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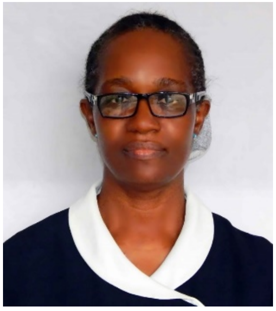
TRANSFER OF METALS FROM SOIL TO *Cucumis sativus* FRUIT AND POSSIBLE HEALTH RISK ASSESSMENT UNDER ACTUAL FIELD CONDITION

Udousoro II[1]* and ME Essien[1]



Imaobong Udousoro

*Corresponding author email: imaobong2i@yahoo.com

[1] Chemistry Department, University of Uyo, Uyo, Akwa Ibom State, Nigeria

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ABSTRACT

Toxic metals levels in *Cucumis sativus* (cucumber) plant and soil in an area of the oil producing Niger Delta of Nigeria were investigated. The study was carried out in a small scale *Cucumis sativus* farm located in Idim Afia village in Eket Local Government area of Akwa Ibom State, Nigeria. Toxic metals levels in soil were lower than the background levels except cadmium. Bioconcentration factor revealed that both toxic and major metals concentrated more in the root except for lead and cadmium which concentrated more in the shoot. Though the fruit is a good source of potassium (bioconcentration factor=14.90), it also hyper-accumulates nickel (bioconcentration factor=84.00), qualifying it as an indicator of nickel pollution. Effective transfer (Transfer Factor>1) of metals were observed for lead and cadmium from root to shoot; zinc, nickel, chromium and cadmium from shoot to leaf; and nickel and chromium from shoot to fruit. Generally, transfer factor within the organs was less than one. Indices of soil pollution indicated low to moderate pollution of farm soil and, also anthropogenic origin for cadmium and chromium (concentration factor>1). Principal component analysis extracted three major components accounting for 94.351% of total variance, and characterised by strong associations with exhaust emissions, leaching of industrial and domestic waste and agricultural activities. The main human exposure route of all toxic metals in Eket was through ingestion of fruit. Non-carcinogenic chronic daily intake and non-carcinogenic hazard quotient were higher in farm and purchased fruit than in the farm soil. Non-carcinogenic hazard quotients of individual exposure pathways and the total non-carcinogenic hazard quotient was <1, indicating no potential health concern for zinc, nickel, lead, cadmium, and chromium pollution in Eket at the time of study. It was observed that chromium posed least risk to the local population, with hazard quotient ranging from 0.000 in soil to 0.0006 in farm fruit. However, cadmium in farm soil, and nickel and lead in the fruit, presented higher values for non-carcinogenic risk in the study area, hence more attention should be paid to cadmium, nickel and lead pollution in future studies. The results of this study may inform policy on the prevention of food contamination by toxic metals.

Key words: Health risk, Metals, Soil, Cucumber

INTRODUCTION

Toxic metals contamination of air, water, agricultural soils, edible and non-edible plant organs pose a serious global environmental problem, and in the oil producing Niger Delta Region of Nigeria, is threatening agriculture and human health [1-4]. Man, in an attempt to control his environment, has sustained the advancement in science and technology, which invariably gives rise to increased industrialization, urbanization, and population growth; leading to contamination of the environment [5, 6]. Soil to plant transfer is a major route of contamination. Plants cultivated in soil polluted with toxic metals bioaccumulate the metals in their edible and non-edible parts in quantities high enough to result in biomagnification, which could cause various ailments including deaths in humans and animals [7, 8]. Food chain contamination is the main pathway of exposure of humans and animals to toxic metals through oral intake of food and water [5, 9]; other exposure routes include ingestion of soil, dermal contact and inhalation [8, 10].

These metals, which exist as trace elements are harmful because of their non-biodegradable nature, long biological half-lives and potential to accumulate in different parts of plants, and body parts of humans and animals. High levels of cadmium, lead and nickel in vegetables and fruits are associated with increased prevalence of upper gastrointestinal tract cancer [11].

Fruits and vegetables form an important part of diets in Akwa Ibom State, and *Cucumis sativum* is one of the fruits commonly available. The cucumber fruit has high water content; therefore, when eaten, the body does not have to use its own water for its digestion. Less energy and resources would thus be needed to digest the fruit - a situation that improves efficiency and makes assimilation faster [12]. Fruits and vegetables contain most nutrients and especially vitamins and minerals needed for proper functioning of the body [13]. Cucumber is rich in vitamins A, B6, C and K, and minerals such as potassium, magnesium, phosphorus, copper and manganese; and is usually recommended by doctors to diabetic patients in Nigeria.

This study seeks to investigate the levels of toxic (zinc, nickel, lead, cadmium, chromium) and major (sodium, potassium, magnesium, calcium) metals in cucumber plant parts (fruit, leaf, shoot, root) and soil; assess the bioconcentration factor (BCF) and transfer factors (TF) in the plant; determine the pollution status of farm soil using pollution indices-concentration factor (CF) and geoaccumulation index (I_{geo}); classify and determine the source of metals pollution using multivariate analysis; and, also the risk associated with ingestion of cucumber fruit and soil.

MATERIALS AND METHODS

Description of study area

The study was carried out in a small scale *Cucumis sativus* (cucumber) farm located in Idim Afia village in Eket Local Government area. Eket Local Government occupies the South Central portion of Akwa Ibom State territorial expanses spanning Northwards between Latitudes 4°33' and 4°45' and Eastwards between Longitudes 7°52' and 5°02'. Eket is bounded on the North by Nsit Ubium Local Government Area, on the East by

Esit Eket Local Government Area, on the West and South by Onna Local Government Area and Ibeno Local Government Area/Bight of Bonny respectively. The cucumber plant was cultivated in mounds of about 30 cm high from ground level with three to five plants grown in a mound, each plant having an average of four fruits.

