, and the highest was recorded at south area as 5.6 while the north was more acidic than other sampling sites up 4.9. The electrical conductivity showed low values and may indicate the accumulation of metals and slow leaching process. The total organic matter was below 2%. This confirmed that vegetation may be struggling to thrive in this region and as well as the absence of heavy, dense organic matter. For each of the selected heavy metals, their concentrations were higher than the control sample. All the metals had a point (west and central) greater than 3000 mg/kg except Zn metal. Cd showed the highest disparity among the 5 studied sites with minimum as 1160 mg/kg and maximum as 4160 mg/kg. The Pb content showed little variation with minimum average as 3162 mg/kg. Subsequently, it is important to recall that the threshold values of metals exceeded Nigeria FEPA guidelines (Cd unfixed, Cu 80, Pb 1.6, Zn 400, mg/kg) as well as the EU threshold values (Cd 3.0, Cu 140, Pb 300 mg/kg, Zn unfixed, mg/kg). Hence the land need remediation. Also, similar results on pH, total organic carbon and electrical conductivity were obtained by the previous study that determined the physicochemical study of soil within the Ishiagu area [24]. Likewise, the inverse correlation of metal concentrations was also detected at the central and north regions of study site [25]. During the harvest, the South produced the highest yield of groundnut while the west and south produced more for maize and melon respectively. The heaviest harvested seedlings of groundnut and melon came from the west sampling point while the west and central produced similarly weighted seedlings during harvest. Hence, the west sampling point may be experiencing some other ecological factors favourable for seed weight increase. Additionally, intervention levels of these metals Cd, Cu, Pb and Zn: (380, 10, 210 and 1500 mg/kg respectively) were also significantly exceeded [28].

3.2 Cadmium Uptake

The Fig. 1. below shows the average metal uptake by each plant. The uptake of cadmium by maize was lowest (200 mg/kg) at central and highest (700 mg/kg) at the south. A comparison of the metal concentration with the initial amount of Cd in the south was 1160 mg/kg and central at 3790 mg/kg was observed at table 1.0. The values showed that an inverse correlation may exist in the uptake of metals by Maize; they absorb more cadmium when the metal exist at lower concentrations. Similarly, the groundnut had the lowest uptake of metal at the central while the melon's lowest uptake was at the east. On the contrary, all the recorded concentrations of melon were below 400 mg/kg and can be said to be a low absorber of cadmium when compared with maize and groundnut. The groundnut showed good phytoextraction ability by absorbing more cadmium metal at the most cadmium concentrated sampling point of soil. However, the parent soil showed more concentration of metals were still present in the soil samples.

More so, in Table 1, an increase in cadmium concentration in the north and south sampling locations, correlated with loss of yield of harvested maize and its harvested seeds. Also, melon uptake of Cd was generally low showing unfavourable interaction and low phytoaccumulator of Cd.

