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Potential Toxic Elements Load and their Health Risk Assessment in Vegetables Grown in Nsukka Area of South-Eastern Nigeria

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Abstract

Seven potential toxic elements (PTEs) (Cr, Pb, Zn, Ni, Cd, Co, and Fe) were assessed in some selected vegetables collected from Nsukka agricultural areas. Flame Atomic Absorption Spectroscopy was used to determine the Potential Toxic Elements (PTEs). The human health risk evaluation was performed and the average detectable concentration of the PTEs were all within the permissible limit of WHO/FAO. The highest concentration of Cr (0.1750±0.1543) was found in *Solanum aethiopicum* fruits from Opanda in Uzo-uwani, Pb (0.6667± 0.1443) in yellow *Capsicum annuum* L. seeds from Opanda in Uzo-uwani, Zn (2.9441 ± 1.7382) in *Solanum melongen* fruits from Opi-Agu, Ni(0.3761 ± 0.1184) in *Gongronema latifolium* leaves in Uzo-uwani, Cd (0.0703 ± 0.0316) in *Solanum melongen* fruits from Opanda in Uzo-uwani, Co (0.0485± 0.0346) in red *Capsicum annuum* L. seeds from Opanda in Uzo-uwani and Fe (13.2460 ± 1.3633) in *Solanum melongen* fruits from Opanda in Uzo-uwani. The health risk assessment of the PTEs showed that only Pb has the hazard quotient in children to be above one in *Solanum melongen* seed of Opi-Agu. However, the health risk associated with the consumption of Cr, Zn, Ni, Co, Cd and Fe were not as high as Pb. The Total Hazard Index (THI) of the PTEs was above 1 for children in *Solanum melongen* seed, and *Solanum aethiopicum* leaf. Therefore, the consumption of *Solanum melongen* fruits and Solanum aethiopicum leaf can be considered not safe for children. Other vegetables assessed did not constitute much potential health risk for both adults and children concerning the HI and HQ evaluated.

Keywords: *Capsicum annuum, Gongronema latifolium* leaf, Potentially Toxic Elements, *Solanum aethiopicum*, Vegetables

1. Introduction

Consumption of vegetables in urban areas increased since they have been aware that vegetables constitute the most affordable and sustainable sources of micronutrients such as vitamins, proteins, carbohydrates, minerals, and fibers[1]. Apart from these benefits, consumers are exposed to different pollutants through eating vegetables. An increase in contamination of the environment by trace metals in the past decades has raised public interest because of its ubiquity, persistence, non-biodegradability, bioaccumulation, and dangerous effects on human health. The toxicity of trace metal increases significantly for ecological, evolutionary, nutritional, and environmental reasons[2].

Trace metal contaminants may gain access to the vegetables through the application of chemical fertilizers, irrigation with contaminated water (like wastewater), using the metal-based pesticides and anthropogenic sources like waste incineration and industrial processes[3]. Factors like atmospheric depositions, concentrations of metals in soil, the nature of the soil in which the vegetables are grown, and

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the degree of maturity of the plants at the time of harvest influences the uptake and bioaccumulation of metals in vegetable[4]. The consumers of vegetables are exposed to trace metals through dermal contact and oral consumption. Trace metal contamination and its impact on human health have been widely studied all over the world[5–9]. In this study, we determined the present concentration levels of trace metals in the selected vegetables, compared the obtained concentration values with WHO/FAO acceptable limits and assessed the potential health risk posed by the consumption of these vegetables due to the metal contaminations through their estimated daily intake, HQ and THI. Presently, concerning toxic metal poisoning through these vegetables, no epidemiological study has been reported most especially in this study area.

2. Material and Methods

2.1 Study Area

The study area includes Opi-Agu in Opi and Opanda. Opi is a tropical semi-urban autonomous community in Nsukka Local Government Area, comprising of three large villages located within latitude 7^0 25^I to 70^0 30^I E and longitude 6^0 43^I to 6^0 48^I N. The three villages comprise of about fifty-three hamlets. It is intersected by numerous green hills and valleys. The vegetation falls within the rainforest-savanna mosaic and the climate is tropical. The people are predominantly farmers and cultivate crops like yam, cocoyam, maize, legumes, and vegetables. The community is also endowed with streams and rivers which serve for domestic, recreational, and agricultural purposes.

Opanda in Uzo-Uwani L.G.A. of Enugu state is located between latitude $6^0$55^I N and $7^0$15^I N and longitude 6^0 30^I E and 7^0 00^I E. It is bounded by Nsukka town, Igbo-Etiti, Udi and Ezeagu Local Government Area (L.G.A.), Anambra State in the west and Kogi State in the North West. The geology of Uzo-Uwani L.G.A. falls into two main geological groups: the Imo clay shale which occupies the western extremities within the northern section of Anambra plain. Opanda in Uzo-uwani and Opi-Agu in Opi is in Nsukka region in Enugu State South-East Nigeria. The environmental area has systematic grasslands and mountains and they are found within the savannah region and this area has categorized incomplete tree canopies[10].