Sampling, sample treatment, dissolution and analysis

The farm was divided into four sections (A, B, C and D). *Cucumis sativus* plant was uprooted randomly with corresponding soil samples, and five composites from each section of the farm to give 20 plants without blemish, and 20 soil samples in the month of August, 2005. The plant was wrapped with paper while the soils were stored in polythene bags for each section and transported in ice thermoflask coolers to the laboratory.

In the laboratory, the plant was rinsed with running tap water to remove dust and soil particles and separated into root, shoot, leaf and fruit, then oven-dried (using Memmert B-40 oven) at 80-90^oC; and the soil samples at 100-105^oC. The dried samples were crushed to powder, passed through 2mm mesh size sieve and preserved in Ziploc bags for analysis.

One gramme each of soil and plant was digested on Gerhart hot plate at 80^oC using 20 ml of concentrated mixture of 70% HNO_3 and 70% $HClO_4$ in the ratio 3:1 (V/V) until a transparent solution was obtained. It was allowed to cool, then filtered through Whattman No. 42 filter paper and diluted to 50 ml with distilled water.

Concentrations of zinc, nickel, lead, cadmium, chromium, sodium, potassium, magnesium and calcium in filtrate were estimated in plant organs (fruit, leave, shoot and root) and soil using atomic absorption spectrophotometer (Solar ATI-UNICAM 939 1995 model). Moisture content was determined using AOAC method (1990) [14].

Blank samples were prepared under same conditions and analysis done in duplicates. The precision and bias in the analysis were less than 10%.

Data analysis

Statistical analyses were done using Microsoft Excel, Stagraphics Centurion® XV and SPSS Statistics version 17.

Bioconcentration factor (BCH)

This was calculated using Equation 1

$$BCF = \frac{C_{\text{plant part}}}{C_{\text{soil}}} \quad - \quad - \quad - \quad - \quad - \quad - \qquad \text{Equation 1}$$

Where $C_{\text{plant part}}$ and C_{soil} are the concentrations of metals in plant parts (root, shoot, leaf and fruit) and in soil, respectively.

Transfer factor (TF)

This was calculated using Equation 2, as a ratio of the concentration of leave/shoot and fruit/shoot.

$$TF = \frac{C_{\text{arial part}}}{C_{\text{root}}} \quad - \quad - \quad - \quad - \quad - \quad - \qquad \text{Equation 2}$$

Where $C_{\text{arial part}}$ and C_{root} are the concentrations of metals in plant arial parts (shoot, leaf and fruit) and root, respectively.

Metal pollution index (MPI)

This was calculated using geo accumulation index (I_{geo}) given by

$$I_{geo} = \frac{\log_2 C_n}{1.5\ B_n} \quad - \quad - \quad - \quad - \quad - \quad - \qquad \text{Equation 3}$$

Where C_n = concentration of metal ‘n’ in soil; B_n = background concentration of the metal ‘n’ [15]; 1.5 = correction factor to take care of possible variations in background values for a given environment as well as small anthropogenic influence.

I_{geo} was divided into seven classes as by Müller [4] as follows:

$I_{geo} \leq 0$ - Class 0, unpolluted;
$0 < I_{geo} \leq 1$ - Class 1, unpolluted to moderately polluted;
$1 < I_{geo} \leq 2$ - Class 2, moderately polluted;
$2 < I_{geo} \leq 3$ - Class 3, moderately polluted to strongly polluted;
$3 < I_{geo} \leq 4$ - Class 4, strongly polluted;
$4 < I_{geo} \leq 5$ - Class 5, strongly polluted to extremely polluted;
$I_{geo} > 5$ - Class 6, extremely polluted.

Calculation of oral intake of toxic metals from soil through fruit

Calculation of oral intake of metals from soil through *Cucumis sativus* fruit from the farm and those purchased from the market was as follows [9, 16, 17]:

$$\text{Daily intake of metal (DIM)} = \frac{C_{\text{metal}}\ x\ Cf\ x\ D_{\text{food intake}}}{B_{\text{average body weight}}} \quad - \qquad \text{Equation 4}$$

Where C_{metal} = levels of toxic metal in *Cucumis sativus* fruit (mg/kg); Cf = conversion factor (0.085); $D_{\text{food intake}}$ = daily intake of *Cucumis sativus* fruit (0.345 kg/adult person/day); and $B_{\text{average body weight}}$ = average body weight (estimated as 60 kg).

Calculation of health risk index of toxic metal contamination of *Cucumis sativus* fruit

Direct ingestion of contaminants in fruit and soil for adult humans and their adverse effects were computed considering the non-carcinogenic risk using equations 5a and b [18-21]:

$$CDI_{\text{Cucumis s.-nc}} = C_m \ x\ \frac{IR_{\text{Cucumis s.}}\ x\ ED\ x\ EF}{BW\ x\ AT_{nc}(365)} \quad - \quad - \qquad \text{Equation 5a}$$

$$CDI_{ingest\text{-}soil,\,nc} = C_m \times \frac{IR_{soil} \times CF \times ED \times EF}{BW \times AT_{nc}(365)} \quad - \quad - \qquad \text{Equation 5b}$$

