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Health Risk Potentials of Some Metals via Consumption of Some Food Crops at Iruekpen, Southern Nigeria

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Abstract

Studies have shown that heavy metals may be retained in food crops at higher than the permissible levels, thus posing health risks to consumers. The aim of the study was to assess the heavy metal health risks of consumption of some food crops in Iruekpen, a typical rural area in Nigeria. Nine metals; As, Cd, Cr, Co, Cu, Pb, Hg, Ni and Zn were assayed in fifteen food crops, while Cr, Cu and Pb were analyzed in soil samples using the atomic absorption spectrophotometer. The food crops included; plantain, coconut, beans, groundnut, ginger, pepper, white yam, cocoyam, cassava, maize, rice (local and foreign), green vegetable, fluted pumpkin and bitter leaf. The samples were processed by standard methods, and analyzed using atomic absorption spectrophotometer. Daily intake of metal (DIM), target hazard quotient (THQ), hazard index (HI) and transfer factor (TF) were estimated to check for potential health risks. Heavy metals were detected in the crops in the order Zn>Pb>Cu>Cr>Ni. The oral reference dose (Rfd) for Cr (0.003 mg/kg) was exceeded in yam (0.009), foreign rice (0.006), local rice (0.012), bitter leaf (0.01), beans (0.004) and pepper (0.005), while the RfD of Pb (0.0036 mg/kg) was exceeded in foreign rice (0.008) and fluted pumpkin (0.037) only. The THQs for Cr and Pb were >1 in 6 and 2 of the food samples respectively. Hazard indices were >1 in 7 food samples. Only Cu and Pb were detected in the soil samples. Chromium and lead exceeded the health risk indices in seven of the fifteen food crops studied and thus pose health risks to consumers of the food crops.

Keywords: Daily intake of metal; hazard index; toxic metal; risk assessment; target hazard quotient

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Introduction

Food safety is a major public concern worldwide. The increasing demand for food and food safety has drawn the attention of researchers to the risks associated with consumption of contaminated foodstuffs. Food contaminants include pesticides, heavy metals and or toxins in food materials. Sources of heavy metals in soils mainly include natural sources (derived from parent materials), and anthropogenic sources (from human activities). Anthropogenic sources are associated with industrialization and agricultural activities such as atmospheric deposition, waste disposal, waste incineration, urban effluents and vehicular fumes.[1]

Heavy metals are very harmful because of their non-biodegradable and non-thermodegradable nature and as such readily reach toxic levels. They have long biological half-lives and thus have the potential to accumulate in different parts of the body. Most of the heavy metals are extremely toxic because of their solubility in water. Even at low concentrations, heavy metals have damaging effects to man and animals because there is no good mechanism for their elimination from the body.[2] Excessive accumulation of heavy metals in soils results in elevated metal uptake by food crops, and this is of great concern because of the potential health risk.[3] The accumulation of heavy metals in agricultural soils is of increasing concern because of food safety issues, potential health risks, and

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its detrimental effects on soil ecosystems.[4,5] Heavy metals like arsenic (As), cadmium (Cd), lead (Pb), mercury (Hg) and nickel (Ni) are of great concern because of their toxicity to human health and other organisms. Chromium (Cr), cobalt (Co), copper (Cu) and zinc (Zn) are essential elements, but their excessive concentration in food and feed plants are also of great concern as they can also cause toxicity to humans and animals.[6] Vegetables take up heavy metals and accumulate them in their edible and inedible parts with various concentrations.