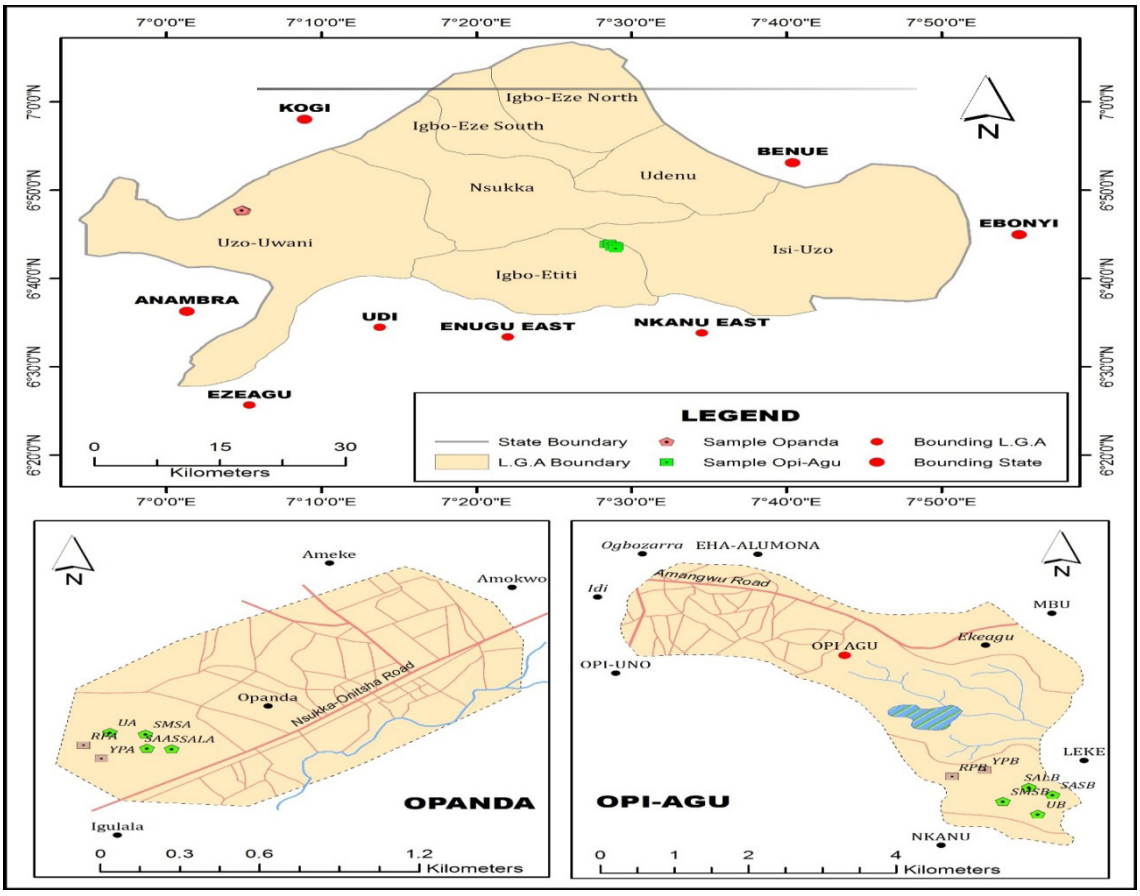


Figure 1. The Map of Opi-Agu and Opanda showing sampling stations in Nsukka region.

2.2 Sampling and Sample Preparation

Twelve fresh vegetables were randomly sampled from two different farm locations in Nsukka (Opanda in Uzo-uwani; farm A and Opi-Agu in Opi; farm B), Enugu State in southeastern Nigeria (Table 1). The crop was ploughed and put inside the washed polyethylene bag and transported to the laboratory for analysis. The samples were identified and classified based on their botanical names by the Taxonomists in the Department of Crop Science, University of Nigeria Nsukka. The samples were prepared as reported by Ezigbo, *et al*[11]. Reasonable amount of fresh leafy and non-leafy vegetables samples each were washed using tap water, then with deionized water and sun-dried for 4 days. *Solanum melogena* seeds and *Capsieum annuum* L. species were cut using a knife to enhance the drying. The samples were oven-dried at 105°C for one hour to a constant weight. The dried samples were ground with wooden mortar and pestle and kept in acid leached nylon bags inside a desiccator for digestion. 2.00 g of each ground samples were placed in a 50 ml digestion flask mixed with $HNO_3/HClO_4$ (2:1) covered with a petri dish and digested on an electric hot plate until a clear fume were obtained. The digested samples were filtered and diluted to a concentration suitable for analysis by FAAS. Sample blanks were prepared in the same manner. Analyses for trace metals in selected RTE vegetables were carried out using Flame Atomic Absorption Spectrophotometer (AA-7000, Germany) equipped with air-acetylene flame.