Where CDI= Chronic daily intake through oral ingestion (mg/kg/day); C_m = level of toxic metal in *Cucumis sativus* fruit or soil (mg/kg); IR = ingestion rate per unit time (mg/day) is 0.013457 kg/fresh weight/day (cucumber) and 100mg/day (soil, adult) [5, 18]; CF= conversion factor (10^{-6} kg/mg); ED = exposure duration (years, 30 years adult); EF = exposure frequency (350 days/years); BW = body weight (kg, 60 kg average weight of residence in study area); AT = averaging time (days) is pathway specific period of exposure for non-carcinogenic(AT_{nc}) effects (i.e. ED x 365 days/year) [18].
Risk to human health by the intake of toxic metal contaminated fruit was then characterized using a hazard Quotient (HQ) [18]. Hazard quotient is the ratio between ADD and the reference oral dose (RfD). If the ratio is lower than one (1), there will be no obvious risk. An estimate of the potential hazard of toxic metal to human health (HQ) through consumption of *Cucumis sativus* fruit was determined by the following equation:

$$HQ = \frac{CDI}{RfD} \quad - \quad - \quad - \quad - \quad - \quad - \quad - \qquad \text{Equation 6}$$

where CDI= chronic daily intake through oral ingestion (mg/kg/day) for toxic metals in *Cucumis sativus* fruit (mg/kg/day) for non-carcinogens or carcinogens and RfD is the chronic oral reference dose for the toxic metals (mg/kg of body weight/day), which is the daily exposure of individuals to toxins or pollutants that can pose no appreciable hazard in their lifetime. Oral reference doses are 0.3 mg/kg/day (zinc), 0.02 mg/kg/day (nickel), 0.004 mg/kg/day (lead), 1 x10^{-3} mg/kg/day (cadmium) and 1.5 mg/kg/day (chromium). An index of more than one is considered not safe for human health [22-24].

RESULTS

Levels of essential and toxic metals in soil and *Cucumis sativus* (cucumber) plant parts

Essential metal concentrations (mg/kg) showed variations in soil and among the different parts of plants (Figure 1). In soil, magnesium (847.6) was highest followed by calcium (661.2) and the least value recorded for zinc (26.2). In the plant parts, the trend was potassium>magnesium>calcium>sodium>zinc for root, shoot of farm fruit and market fruit; for the leaf the trend was potassium>calcium>magnesium>sodium>zinc. Highest levels of all essential metals-sodium, potassium, magnesium, calcium and zinc were found in the root (3986, 11688, 7426, 4464 and 538.8, respectively) while the levels of sodium (471.4), magnesium (1784), calcium (691.5) and zinc (46.0) were lowest in fruit purchased from the market, and potassium (4162) in fruit obtained from the farm. In comparison, soil essential metals were lower than levels obtained in the various plant organs indicating the ability of cucumber plant root to bioconcentrate these metals. The fruit contained good quantity of essential nutrients.

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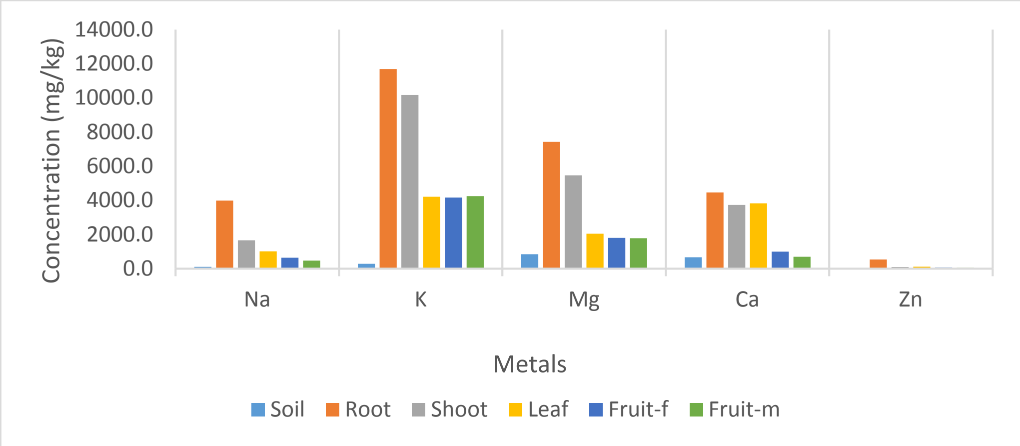

Figure 1: Essential metals in cucumber plant parts and soil
KEY: Fruit-f = fruit sampled from the farm, **Fruit-m** = fruit purchased from the market

Toxic metals (mg/kg) also varied in soil and cucumber plant parts (Figure 2). The soil revealed lowest levels in zinc (26.2) and nickel (0.25), and the highest levels in chromium (36.17) compared with plant parts. Within the plant parts, the maximum levels of zinc, nickel, and chromium were found in root, while lead and cadmium were highest in the shoot. The levels of toxic metals-zinc, nickel, lead, cadmium, and chromium were 67.5, 21.0, 3.95, 0.44 and 4.39, respectively in fruit collected from the farm, and 46.0, 26.2, 3.25, 0.55 and 0.50, respectively in fruit purchased from the market.