According to Tripathi and co-workers, dietary intake is the main route of exposure for most people, although inhalation can play animportant role in very contaminated sites.[7]Thus, information about heavy metals concentrations in food products and their dietary intake is very important for assessing their risk to human health. A number of serious health problems can develop as a result of excessive uptake of dietary heavy metals. Furthermore, the consumption of heavy metal-contaminated food can seriously deplete some essential nutrients in the body causing a decrease in immunological defenses, intrauterine growth retardation, impaired psycho-social behaviors, disabilities associated with malnutrition and a high prevalence of upper gastrointestinal cancer.[8]

Soil-to-plant transfer of heavy metals is the major pathway of human exposure to soil contamination by these elements. The intake of the edible parts of vegetables and crops therefore, is an important path for heavy metals in the soil to harm human health. Metals concentrations vary from soil to soil. Metals concentrations of plants mainly depend on the texture of soil or media on which they grow but this also depends on the type and nature of the plant.

Current non-cancer risk assessment methods do not provide quantitative estimates on the probability of experiencing non-cancer effects from contaminant exposures, unlike the methods for carcinogenic pollutants. These are typically based on the target hazard quotient (THQ), which is a ratio of determined dose of a pollutant to the dose level (a reference dose). If the ratio is less than one, there will not be any obvious risk. Conversely, an exposed population of concern will experience health risks if the dose is equal to or greater than the reference dose (RfD). The method for the determination of THQ was provided in the U.S. EPA Region III risk-based concentration table.[9] It was further assumed that the ingested dose is equal to the absorbed pollutant dose as stated in the U.S. EPA guidance.[10] Although the THQ-based risk assessment method does not provide a quantitative estimate on the probability of an exposed population experiencing a reverse health effect, it indeed provides an indication of the risk level due to pollutant exposure. This risk estimation method has been employed by many authors,[11-13] and has proved to be valid and useful. Various studies using the risk estimation method have demonstrated some potential risks to health due to presence of heavy metals in some food crops and imported fish in some parts of Nigeria and Africa.[14,15] The U.S. EPA is developing approaches for quantitative estimates of health risks for non-carcinogenic effects. Similar techniques used in cancer risks (i.e., dose-response data and linear low dose extrapolation) are being applied for these purposes, but are not yet widely used.[16] We applied this non-cancer risk assessment method to evaluate multiple heavy metals health risks in this study.

This study evaluated the concentrations of nine heavy metals in fifteen food crops commonly consumed in Iruekpen, Nigeria, with a view to estimating the potential dietary intake of the metals, and transfer characteristics of the metals from soil to plant. Multiple health risks based on THQ of heavy metals exposure were also estimated.

Materials and Methods

Sample Collection

Both the food crops and soil samples were collected from Iruekpen in Edo State, Southern Nigeria, a town in which the major occupation of her residents is farming. Fifteen food crops from six different food classes and three soil samples from three farm settlements were used for the study.

The food crops studied were: fruits – plantain (*Plantago majora*) and coconut (*Coscos nucifera*); legumes – beans (*Phaseolus vulgaris*) and groundnut *(Arachis hypogaea*); spices – ginger (*Zingiber officienale*) and pepper (*Capsicum annuum*); tubers – white yam (*Dioscora rotundata*), cocoyam (*Colocasia esculenta*) and cassava (*Manihot esculenta*); cereals – maize (*Zea mays)* and rice (*Oryza sativa*) (both foreign and local types); and leafy vegetables – green (*Amaranthus spinosus*), fluted pumpkin (*Telfairia occidentalis*) and bitter leaf (*Vernonia amygdalina*). The samples were collected from Uwehor, Idumebo and Emalua farm settlements of Iruekpen, where some of the crops were harvested, while those that were not cultivated locally were purchased from the

major market in Iruekpen. The samples were stored in dried polythene bags and transported to International Energy Services Limited (IESL), Port Harcourt, Nigeria, for analysis.

The soil samples (3 kg each)were collected from the above three farm settlements at a depth of 20 cm, and were air-dried with stones and plant roots or residues removed. They were thoroughly mixed, crushed, passed through a 2-mm mesh sieve, and then stored in polyethylene bags at ambient temperature prior to analysis.