Table 1. Sampling location, common and botanical names of the sampled vegetables

Sample	Botanical Name	Common Name	Location
RPA	Red *Capsicum annuum* L. seeds	Pepper	Opanda
RPB	Red *Capsicum annuum* L. seeds	Pepper	Opi-Agu
YPA	Yellow *Capsicum annuum* L. seeds	Pepper	Opanda
YPB	Yellow *Capsicum annuum* L. seeds	Pepper	Opi-Agu
UA	*Gongronema latifolium* leaves	Utazi	Opanda
UB	*Gongronema latifolium* leaves	Utazi	Opi-Agu
SMSA	*Solanum melogena* seeds	Eggplant	Opanda
SMSB	*Solanum melogena* seeds	Eggplant	Opi-Agu
SAAS	*Solanum aethiopicum* seeds	Eggplant	Opanda
SALA	*Solanum aethiopicum* leaves	Eggplant	Opi-Agu
SABS	*Solanum aethiopicum* seeds	Eggplant	Opanda
SALB	*Solanum aethiopicum* seeds	Eggplant	Opi-Agu

2.3 Materials

The samples of *Solanum melogena* (eggplant) seeds, *Gongronema latifolium* (utazi) leaves, *Capsicum annuum* L. (pepper) seeds and *Solanum aethiopicum* (eggplant) leaves and seeds vegetables were harvested from two different farm locations: Opanada in Uzo-uwani (farm A) and Opi-Agu in Opi (farm B) both in Nsukka, Enugu State in South-East Nigeria. The reagents used were analytical grade nitric acid and percholic acid from Merck Chemicals Company, USA.

2.4 Quality Control Measures

Flame Atomic Absorption Spectrophotometer (AA7000, Germany) equipped with air/acetylene flame was used. Analytical grade reagents were used all through. The metal standards were prepared from their respective salts and used for the calibration curve for Cr, Pb, Zn, Ni, Cd, Co, and Fe determination. The limit of detection (LOD) and the limit of quotation (LOQ) for the metals were calculated as three times the standard deviation for the digested blanks.

2.5 Health Risk Assessment

The exposure as a result of the consumption of toxic metal-contaminated ready to eat vegetable samples was quantified using equation 1 according to USEPA[12] to obtain the consumption of vegetables (mg/kg/day):

$$EDI = \frac{Ci \times IR \times EF \times ED}{BW \times AT} \quad (1)$$

Where Ci = metal concentration in the sample, IR = ingestion rate (kg/day) *Capscium annuum* L. fruits (0.05), *Gongronema latifolium* leaves (0.05), *Solanum melongen* fruits (0.22), *Solanum aethiopicum* fruits (0.10) and *Solanum aethiopicum* leaves (0.15)[12], EF = exposure frequency (365 days/year) USEPA[13], ED= exposure

duration/ reference body mass 70years for Nigeria, BW = body weight of consumer (adult = 70kg and children 16kg,[14]) and AT = average time (25,550days)[15].

Health risk assessment of the contaminants was judged based on HQ and THI values. However, HQ or THI < 1 indicates no risk while, HQ or THI > 1 indicates a greater level of risk of toxicants manifesting long term health hazard effects[16,17]. Hazard quotient (HQ) was estimated using equation 2:

$$HQ = \frac{EDI}{RFD} \quad (2)$$

where RfD is the tolerable daily intake or oral reference dose which is obtained from United States Environmental Protection Agency tables[18] and ATSDR[19], and it refers to the maximum amount of toxicants which does not have an adverse effect on one consuming the toxicant.

3. Results and Discussion

Table 2 presents the percentage recovery for Cr, Pb, Zn, Ni, Cd, Co and Fe in the Vegetable Samples: red and yellow *Capscium annuum* L. seeds, *Gongronema latifolium*, leaves, *Solanum melongen* seeds, *Solanum aethiopicum* seeds and leaves from two different farms.
The LOD and LOQ as a quality control measure are as presented in Table 3. The LOD was within 0.0001 to 0.0003 while the LOQ was within 0.0003 to 0.0010.

The results of the determinations of PTEs in the studied vegetables are shown in Table 4. The PTEs content for the tested vegetables from two different farm locations varied considerably as a function of plant edible organs, plant species, as well as growth location. Vegetable samples investigation resulted in the statistically confirmed fact that vegetable species have a specific accumulation capacity and considerably in the edible parts of vegetables grown in two different localities in Nsukka environment.