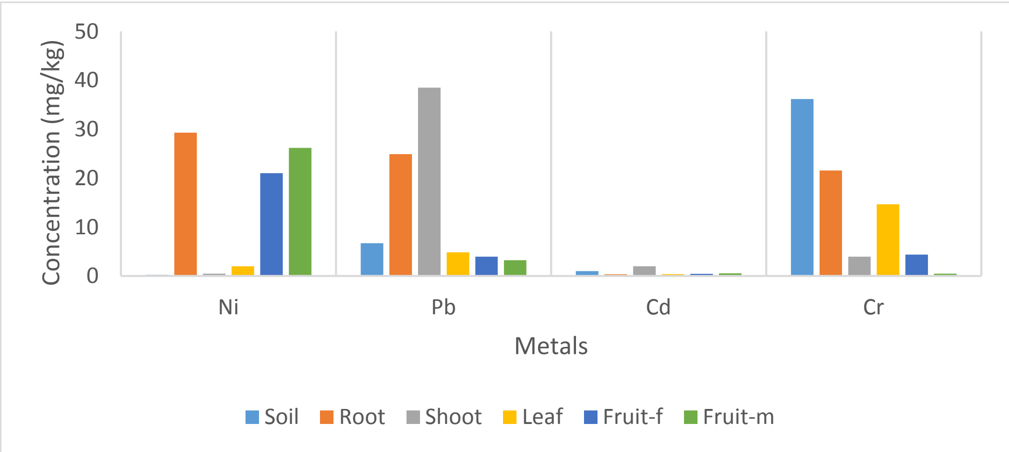

Figure 2: Toxic metals in cucumber plant parts and soil
KEY: Fruit-f = fruit sampled from the farm, **Fruit-m** = fruit purchased from the market

Bioaccumulation factor, transfer factor in plant organs and geo-accumulation index of soil pollution from *Cucumis sativus* farm

Bioaccumulation factor (BCF) values of essential and toxic metals in plant parts are presented in Table 1. Bioaccumulation factor values of nickel were highest in the root (117) and fruit (84) compared to other metals. Within the plant parts, bioaccumulation factor values ranged from 6.04 (fruit)-37.57 (root) for sodium, 14.90 (fruit)-41.86 (root) for potassium, 2.13 (fruit)-8.76 (root) for magnesium, 1.50 (fruit)-6.75 (root) for calcium, 2.58 (fruit)-20.56 (root) for zinc, 8.00 (leaf)-117.2 (root) for nickel, 0 59 (fruit)-5.75 (shoot) for lead, 0.34 (root)-1.96 (shoot) for cadmium and 0.12 (fruit)-0.60 (root) for

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chromium. Chromium (Cr) in all plant parts, cadmium in root, leaf and fruit, and lead in leaf and fruit had bioaccumulation factor (BCF) <1 indicating that these plant parts have little potential for chromium, cadmium and lead extraction. Among the metals, potassium was hyper-accumulated (bioaccumulation factor >10) in all plant parts, implying an excellent source of potassium mineral to humans. Also, there was hyper-accumulation of sodium in the root and shoot, nickel in the root and fruit, zinc in the root. *Cucumis sativus* plant is an accumulator (bioaccumulation factor >1) of magnesium and calcium in all plant parts, sodium in the leaf and fruit, cadmium in the shoot, lead in the root and shoot, nickel in the shoot and leaf and zinc in the shoot, leaf and fruit.

The transfer factor (TF) is presented in Table 1. Transfer factor value greater than one (TF >1) implies effective transfer of toxic metals from the root to the aerial parts, and from the shoot to the leaf and the fruit. Generally, transfer factor values within the organs were less than one. From the study, however, lead was effectively translocated from root to shoot (transfer factor =1.55). Cadmium was effectively translocated from root to shoot (transfer factor =5.71), root to leaf (transfer factor =1.14) and root to fruit (transfer factor=1.26). Zinc, on the other hand, was effectively translocated from shoot to leaf (transfer factor =1.24) while both nickel and chromium where effectively translocated from shoot to leaf (transfer factor =4.26 and 3.12, respectively) and from shoot to fruit (transfer factor =44.68 and 1.11, respectively).

Geo-accumulation index (I_{geo}), an estimate of the extent of metal pollution of soil is presented in Table 1. The soil of the study area was classified as unpolluted (Class 0, $I_{geo} \leq 0$) to zinc, nickel, lead and chromium, and moderately polluted (Class 2, $1 < I_{geo} \leq 2$) to Cd.

Source identification of metal pollution in the study site

Principal component analysis (PCA) was performed to determine the most common source of pollution in the study area. Three principal components (PCs) with eigen value >1 were extracted, and accounted for 94.4% of cumulative variances as presented in Table 2.

Principal component one (PC1) contributed 55.6% to the total variance with a high positive loading for sodium, potassium, magnesium, zinc and lead. Principal component two (PC2) contributed 22.9% to the total variance with a high negative loading for nickel (-0.852) and high positive loading for cadmium (0.934). Principal component three (PC3) contributed 14.8% to the total variance with chromium showing very strong association with the third PC (0.970). Communalities ranged from 0.775 (calcium) to 0.999 (potassium) as shown in Table 2.

Health risk through ingestion of *Cucumis sativus* fruit and farm soil

Estimated dietary intake of metal (DIM), chronic dietary intake (CDI) and non-carcinogenic hazard quotient (HQ) were used to assess the health risk of ingestion of toxic metals in *Cucumis sativus* fruit and the farm soil.

Daily Intake of toxic Metal (DIM)

The Estimated Daily Intake of toxic Metal (DIM) through consumption of *Cucumis sativus* fruit for adults in Eket Local Government Area is presented in Table 3. The trends of toxic metals for both farm and market fruit were in the order:

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Cadmium<lead<chromium<nickel<zinc. There was no significant difference between them. The highest daily intake of toxic metal was recorded for zinc (0.0330 mg/person/day in the farm and 0.0225 mg/person/day in market) and the lowest value of 0.0024 mg/person/day for both farm and market fruit.