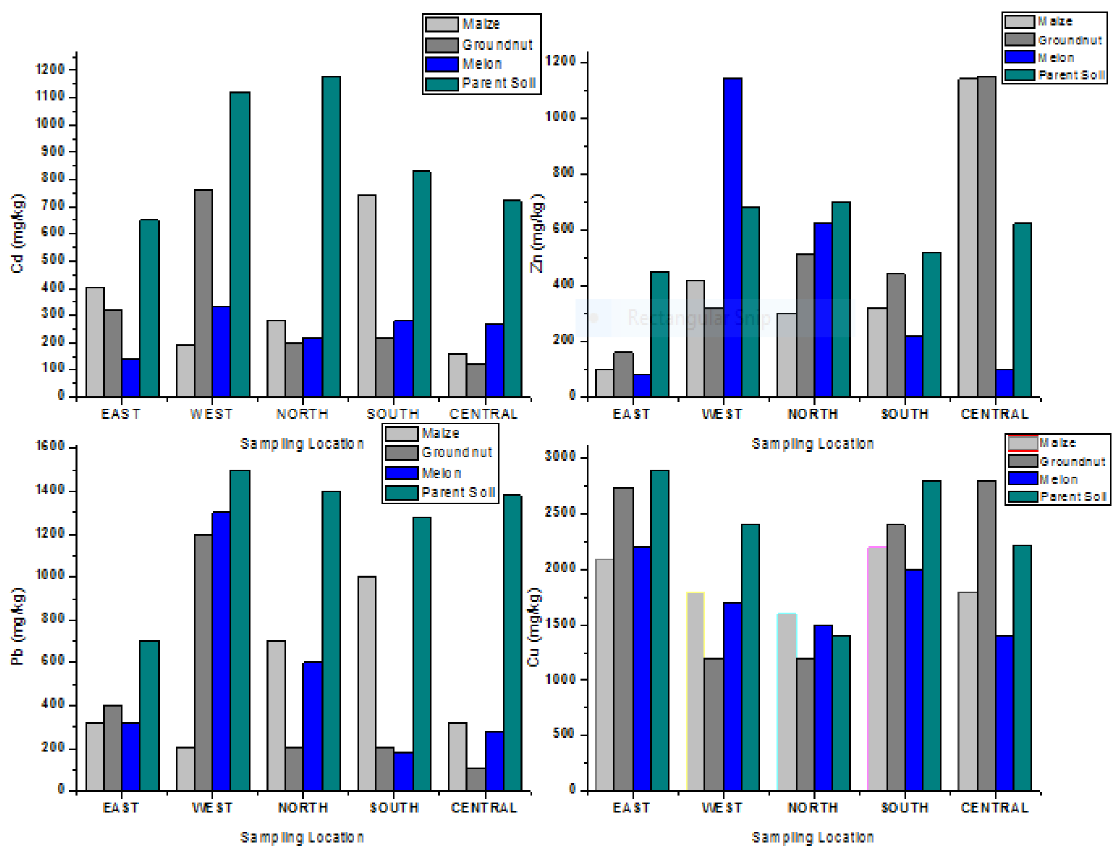

Fig. 1. Metal uptake by Melon, G. Nut and Maize, and the amount present in parent soil after harvest

Table 1. Soil properties and yield of the sampled area

	North	East	West	South	Central	Control
pH	5.1	5.2	5.2	5.6	4.9	6.5
Electrical conductivity µs/cm	45	57	60	120	70	150
Total organic carbon (%)	1.21	1.52	0.82	1.80	0.50	23
Cd (mg/kg)	1630	2180	4160	1160	3720	530
Cu (mg/kg)	4600	4120	4500	4110	3290	1250
Pb (mg/kg)	3400	3220	3130	2980	3080	1820
Zn (mg/kg)	2090	1650	2170	2060	1890	1030
The average weight of harvested G.Nut (kg/plot) after 16 weeks	17.5	17.0	18.5	19.2	18.8	20
The average weight of 50 seeds of G.Nut (g)	8.0	8.1	8.2	7.6	8.1	7.9
The average weight of harvested Maize (kg/plot) after 16 weeks	30.0	32.5	32.9	31.7	30.2	33
The average weight of 50 seed of Maize (g)	5.6	5.9	6.0	5.1	6.0	6.1
The average weight of harvested Melon (kg/plot)	435.0	430.9	440.7	450.6	430.4	440
The average weight of 50 seeds of Melon (g)	4.2	4.7	5.0	4.8	4.2	4.8