Sample Preparation

The leafy vegetables were washed and cut into pieces while the fruits were washed and peeled. They were then oven-dried at 105°C for 24 h to obtain the moisture content. The samples were ground to powder using a grinding machine and 0.5 g each of the samples were digested in a mixture of conc. $HClO_4$ and conc. HNO_3(1:5) in a conical flask under a fume hood. The final solution was analyzed using a Unicam atomic absorption spectrophotometer (Model 969 502369 v5.67) (UK),using flame atomization technique.[17] The metals were analysed according to their wave lengths as follows: Pb (217nm), Cu (384.8nm), Cr (357.9nm), Zn (213.9nm), Ni (232nm), Cd (228.8nm), Co (240.7nm), As (193.7nm) and Hg (229nm). The scaling factor was at 1.0000 and the limit of detection for all the metals analyzed were 0.001 mg/kg, with blank values reading as 0 mg/kg in deionized water.

The three bulk soil samples were oven-dried at 105°C prior to analysis. The samples were crushed to enable it pass through a 2-mm mesh sieve and digested in a concentrated acid mixture($HClO_4$, $HNO_3$and HF). The samples were centrifuged and the supernatant decanted into a clean test tube. The clear supernatants were aspirated into the flames and analyzed for Cu, Cr and Pb. The pH of the soil samples was determined potentiometrically using a Windlab pH meter (Model 788, Germany). Samples were analyzed in triplicates.

Quality Control

Appropriate quality assurance procedures and precautions were carried out to assure the reliability of the results. Reagents used to calibrate the instrumentation were of analytical grades. A spike-and-recovery analysis was performed to assess the accuracy of the analytical techniques used. Post-analyzed samples were spiked and homogenized with varying amounts of the standard solutions of the different metals. The spiked samples were then processed for the analysis by the dry ashing method. Quality control measures were taken to assess contamination and reliability of data. The coefficients of variation of replicate analysis were determined for precision of analysis and found to be less than 10%.

Risk Assessment Indices

Daily Intake of Metal (DIM)

The DIM for the different metals in adults was determined using the equation by World Health Organization:[18]

$$DIM = \frac{C_{metal} \times C_{factor} \times D_{food\ intake}}{B_{average\ weight}}$$

Where,

C_{metal}= Heavy metal concentration in plant (mg/kg)

C_{factor}= Conversion factor. The conversion factor of 0.085 was used to convert fresh vegetable weight to dry weight.[19]

$D_{food\ intake}$ = Daily intake of vegetable (kg/person)

$B_{average\ weight}$ = Average body weight. The average body weight of 65 kg was used for this study.[20]

The estimated daily intake of the analysed food samples according to the Edo State Ministry of Agriculture and Natural Resources records were as follows: yam 9.0g, cocoyam 2.8g, cassava 9.8g, rice 7.6g, maize 6.4g, pumpkin vegetables 18.1g, green vegetables 18.0g, bitter leaves vegetables 17.2g, coconut 5.7g, plantain 6.4g, beans 2.8g, groundnut 7.8g, ginger 0.87g and pepper 11.2g.

Target Hazard Quotient (THQ)

Target hazard quotient is a complex parameter used for the estimation of potential health risks associated with long term exposure to chemical pollutant. It is an indication of risk based on known safe dose limits of metals in the food samples and was determined by the following equation:

$$THQ^{10} = \frac{DIM \times E_D \times E_F}{RfD \times T_A \times 365}$$

Where,

DIM = Dietary intake of metal (in mg/kg/day).

E_D = Exposure duration, taken as 40yrs equivalent to the average lifetime.

E_F = Exposure frequency (350 days/year).