Non-carcinogenic risk characterization of toxic metals using the hazard quotient (HQ)

Non-carcinogenic chronic daily intake of zinc, lead, and chromium were slightly higher in farm fruit than those purchased from the market; while chronic dietary intake of lead and cadmium were higher in purchased fruit for non-carcinogenic effect. Non-carcinogenic chronic dietary intake for metals was much lower in farm soil than in both the farm and purchased fruit (Figure 3). The lowest and highest non-carcinogenic chronic dietary intake was recorded for cadmium (9.46E-05 mg/kg/day) and zinc (0.0145 mg/kg/day), in farm fruit, chromium (0.00011 mg/kg/day) and zinc (0.0099mg/kg/day), in purchased fruit, and chromium (0.0000mg/kg/day) and cadmium (5.78E-05 mg/kg/day), in farm soil.

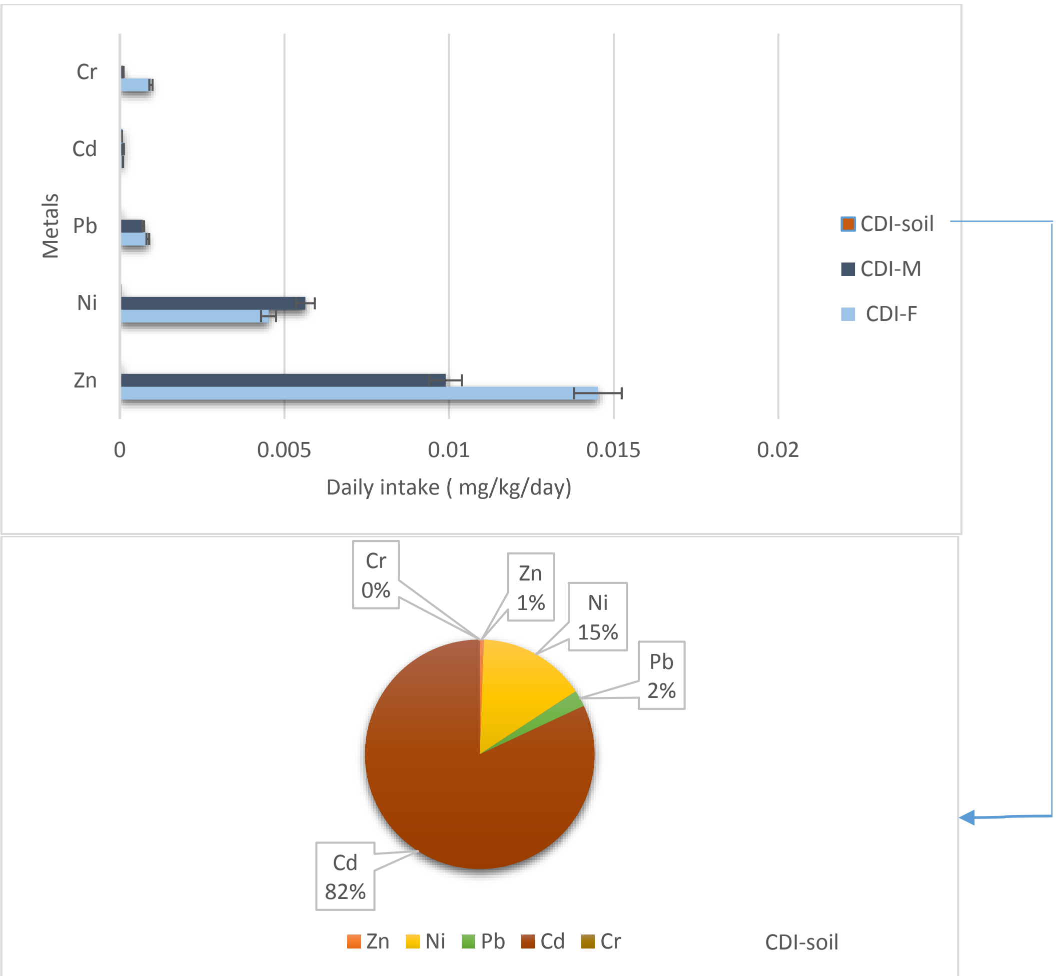

Figure 3: Estimated non-carcinogenic chronic daily intake of toxic metals by adults from ingestion of *Cucumis sativus* grown and sold in Eket

KEY:

CDI-F = Non-carcinogenic chronic daily intake of toxic metals in fruit sampled from the farm

CDI-M = Non-carcinogenic chronic daily intake of toxic metals in fruit purchased from the market

CDI-soil = Non-carcinogenic chronic daily intake of toxic metals in farm soil.

Non-carcinogenic risk characterization of toxic metals using the hazard quotient (HQ) Non-carcinogenic risk characterization of toxic metals (nickel, lead, cadmium, chromium, zinc) consumed in *Cucumis sativus* are summarised in Figure 4. In fruit (farm and Market), hazard quotient **(**HQ) of nickel was highest, followed by lead and cadmium; while in soil, cadmium was highest, followed by nickel and lead. Hazard quotient increased in the following sequence: chromium<zinc<cadmium<lead<nickel (0.0006, 0.0484, 0.0946, 0.2124 and 0.2258, respectively for farm fruit; 7.17E-05, 0.0330, 0.1183, 0.1747 and 0.2258, respectively for market fruit); chromium<zinc< lead<nickel<cadmium (0.000, 1.33E-06, 0.0004, 0.0005 and 0.0578, respectively for soil). Hazard quotient of less than one was recorded for both fruit (farm and market) and soil; therefore, it is of non-carcinogenic health risk to residents. The total hazard quotient (HQ-tot) [hazard quotient for farm fruit (HQ-F) + hazard quotient for market fruit (HQ-M) + hazard quotient for soil (HQ-soil)] was: chromium (0.0007), zinc (0.814), cadmium (0.2707, lead (0.3875) and nickel (0.5081); and less than one, the threshold value.