3.3 Lead Uptake

The metal lead (Pb) has been described as a toxic metal with health consequences if absorbed by the human body. The research study showed that the parent soil had more Pb than any of the three edible plants. The lowest recorded concentration of Pb was at east at about 700 mg/kg which was almost doubled by the Pb concentrations at the other sampling locations at 1500 mg/kg, 1400 mg/kg, 1300 mg/kg and 1200 mg/kg. Hence, the soil properties may not have favoured Pb depleting from the soil by other natural mechanisms rather than plant uptake or the element did not exist in forms easily absorbed by the plants. However, on the average, all the three plants absorbed Pb conveniently especially G. Nut [3] and melon in the west. Thus they can be described as good phytoextractor of Pb. But contrary, the on the west only, the melon and groundnut planted showed significant uptake of the metal by the plants except for the maize. Thus they melon and groundnut may have experienced some factors driving the mechanism of absorption to their advantage. Thus, observation demonstrated that Pb absorption is affected by soil conditions and phytoability of the plant. Similarly, the uptake of lead by peanut was reported by in some research, even as high as 200 mg for Pb. Hence G. Nut tolerates the presence of this metal [2,4]. On the average, the maize appreciably absorbed more Pb than melon and G. Nut [9,13]. Only the west showed good phytoaccumulation of Pb by melon up to 1200 mg/kg. The other planting areas were below 600 mg/kg. Hence, absorption of Pb is not favourable to melon. Although the amount of Pb in the soil as shown in table 1 had the significant concentration in the west. This may have caused an equivalent spike of Pb absorption by melon (west) as seen in figure 1. Also, it may be caused by the loss or absence of other competing nutrients [22].

3.4 ZIINC Uptake

The presence of Zn metal was more pronounced at the west sampling location. The melon grown at the west sampling point absorbed zinc concentrations of up to 1100 mg/kg. This concentration almost doubled the amount of Zn metal at the North at 600 mg/kg. The melon grown at the central and east were below 100 mg/kg and were insignificant compared to the uptake at the west. The results when compared to Table 1, confirmed that the west sampling point had the highest zinc concentration and followed closely by the north. This synergy may be the result of some mechanism driving the melon uptake of zinc which exceeded the concentration of zinc metal in the parent soil. A similar correlation was observed at the central sampling point were the significant uptake of zinc by maize and groundnut outwitted that of melon. The soil condition may have been favourable towards the metal uptake. Primarily, each of the three edible plants at west and central exceeded the parent soil level of the metal respectively. Hence, these shows that zinc is the major elemental component of these plants and are more likely to be absorbed in the soil if the conditions are favourable to the plants. On the contrary, the south and the east sampling location depicted the parent soil to show more zinc metal presence than in any of the groundnut, maize and melon plants. Similarly, the uptake of Zinc by G. Nut and maize was reported in literature, even as high as 402 mg for Zn. Hence G. Nut/Maize tolerates the presence of Zn metal as evidenced in the central area [2,4,10]. Another interesting finding in figure 1 showed that melon is also a good phytoaccumulator of Zn. In Table 1, the highest and lowest Zn concentrations were recorded in west and east and similarly demonstrated in figure 1. Here, the maximum in the west showed absorption of up to 1100 mg/kg and the east with a minimum below 100 mg/kg. This difference may have been a side effect of synergistic interaction and the neutralizing combination of activities [19].

3.5 Copper Uptake

The uptake of copper metals by the plants was more significant than any of the other metals. The result may indicate that copper is an essential nutrient to the efficient metabolism of the three studied plants. Although the amount of Cu in the parent soil exceeded the absorption by any of the three plants. However, the result showed that some form of competitive mechanism exists in the absorption of copper metal. At the North sampling location, Maize showed a more resilient uptake of the copper metal up to 1600 mg/kg. This confirmed that maize may perform better as a phytoextractor when the competition of basic nutrient is experienced. Hence the low absorption of the copper metal by maize at other sampling sites compared to groundnut and melon. Additionally, on the average, groundnut, showed a better phytoextractor at the east, south and central sampling points. Remarkably, these sites in Table 1 showed the low amount of copper present in the soil before planting. Hence a correlation that at lower concentrations of copper, groundnut is a better phytoextractor of copper. Then it is worthy of note that copper concentration at North and west were highest before planting and showed well-reduced absorption level/concentration when compared to South, Central and East. Hence the existence of copper metal at lower concentrations will favour equivalent increase in weight of harvested groundnut seed. On the average, literature focus on melon has been on its pharmacological, photochemistry and nutritional value [16,19]. Interestingly, the maximum metal uptake was in the east area and up to 2300 mg/kg while the minimum was in the north up to 1500 mg/kg. Hence our work found a correlation with reported literature that melon is a good phytoaccumulator of Cu as evidenced in Fig. 1 [22].