RfD = Oral reference dose (in mg/kg/day); defined as the maximum acceptable concentration of a chemical substance by oral route daily that will not result in adverse health effect.[21] The recommended RfD (in mg/kg body weight) of the respective metals are given as follows: As 0.0003, Cr (VI) 0.003, Cu 0.04, Cd 0.001, Ni 0.02, Zn 0.3, Co 0.0004,Hg 0.0003,[21]and Pb 0.0036.[22]

T_A = Averaged exposure time for non-carcinogens. This variable is site-specific and related to ED. Specifically; the T_A for non-carcinogens is numerically the same as ED. This default value is consistent with U.S. EPA.[10,23,24]

If the value of THQ is < 1, the exposed population is unlikely to experience obvious adverse effects.[25]

Hazard Index (HI)

The hazard index (HI) is the sum of hazard quotients. The HI through daily average consumption of each food for a human being was calculated as follows:

HI = ∑THQs.[25]

When exposure involves more than one chemical, the sum of the individual hazard quotients for each chemical is used as a measure of the potential for harm and a value > 1 is index of concern.

Transfer Factor (TF)

The Transfer factor (TF) of the metals from soils to food substances was calculated as follows:

$$TF = \frac{C_{plant}}{C_{soil}}$$

Where C_{plant} and C_{soil} represent the heavy metal concentrations in the analyzed plant food and soil samples respectively.[26]

Transfer coefficient values of > 0.5 indicate greater chances of metal contamination by anthropogenic activities and so, the need for environmental monitoring of the area is required.[27]

Statistical Analysis

Data were analysed using the GraphPad Prism 5.03. Kruskal-Wallis (One-way ANOVA) test was used in comparing data among all the groups, while Dunn's multiple comparison test was used to compare data between groups.

Results

Nine metals (Pb, Cu, Cr, Zn, Ni, As, Cd, Co and Hg) were assayed in the 15 food samples, and only 5 of the metals (Pb, Cu, Cr, Zn and Ni) were detected in some of the samples (Table 1). All the 5 metals were detected in rice and bitter leaves, while Pb, Cu, Cr, Zn, were detected in at least 11 of the 15 samples. The presence of the metals detected in the crops was in the order Zn >Pb> Cu > Cr > Ni.Median Pb level was highest in legumes and lowest in fruits (Table 1), while median Cu level was highest in fruits and lowest in spices. Cr was highest in tubers and lowest in fruits, while the median Zn level was highest in spices and lowest in tubers. Ni was only detectable in leafy vegetables and cereals. There was a significant difference between the median levels of the metals in the different classes of food crops(P = 0.01), but not significant in the soil samples (P = 0.08).

Table 1. Median metal concentrations (mg/kg) in the different classes of food crops

Food Class	Pb	Cu	Cr*	Zn#	Ni*#
Tubers	0.128	0.102	0.634	0.136	0
Cereals	0.052	0.048	0.608	0.163	0.008
Leafy vegetables	0.124	0.125	0	0.364	0
Fruits	0.0255	0.2365	0.015	0	0
Legumes	0.2555	0.0365	0.2745	0.2545	0
Spices	0.044	0.021	0.607	1.682	0

Kruskal-Wallis test: P= 0.01
Dunn's multiple comparison test:
*Cr concentrations significantly different from Ni
#Zn concentrations significantly different from Ni

Table 2 shows the daily intake of metals (DIM) of the food samples. From the table, only the foreign rice exceeded the oral reference dose (RfD) of Pb (0.0036mg/kg). The RfD for Cr (0.003mg/kg) was exceeded in yam (0,009), local rice (0.012), foreign rice (0.006), bitter leaves (0.01), beans (0.004) and pepper (0.005). The concentrations of Zn, Cu and Ni were not at levels that could pose any danger of metal toxicity in the food samples.