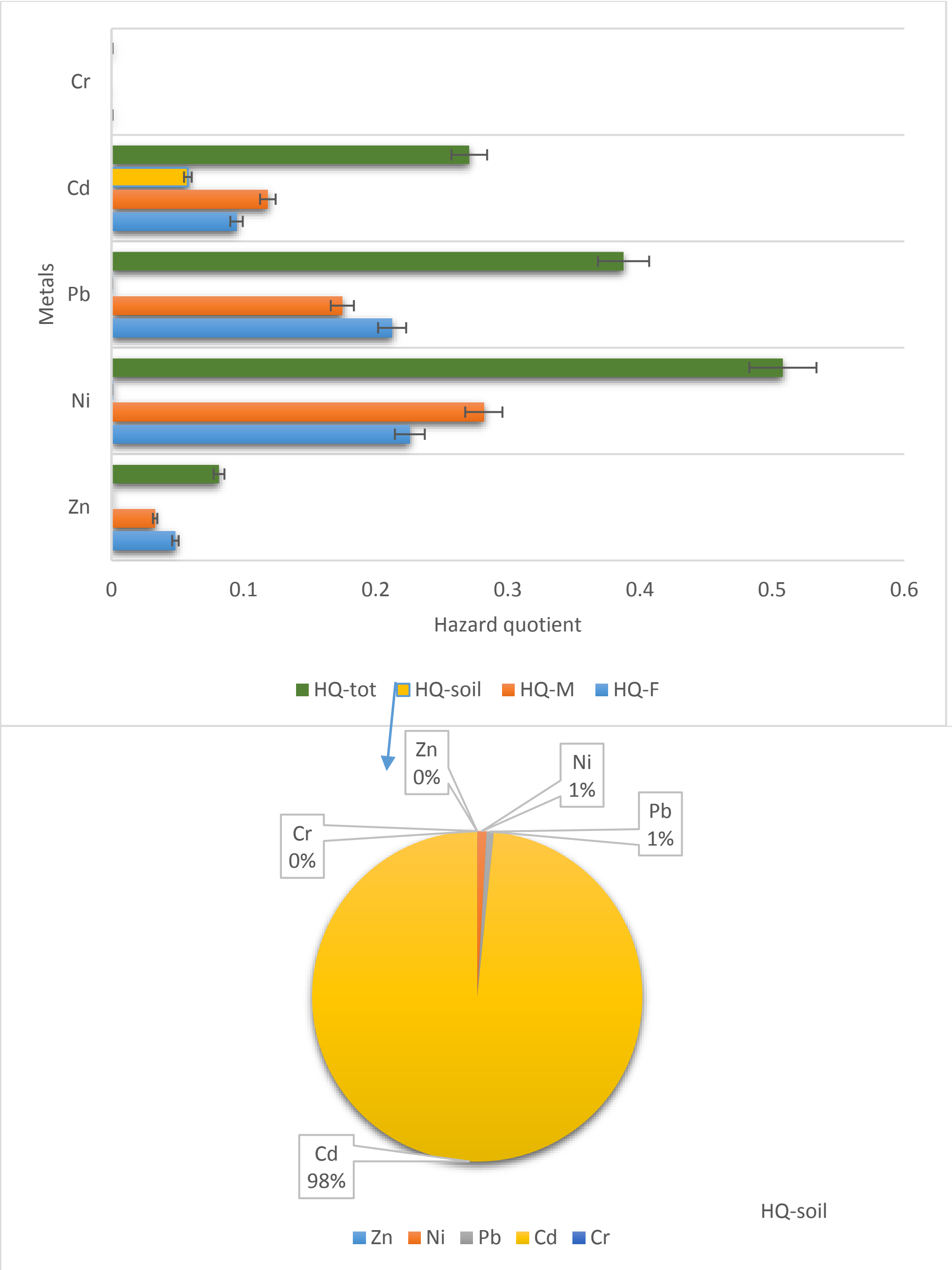

Figure 4: Estimated non-carcinogenic hazard quotient of toxic metals by adults from ingestion of *Cucumis sativus* grown and sold in Eket

KEY:
HQ-F = Non-carcinogenic hazard quotient of toxic metals in fruit sampled from the farm
HQ-M = Non-carcinogenic hazard quotient of toxic metals in fruit purchased from the market
HQ-soil = Non-carcinogenic hazard quotient of toxic metals in farm soil.

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DISCUSSION

Toxic metals in the soil (Figure 2) compared with soil normal ranges, tolerable levels, background values and guidelines are presented in Table 4. All toxic metals in this study were lower than the guidelines for soil [25]. Zinc, nickel and lead were within the normal range found in the soil but chromium was lower [17]. Only cadmium and chromium exceeded the background levels in the soil [15] while zinc, nickel and lead were less than the tolerable levels [17].

Metals in *Cucumis sativus* grown in the farm and those purchased from the market (Figure 2) compared with the standard values set by different bodies are presented in Table 4. Zinc (farm and market), lead (farm and market), and chromium (market) exceeded FAO/WHO-Codex maximum limits for vegetables while nickel (farm and market) and chromium (market) were lower [26]. Zinc (Zn) and lead in farm and market fruit exceeded the Nigerian NAFDAC (National Agency for Food and Drug Administration and Control) limits [3], while zinc (farm), lead (farm and market), cadmium (farm and market) and chromium (market) were higher than European Union’s (EU) limits [27].The levels of metals in *Cucumis sativus* in this study and those reported in Asian and African countries were also compared. Cadmium was found to be lower than reported in India [28]; zinc, nickel, lead and cadmium were higher than in Libya [13] for farm and market fruit; Zinc was 3-folds for farm fruit and 2-folds for market fruit greater than levels reported in Algeria, but lead and cadmium (farm and market) were lower [5].