3.6 Statistical Evaluation

A literature search was performed on the scientific databases including ACS, Google Scholar, PubMed, Scopus, SciFinder, Web of Science and published books for risk assessment of *Arachis hypogea* (groundnut), *Zea maize* (Corn) and *Citrullus colocynthis L.* (Melon) in mining site but found a knowledge gap. Hence due to the dearth of published research; this work will stand as a reference point to similar research work that may be conducted by researchers in the future.

3.6.1 <u>Coefficient of Variation (CV)</u>

The coefficient of variation was plotted in figure 2 below. This parameter provides a means for assessing the distribution of metals within the studied area. The most evenly distributed metal was Cu and ranged from 0 to 50 on software auto plotting of average values. This blue colouration can be seen spreading from maize to melon, G. Nut and entire parent soil region. Cu metal showed a higher distribution in maize and G. Nut (50-100) but less in the melon and soil. Hence, the CV agreed with an earlier description that melon was a low phytoaccumulator of cadmium when compared to G. Nut and maize. The CV for Pb was highest in G. Nut (100-150) and lowest in the soil. Thus the CV correlated with previous description that G. Nut tolerates the presence of Pb and hence accumulates more Pb at favourable conditions [2,4]. Only the Zn level in the soil was generally low (0-50). However, G. Nut and maize showed even distribution of the metal while melon was a hyperaccumulator of Zn as per seen in Fig. 1 [2,4,5,10]. Therefore, the CV plot described a correlation that hyper phytoaccumulators will demonstrate equivalent higher CV distribution.

3.6.2 <u>Daily Intake of Metals (DIM)</u>

The values of Daily Intake of Metals (DIM) were plotted in Fig. 2 below above. Generally, the calculated cadmium DIM value was lower compared to the other metals. The results, when compared to their respective values, shows that Cd at 0.02, Cu at 0.16 and Pb at 0.045 exceeded their *RfD* requirements in the maize except for Zn metal at 0.04. Thus the daily consumption of maize grown within the sampled area may pose