Table 2. Daily Intake of Metal (DIM) (mg/kg/body weight) in the Samples

Sample	Pb	Cu	Cr	Zn	Ni
Tubers					
Yam	0.002	0.0014	0.009*	0.002	–
Cocoyam	0.0002	0.0004	0.002	0.0005	–
Cassava	0.0016	–	0.0003	–	–
Cereals					
Rice (local)	0.0002	0.0005	0.012*	0.002	0.00008
Rice (foreign)	0.008*	0.0008	0.006*	0.0012	0.0001
Maize	0.0004	–	–	0.001	–
Leafy vegetables					
Pumpkin vegetables	0.0037*	0.003	–	0.009	–
Green vegetables	0.0006	0.003	–	0.007	–
Bitter leaves	0.0027	0.0008	0.01*	0.008	0.0002
Fruits					
Coconut	–	0.0003	0.0002	0.0001	–
Plantain	0.0007	0.00007	0.001	0.0001	–
Legumes					
Beans	0.0008	0.00013	0.004*	0.001	–
Groundnut	0.003	0.0004	–	0.002	–
Spices					
Pepper	0.0001	–	0.005*	0.04	–
Ginger	–	0.00005	0.0009	0.0004	–

*DIM values higher than corresponding RfD values of the metals concerned.

The target hazard quotients (THQs) of foreign rice (2.22) and pumpkin vegetables (1.02) were of health concern for Pb being > 1. Also, Cr gave THQs > 1 in yam (3), local rice (4), foreign rice (2), bitter leaves (3.3), beans (1.3) and pepper (1.6) (Table 3). The hazard indices of toxic metals in the food samples studied indicated that 7 of the food samples: white yam (3.54), rice (local [4.07] and foreign [4.25]), fluted pumpkin (1.13), bitter leaves (4.11), beans (1.53) and pepper (1.76), had values > 1 (Fig. 1).

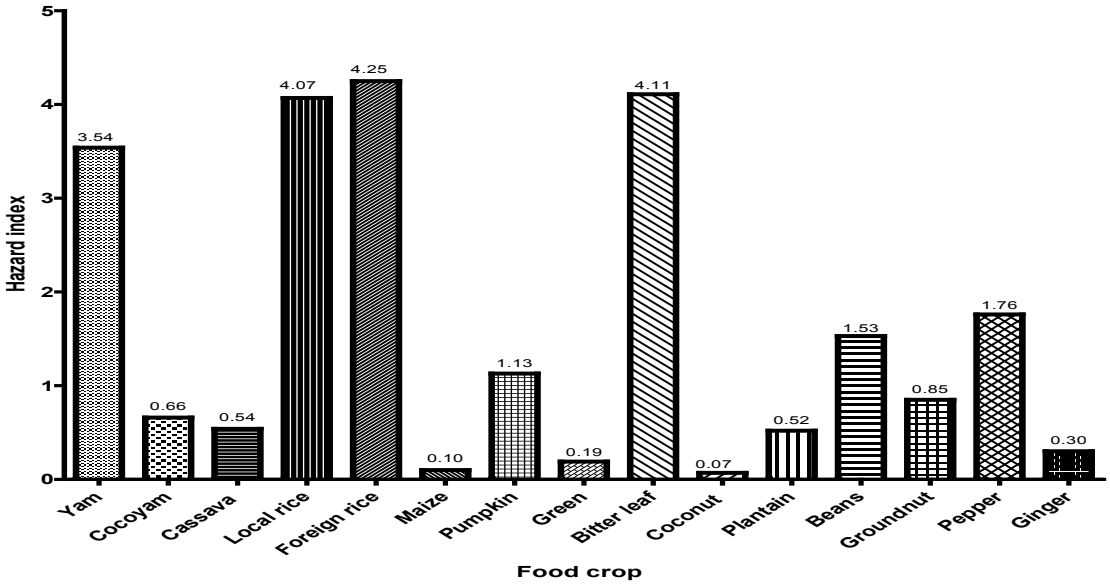


Figure 1. Hazard Indices for the Food Crops from Iruekpen.