Bioconcentration factor (BCF) revealed that both toxic and major metals concentrated more in the root except for lead and cadmium which concentrated more in the shoot. Though the fruit is a good source of potassium (bioaccumulation factor=14.90), it also hyper-accumulates nickel (bioaccumulation factor=84.00) qualifying the fruit as an indicator of nickel pollution. Effective transfer (transfer factor >1) values of metals were observed for lead and cadmium from root to shoot; zinc, nickel, chromium and calcium from shoot to leaf and nickel, and chromium from shoot to fruit. Generally, transfer factor within the organs was less than one. Indices of soil pollution indicate low to moderate pollution of farm soil and, also anthropogenic origin for cadmium and chromium (concentration factor>1).

The degree of pollution by toxic metals from lithogenic and anthropogenic sources has been determined using principal component analysis (PCA) [2, 29, 30]. Principal component one (PC1) is suggestive of agricultural activities and emissions from combustion of fuel. Sodium, potassium, magnesium, calcium and zinc are plant nutrients introduced as fertilizers and soil buffer for reduction of soil acidity. Zinc and NPK (nitrogen-phosphorus-potassium) fertilizers may contribute greatly to high loading for zinc and potassium. Vehicular and generator exhausts emissions may be the main source of lead in the farm. It means, therefore, that Principal component one (PC1) represents anthropogenic sources from both agricultural activities and emissions from fuel combustion. Nickel and cadmium pollution could be due to burning of oil in the area- the principal culprit being gas flares from petrochemical industries; mechanical wearing and leachates from dump site containing cadmium batteries, mechanic workshops and

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electronic wastes carried by flood water to the farm. Principal component two (PC2) represents anthropogenic source from industrial activities. Chromium associated strongly with principal component three (PC3) and is linked with industrial processes such as welding and electroplating, and agricultural practices like fungicides application and wood preservation.

An important aspect of assessing risk to human health from potentially toxic metals is the knowledge of the dietary intake of the metals (DIM), which must remain within the established safety margin as in the Provisional Tolerable Daily Intake (PTDI) by FAO/WHO, 2001 [5, 10], the Global Estimated Daily Intake (GEDI) [5] and the Recommended Dietary Allowances (RDA) by the Food and Nutrition Board, 2004 [17] in Table 3.The dietary intake of zinc, lead and chromium in farm and market fruit was found to be lower than the PTDI values; zinc, nickel, lead and chromium lower than RDA values; and nickel, lead and chromium lower than those reported in Libya [13]. However, dietary intake of zinc was found to be higher than the Global Estimated Daily Intake, and that reported in Algeria (for zinc, lead and chromium), Libya (for zinc) and India (for nickel) (Table 3).

Chronic daily intake (CDI) is exposure expressed as mass of a substance contacted per unit body weight per unit time, averaged over a long period of time (30 years for this study) [6]. Chronic daily intake of toxic metals (mg/kg/day) through consumption of cucumber fruit increased in the order: Cd<lead<chromium<nickel<zinc (farm fruit), chromium<cadmium<lead<nickel<zinc (purchased fruit), and chromium<zinc<lead<nickel<Cd (soil). The difference in CDI was in the content of cadmium in soil, which was more than in farm and purchased fruit.

Health quotient has been a useful parameter for evaluation of risk associated with consumption of metal contaminated food crops [17, 24]. The non-carcinogenic health quotient (HQ) of individual metals through two exposure pathways- diet (ingestion of fruit) and soil ingestion, and the total non-carcinogenic health quotient (the sum of health quotients for soil, farm and market fruit) are presented in Table 4. The main exposure route of all toxic metals in the study was through ingestion of fruit. The same pattern was observed by Liu *et al*. [8] in China though the non-carcinogenic health quotients 0.6657 (lead), 0.2363 (cadmium) and 0.7073 (chromium) through diet were all higher than in the present study; and their 0.02754 (lead), 0.00099 (cadmium) and 0.02168 (chromium) through soil ingestion were also higher except for cadmium. Hazard quotient was less than one when all their pathways were summed up indicating the absence of potential metals hazard of chromium, zinc, cadmium, lead and nickel to human health through ingestion of *Cucumis sativus* fruit and soil by residents in Eket. The observation that cadmium presented higher value for non-carcinogenic risk in the farm soil than other metals was similar to that reported by Liu *et al*. [8] in soil growing vegetables; on the other hand, non-carcinogenic health quotient value was highest for nickel, followed by lead for farm and purchased fruits and, the sum of all their exposure pathways (Table 4). The existential potential for nickel and lead contamination and toxicity raises the issue of future monitoring.

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CONCLUSION

Cucumis sativus fruit, a rich source of potassium and other minerals, presents a valuable and nutritious food item for all including diabetics, and should form part of a balanced diet. *Cucumis sativus* fruit may contribute to bio-concentration and magnification of nickel and chromium in humans, while the shoot and root may be considered suitable for phytoextraction. The farm soil quality indicated no pollution to zinc, nickel, lead and chromium; but some degree of pollution to cadmium-varying from unpolluted to moderately polluted. Three principal sources accounted for 94.4% of cumulative variance, which could be explained by anthropogenic input from agricultural and industrial processes. Although the human health risks associated with cucumber fruit consumption were negligible (health quotient<1), it was observed that cadmium in farm soil and nickel and lead in the fruit presented higher values of non-carcinogenic risk in the study area. The results of this study may inform policy on prevention of food contamination by toxic metals.