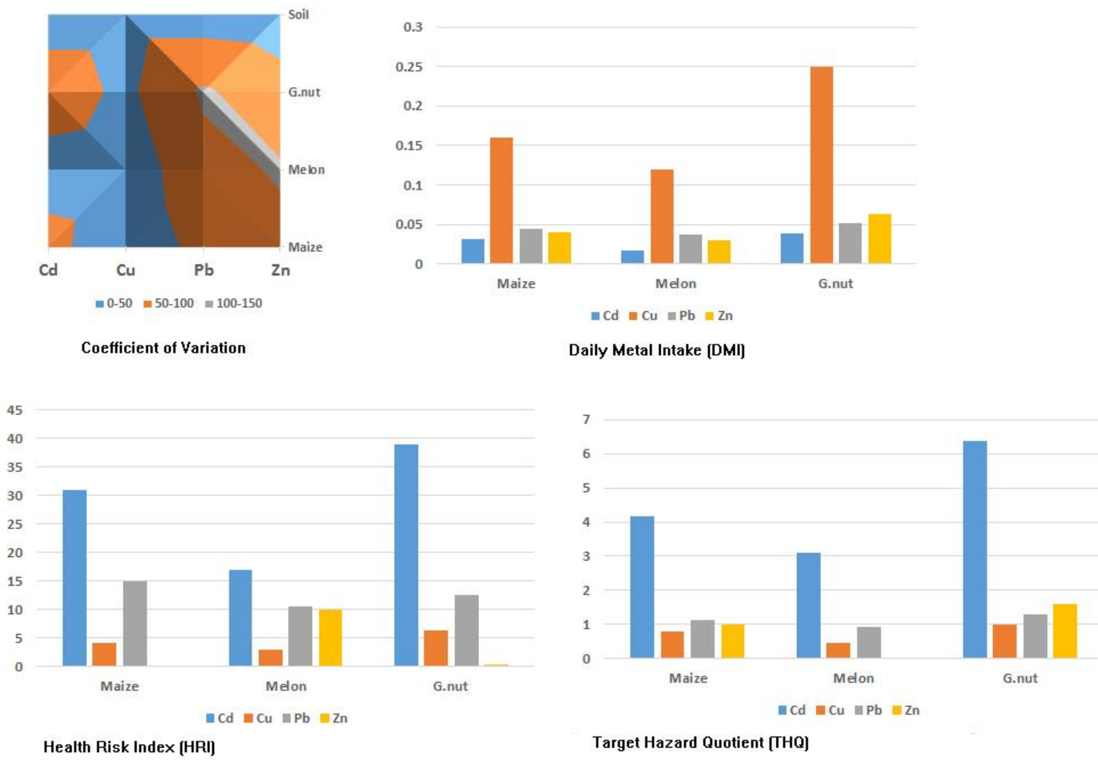

Fig. 2. Graphical charts for CV, DIM, HRI, THQ in Maize, Melon and G. Nut edible portions

a health risk to the locals. Similarly, the *RfD* values of Cu and Pb metals were exceeded in the melon, while Cd and Zn where just at their respective *RfD* threshold values. However, Pb and Cu intake through melon consumption makes the melon unsafe for daily consumption due to possible health effects that may arise from them. The G. Nut showed the highest DIM values of which Cd had 0.04, Cu at 0.25, Pb at 0.05. Each of the metals tripled their threshold value. However, only Zn was lower than its *RfD* value. Hence the consumption of G. Nut has greater likelihood to trigger related health diseases than any of melon and maize.

3.6.3 Health Risk Index (HRI)

The HRI is usually compared to 1 as the standard value for its risk assessment. The plot in Fig. 2 showed that Zn metal was below 1 in the maize and G. Nut except in the melon. This showed that the HRI captured melons ability to phytoaccumulate Zn [19]. Also Cd was highest in both maze and G. Nut as correlated with Fig. 1 above showing both plants as hyperaccumulators. Summarily, the values of Cd, Cu and Pb exceeded the HRI value of 1 in all the three edible phytoplants and hence their presence is a health risk and is unacceptable in the phytoplants. Consequently, at this high HRI values, the phytoplants will be useful for phytoremediation and for biomass energy yield especially melon and maize [6,10].

3.6.4 Target Hazard Quotient (THQ)

The THQ was graphically depicted in Fig. 2. All the THQ values of Cu, Pb and Zn were below the nominal value of 1.0. Hence, only nominal hazard would be associated with the consumption of either maize, melon or G. Nut. However, the presence of Cd was as high as 6.5 in G. Nut, 4.0 in Maize and 3.0 in Melon and exceeded 1.0 value. Thus THQ values of 1.1 to 10 confirms moderate hazard associated with their consumption. Also a closer observation would show that melon was the safest edible to consume by THQ approach. Maize and G. Nut identified as unsafe to consume. Thus, THQ results agreed with the DIM results that consumption of any of the three edible plants are unsafe and poses health risk to locals; hence, the synergy of THQ and DIM in evaluating experimental data is established in this study.

Table 2. The BCF values of edible plants

	North				East				West				South				Central			
	Cd	**Cu**	**Pb**	**Zn**	**Cd**	**Cu**	**Pb**	**Zn**	**Cd**	**Cu**	**Pb**	**Zn**	**Cd**	**Cu**	**Pb**	**Zn**	**Cd**	**Cu**	**Pb**	**Zn**
Maize	0.18	0.34	0.20	0.14	0.18	0.50	0.12	0.06	0.03	0.38	0.41	0.18	0.60	0.51	0.30	0.14	0.04	0.36	0.09	0.58
Melon	0.13	0.32	0.17	0.23	0.04	0.53	0.09	0.05	0.07	0.35	0.06	0.51	0.21	0.48	0.06	0.09	0.06	0.38	0.08	0.05
G.Nut	0.12	0.26	0.05	0.28	0.13	0.66	0.09	0.09	0.17	0.26	0.38	0.13	0.17	0.55	0.06	0.19	0.05	0.79	0.03	0.58