Table 3. Target Hazard Quotient (THQ) of Food Crops

Sample	Pb	Cu	Cr	Zn	Ni
Tubers					
Yam	0.5	0.035	3*	0.006	–
Cocoyam	0.05	0.01	0.6	0.002	–
Cassava	0.44	–	0.1	–	–
Cereals					
Rice (local)	0.05	0.0125	4*	0.006	0.004
Rice (foreign)	2.22*	0.02	2*	0.004	0.005
Maize	0.1	–	–	0.003	–
Leafy vegetables					
Pumpkin vegetables	1.02*	0.075	–	0.03	–
Green vegetables	0.16	0.075	–	0.02	–
Bitter leaves	0.75	0.02	3.3*	0.03	0.01
Fruits					
Coconut	–	0.0075	0.06	0.0003	–
Plantain	0.22	0.0012	0.3	0.0003	–
Legumes					
Beans	0.22	0.003	1.3*	0.003	–
Groundnut	0.83	0.01	–	0.006	–
Spices					
Pepper	0.03	–	1.6*	0.13	–
Ginger	–	0.0012	0.3	0.0013	–

*THQ levels > 1

Copper was detected in all the soil samples analyzed, while Pb was detected in soil samples from Uwehor and Idumebo farm settlements only (Fig. 2). Chromium was not found in any of the soil samples. The pH values of all the soil samples were slightly acidic (Fig. 2).The TFs of Pb in soils from Uwehor and Idumebo farm settlements are shown in Fig. 3. From the figure, 3 food samples (yam, fluted pumpkin and groundnut) had TF of > 0.5 for Pb in the Uwehor soil, while 9 samples (yam, cassava, maize, fluted pumpkin, bitter leaves, coconut, plantain, groundnut and pepper) had potential transfer factor of > 0.5 in the Idumebo soil sample. In all the food samples, the TF for Pb was higher in the soil sample from Idumebo than Uwehor (Fig. 3). For Cu, 2 food samples (cocoyam and green vegetable) had TF > 0.5 in the Uwehor soil sample, while 4 samples (yam, cocoyam, pumpkin and green vegetables) had transfer factor > 0.5 in the Emalua soil sample. All the food crops had TFs < 0.5 in the Idumebo soil sample (Fig. 3).

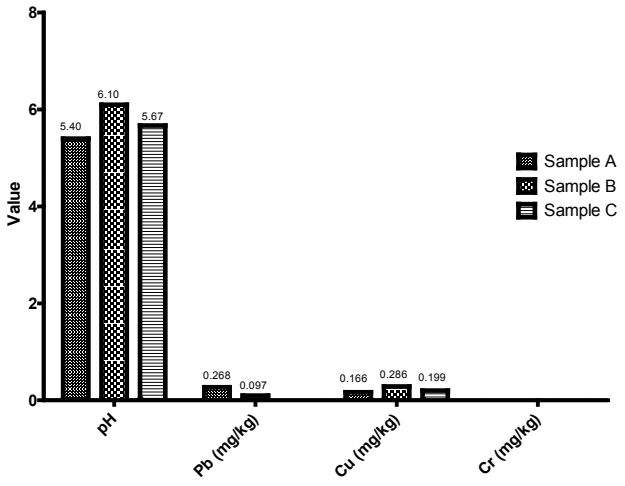


Figure 2. pH Values and Metal Concentrations of Soil Samples from Uwehor (A), Idumebo (B) and Emalua (C) Farm Settlements in Iruekpen. Kruskal-Wallis test $P = 0.08$