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Table 1: Bioaccumulation factor, Transfer factor in plant organs and Geo-accumulation index of soil pollution from cucumber farm

		Toxic metals					Major metals			
		Zn	Ni	Pb	Cd	Cr	Na	K	Mg	Ca
BCF	Root	20.56	117.2	3.72	0.34	0.60	37.57	41.86	8.76	6.75
(Plant	Shoot	3.48	1.88	5.75	1.96	0.11	15.68	36.43	6.44	5.64
parts)	Leaf	4.29	8.00	0.72	0.39	0.40	9.55	15.07	2.42	5.79
	Fruit	2.58	84.00	0.59	0.43	0.12	6.04	14.90	2.13	1.50
TF	Shoot/Root	0.17	0.02	1.55	5.71	0.19	0.42	0.87	0.74	0.84
(Plant	Leaf/Root	0.21	0.07	0.20	1.14	0.68	0.25	0.36	0.28	0.86
parts)	Fruit/Root	0.12	0.72	0.16	1.26	0.20	0.16	0.36	0.24	0.22
	Leaf/Shoot	1.24	4.26	0.13	0.20	3.12	0.61	0.41	0.38	1.03
	Fruit/Shoot	0.74	44.68	0.10	0.22	1.11	0.38	0.41	0.33	0.27
I_{geo}	Soil	-1.40	-4.80	-1.50	1.90	-0.40				

KEY: **BCF** = Bioaccumulation factor, **TF** = Transfer factor, **I_{geo}** = Geo-accumulation index

Table 2: Rotated (Varimax with Kaiser Normalization) Principal Component matrix[a]

Variable	Component			Communalities
	1	2	3	
Na	**0.972**	-0.194	0.097	0.992
K	**0.937**	0.027	-0.347	0.999
Mg	**0.986**	0.014	-0.129	0.989
Ca	**0.866**	0.147	0.061	0.775
Zn	**0.873**	-0.440	0.202	0.997
Ni	0.236	**-0.852**	-0.348	0.903
Pb	**0.792**	0.548	-0.195	0.965
Cd	0.129	**0.934**	-0.200	0.929
Cr	-0.006	0.005	**0.970**	0.941
Eigenvalue	5.007	2.154	1.331	
%of total variance	55.634	22.929	14.787	
Cumulative (%)	55.634	79.564	94.351	

a. Rotation converged in 4 iterations

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Table 3: Dietary intake of toxic metals (mg/day) in *Cucumis sativus* farm and main market compared with others and standard

Source	Metals				
	Zn	Ni	Pb	Cd	Cr
This Study, Nigeria					
Farm: Idim Afia, Eket	***0.0330***	***0.0103***	***0.0019***	***0.0002***	***0.0024***
Market: Eket	***0.0225***	***0.0128***	***0.0016***	***0.0003***	***0.0024***
Other countries					
*India [10]	10492	1.30	25.10	4.33	-
*Algeria [5]	0.2720	-	0.1690	-	0.0960
Libya, 2012 [13]	0.0082	0.116	0.0240	0.0133	-
Provisional tolerable daily intake, PTDI (FAO/WHO,2001) [5]	1.0000	-	0.0036	-	1.5000
Global estimated daily intake GEDI, [5]	0.0180	-	0.0157	-	7.5470
Recommended Dietary Allowances (RDA) [17] Male	9-11	0.7-1.0	*10-20	-	*25-30
RDA [17]Female	6-8	0.6-1.0	*10-15	-	*15-20

bw = body weight ***** µg/kg bw/day

Table 4: Non-carcinogenic chronic daily intake and hazard quotients of toxic metals in *Cucumis sativus* and soil

	Zn	Ni	Pb	Cd	Cr
			Non-carcinogenic Chronic Daily Intake		
CDI-F	0.0145	0.0045	0.0008	9.46E-05	0.0009
CDI-M	0.0099	0.0056	0.0007	0.0001	0.0001
CDI-soil	3.9954E-07	1.0708E-05	1.63014E-06	5.78E-05	0
			Non-carcinogenic Hazard Quotients		
HQ-F	0.0484	0.22582	0.2124	0.0946	0.0006
HQ-M	0.0330	0.281737	0.1747	0.1183	7.17E-05
HQ-soil	1.33E-06	0.0005	0.0004	0.0578	0
HQ-tot	0.0814	0.5081	0.3875	0.2707	0.0007

CDI-F= Non-carcinogenic Chronic Daily Intake of metals from farm fruit

CDI-M= Non-carcinogenic Chronic Daily Intake of metals from fruit purchased from market

CDI-soil= Non-carcinogenic Chronic Daily Intake of metals from farm soil

HQ-F= Non-carcinogenic Hazard Quotients of metals farm fruit

HQ-M= Non-carcinogenic Hazard Quotients of metals from fruit purchased from market

HQ-soil= Non-carcinogenic Hazard Quotients of metals from soil

HQ-tot= Total non-carcinogenic Hazard Quotients of metals through ingestion of fruit and soil

Table 5: Guidelines of toxic metals in soil food and vegetable

Zn	Ni	Pb	Cd	Cr	Standards
					SOIL (mg/kg)
1-100	0.02-5.20	5.0-15.0	-	0.03-14.0	Normal ranges[17]
300	60	100	-	-	Tolerable levels [17]
71.0	20.0	20.0	0.098	35.0	Background value [15]
300	50	100	3.0	100	Guidelines for soil [25]
					FOODS and VEGETABLES (mg/kg)
9.40	66.9	0.30	-	2.30	Recommended maximum levels for vegetables FAO/WHO-codex 2001[17, 26]
50.0	-	2.0	-	-	NAFDAC[3]
50	-	0.43	0.2	1.0	EU, 2006[27]

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