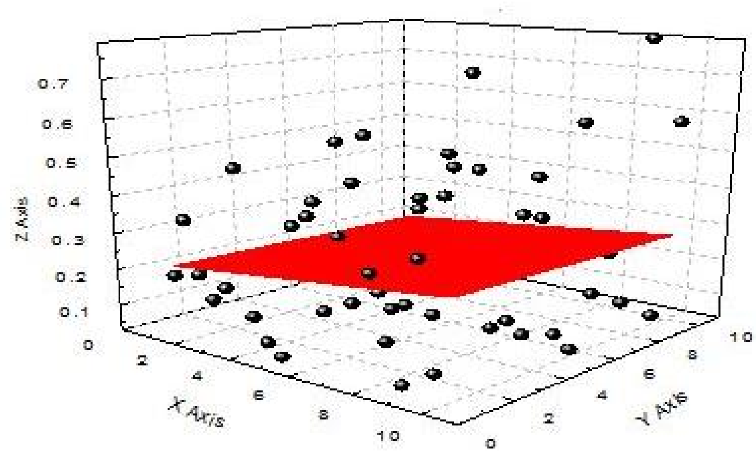

Fig. 3. Calculated 3D bioconcentration factors (BCF) for the edible Maize, Melon and groundnut

3.6.5 Bioconcentration Factor (BCF)

The BCF shows the movement of metals within the tissues. It was demonstrated that no BCF from Table 2 below was above 1. Hence showing similar phytoremediation ability. The highest BCF value for Cd accumulation in maize at South sampling area was 0.60, however the BCF value at all other points remained very low. Similarly, Cu metals in the south and east showed the highest BCF value in the Maize, melon and G. Nut (0.79) respectively. On the contrast, the Cd demonstrated the lowest BCF value (0.03) both within the sampling area, studied metals and the three edible plants. This correlated with Cd demonstrating the lowest DIM within the studied phytoplants and metals. summarily the low BCF values (< 0.50) indicated that the plants experienced difficulty in translocation of metals within their tissues especially in the east and central sampling areas. This may have arisen because of interfering ecological factors like rainfall, sunlight, chlorination, soil pH and soil bacteria. The BCF values greater than 0.5 showed greater chances for anthropogenic activity contamination especially in the South and east as observed for Cu. [12, 27]. Also 0.79 BCF was similarly observed in G.Nut at Central site showing anthropogenic disturbance. The results can better be demonstrated as also seen in Fig. 3 showing the BCF values of the plants.

4. CONCLUSION

The experimental study showed that the site particularly the west was heavily contaminated with Cd, Cu, Pb and Zn. Maize and groundnut were better phytoaccumulators of Cd than melon. On the contrast, the Melon competed with maize and G. Nut over Zn accumulation. Pb and Cu showed no clear accumulation pattern because they were affected by soil conditions and nutrients. Cu showed consistency in CV distribution. Each of the metals tripled their DIM threshold value. The HRI showed that the plants can be used as hyperaccumulators and biomass energy yield while the BCF value in east and south for Cu in all the three plants showed tendency towards anthropogenic contamination.

5. RECOMMENDATION

From the research study presented above, it would be recommended that the sampled area needs urgent remediation and cleanup; having reached the soil intervention level [28]. Government should urgently intervene to clamp down on illegal mining as well as sanctions for pollution caused by licensed miners. The use of Maize, Melon and Groundnut for phytoextraction would be natural, slow and gradual technique that would take a number of years. Wherein the economic benefit of these plants are not sustainable, other techniques like biostimulation, extraction, immobilization, isolation and electrokinetic treatment may be utilized [28,29]. Additionally, research conducted to understand compounds that may be related to the factor of absorption of metals may be the panacea to plant metal uptake kinetics. Also the consumption of edibles planted around the region is a health risk and locals should discontinue from the practice; having exceeded the WHO/FAO maximum allowable standard for vegetables [30].

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COMPETING INTERESTS

We declare that no conflict of interest exists for this research work.

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