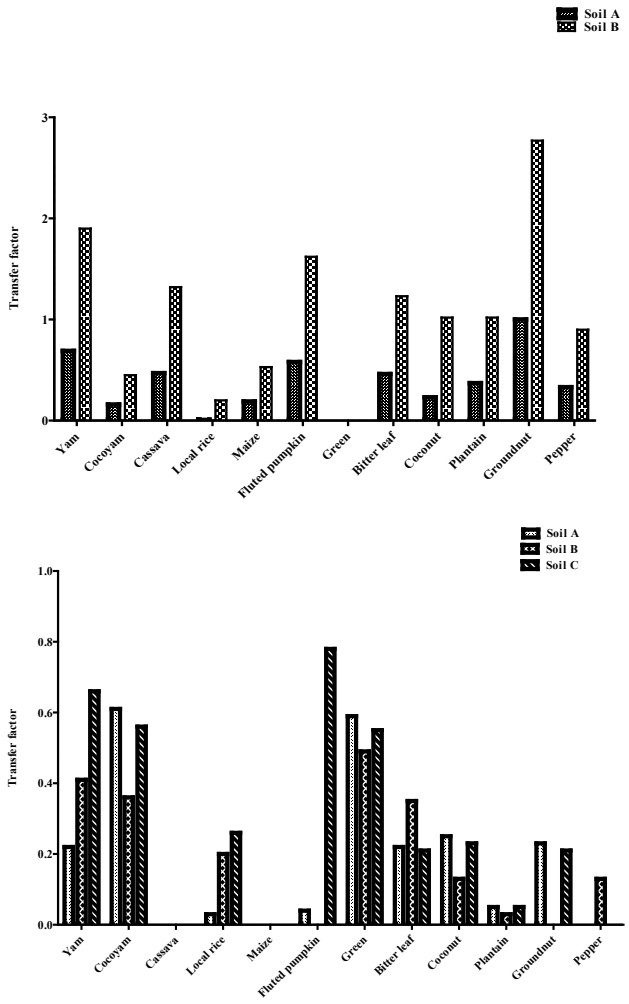


Figure 3. Potential transfer factors for Pb (top) and Cu (below) in soil samples from Uwehor (A) and Idumebo (B) and Emalua (C) farm settlements in Iruekpen.

Discussion

The health risk assessment of nine metals in some food crops and soil samples at Iruekpen, Southern Nigeria was studied. Iruekpen is a small town in Edo State, Southern Nigeria, with farming as the main occupation of the residents. Only a few factories and industrial activities take place in the area, and thus depicted a typical area of low industrial activity, which formed the target of the study.

This study showed that there were no significant differences in the concentrations of the metals assayed in the food samples. This might be due, in part, to the ability of the crops and their specific parts to accumulate metals, or the geological status of the areas of cultivation of the crops. Metal contents in plants have been reported to be a function of the metal concentration in the soil or in the growth solution,[6] although the relationship may differ according to the plant species and tissue. Agronomic practices such as fertilizer, water management and crop rotation system can affect bioavailability and crop accumulation of heavy metals, thus influencing the thresholds of assessing dietary toxicity of heavy metals in food chain. The metals detected in the crops were in the order Zn>Pb>Cu>Cr>Ni. Zinc and copper occur naturally in food as essential trace elements needed for good health, although they could be toxic when their concentrations exceed safe limits. Neither Zn nor Cu was present at risk levels in any of the food samples. This result agreed with some studies in Nigeria and elsewhere,[13,28,29] while disagreeing with others.[15,30]

Dietary intake of contaminated foods results in long-term body accumulation of heavy metals and the detrimental impact becomes apparent only after several years of exposure. From this study, the highest daily intake of metal (DIM)values exceeded the tolerable daily intake (TDI) for Pb in foreign rice (0.008 mg/kg) and fluted pumpkin (0.0037mg/kg). Also, Cr exceeded the TDI in five food samples; yam (0.009), local rice (0.012), foreign rice (0.006), bitter leaves (0.01) and beans (0.004). This indicates that consumption of some of these food samples would expose the consumers to risk of Pb and Cr toxicity, since it is posited that exposure to the dose of a metal equal to or greater than its reference dose, places the exposed population to possible health risks.[13,25] Lead is an unnecessary metal for human body, and any amount of it would be harmful. In a study in Lagos, Nigeria, by Sobukola et al.[28] Pb was found to be accumulated most in fluted pumpkin.

The United State Environmental Protection Agency (USEPA) developed the target hazard quotient (THQ) for the estimation of potential health risks associated with long term exposure to chemical pollutants.[31] The THQ is a ratio between the measured concentration of pollutant and the reference dose (RfD), weighted by the length and frequency of exposure, amount ingested and body weight. The THQ < 1 means the exposed population is assumed to be safe and 1 < THQ < 5 means that the exposed population is in a level of concern interval. The THQ parameter is a dimensionless index and its values are additive, but not multiplicative. It must be noted

that THQ is not a measure of risk but indicates a level of concern. Owing to differences in average weight and lifespan, the THQ values are raised for females.[29,32] From our THQ calculations, Pb poses some health concern in foreign rice and fluted pumpkin and Cr in yam, local rice, foreign rice, bitter leaves and beans. A similar study in Owerri, South-East Nigeria, also showed similar results for Pb and Cr.[14]

It has been reported that exposure to two or more pollutants may result in additive and/or interactive effects.[33] We evaluated health risk of heavy metals by the hazard index (HI) as derived by the methods of Chien et al.[11] and Wang et al.[12] When HI is < 1, it implies that there is no obvious adverse health effects. The values obtained indicated that the population are exposed to some degree of metal toxicity concern in 7 of the 15 food substances tested. These food samples of concern were yam, rice (local and foreign), pumpkin vegetables, bitter leaves, beans and pepper. Coconut, maize and ginger had the lowest HI values of 0.07, 0.1 and 0.3 respectively. Regular monitoring of these metals in foods is essential, to prevent excessive build-up in the food chain. Therefore, screening of metal exposures and prevention strategies should be a priority for government and individuals in this area.

Soil pH is an important factor in plant growth. Viability of plants is directly affected by soil pH in addition to the nutrient availability. The protoplasm of plant root cells is severely damaged below pH 3 and above pH 9.[34] Soil pH is important to plant development, as the availability of some nutrients is affected by pH. Soils with pH lower than 6.5 are generally considered to be acidic.[35] The three soil samples assayed, had pH values within the normal acceptable range. The degree of acidification by soil organic matter or humus varies with the type of vegetation, as coniferous vegetation has a lower pH than deciduous.

The transfer factor (TF) provides a useful indication of relative metal availability from soils to plants.[36] Once heavy metals enter the soil, they may undergo several changes depending upon physical, chemical and biological properties of the soils. Heavy metal uptake by food crops depends upon soil physicochemical characteristics and plant species. Bioavailability of these metals is very important as it is a gateway for the metals into the food chain.[37] Soil-to-plant transfer is one of the key components of human exposure to metals through the food chain. From this study, the highest transfer factor for Pb was detected in groundnut at both the Idumebo (2.77) and Uwehor farm settlements (1.0). This implies that groundnut tends to accumulate Pb more at these farm settlements. This high accumulation of Pb in the groundnut however, did not translate to high total metal THQ. The different metals from the three soil samples revealed that transfer values differed significantly among farm location or plant species. The difference in transfer factors between the three farm sites may be related to soil properties and soil nutrient management.

Conclusion

The hazard indices of the metals in yam, local and foreign rice, bitter leaf, beans, fluted pumpkin and pepper indicate that the consumers of these crops are exposed to some risks of metal toxicity via consumption of these food substances. Also, the DIM and THQ values for Pb show that foods like foreign rice and fluted pumpkin pose some health concerns to the consumers. Also, Cr poses some hazards via consumption of yam, rice, bitter leaf, beans and pepper in this area. Though the TF for Pb and Cu were of concern for some of the food samples from Uwehor and Idumebo farm settlements, the soil-to-plant transfer did not translate to any health index of concern in the crops. Regular monitoring of heavy metals in plant foods, even in low industrialized areas like Iruekpen is recommended in order to prevent excessive build-up of these metals in the food chain.

Declaration of Conflicting Interests

The authors declare no conflicts of interest with respect to the research, authorship, and/or publication of this article.

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