Table 2. Percentage recovery for Cr, Pb, Zn, Ni, Cd, Co and Fe in the Vegetable Samples

Metal	Amount of spike (mg/kg)	Conc. of spiked sample (mg/kg)	Conc. of un-spiked sample (mg/kg)	Recovered conc. (mg/kg)	% Recovery
Cr	2	1.9667	0.1165	0.9251	93%
Pb	2	2.4810	0.6667	0.9071	91%
Zn	2	2.0346	0.1414	0.9466	95%
Ni	2	2.1962	0.3077	0.9443	94%
Cd	2	2.6736	0.0340	0.8799	88%
Co	2	2.7036	0.0000	0.9012	90%
Fe	2	4.2686	2.4453	0.9117	91%

Table 3. LOD and LOQ of toxic metals using FAAS

PTE	LOD	LOQ
Chromium	0.0003	0.0009
Lead	0.0002	0.0006
Nickel	0.0001	0.0003
Cadmium	0.0001	0.0003
Cobalt	0.0001	0.0003
Iron	0.0005	0.0010
Zinc	0.0001	0.0003

chemical composition. To determine PTEs accumulation in selected vegetables, the edible organs were used. The total concentrations of Cd, Pb, Cr,, Co, Fe, Zn, and Ni varied

Table 4 presents the average PTEs in the sampled vegetables. The concentration levels of total Cr ranged: 0.0292±0.0412 - 0.1363±0.00335, 0.0778±0.0337 to 0.1361±0.1348, 0.1167± 0.0584 to 0.1556±0.1215, 0.0778±0.0337 to 0.1167±0.0584 and 0.1556±0.0337 to 0.1750±0.01543 mg/kg in yellow and red *Capsicum annuum* L. fruits, *Gongronema latifolium* leaves, *Solanum molegian* fruits, *Solanum aethiopicums* leaves, and *Solanum aethiopicums* fruits respectively. It showed that the levels of accumulated Cr in all the selected vegetable species were within the maximum permissible value (5.0mg/kg) recommended by the WHO/FAO[20]. Tasrina *et al.*[21] recorded Cr concentration of <0.1mg/kg in potato, spinach amarantha and carrot, and 0.495, 0.75mg/ kg in cabbage and tomato respectively with a standard limit

of 2.5mg/kg according to Codex Alimentarius Commission, Joint FAO/WHO[22]. Our findings agree with the works of Kosak *et al.*[23], that recorded Cr concentration of 0.4mg/kg in Ipomoea pescaprae medicinal plant in tsunami impacted area of Bang mor, South Thailand. Also, our findings were below that reported by Tasrina *et al.*[21], with Cr level of 0.495mg/kg in Cabbage in a farm around Pakshi, Bangladesh. The study showed that Cr level in the selected vegetables might not pose health risk to consumers. Cr is essential for insulin activity and deoxyribonucleic acid transcription in living organism most especially human beings. Therefore, the concentrations of Cr metal in the vegetables are apt for proper cellular response to insulin, but the accumulation of Cr in edible plants may be toxic to animals[24]. Lente *et al.*[25], recorded Cr values below the detection limit of 0.002mg/kg in vegetables grown in extended waste water irrigated farm. An investigation has shown the possibility of phytotoxic effect as Cr levels exceed 1mg/kg[26], which clearly shows possible Cr hazard with the consumption of the vegetable.

The concentration levels of total Pb ranges: 0.2500±0.0000 to 0.6667±0.1443, 0.2500±0.0000 to 0.3750±0.1768, 0.0000 to 0.3750±0.1768, and 0.3750±0.1768 to 0.4167±0.1443 mg/kg yellow and red *Capsicum annuum* L. fruits, *Gongronema latifolium* leaves, *Solanum molegian* fruits, and *Solanum aethiopicums* leaves respectively. It was not detected in *Solanum aethiopicums* fruits. Agneta, *et al.*[27], reported a Pb concentration of 40–530µg/kg (0.04–0.530mg/kg) dry weight in water spinach (Ipomoea aquatica) in Bangkok region of Thailand and this compares with the present results. The levels of Pb reported were within the recommended limit by FAO/WHO. Pb has harmful effects on organs like lung, kidneys, liver, and spleen which cause different biochemical impairments. Adults exhibit neuropathology when accidentally or occupationally exposed to higher concentration. There is a relationship between Pb in the human body and the increase of blood pressure of adults[17]. The highest content of lead was measured in *Capscium annuum* L. fruits from farm A with concentration of about 0.6667±0.1443, while the yellow *Capscium annuum* L. fruits, *Solanum melongen* fruits and *Solanum aethiopicum* fruits from farm A and *Solanum aethiopicum* from farm B were below detection limits. The study disclosed that Pb concentration in the six vegetables was partially above the WHO/FAO set standard (0.30mg/kg). Lente *et al.*[25], reported a mean Pb concentration range (5.59 to 10.51 mg/kg) in lengthy wastewater irrigated vegetables in Accra. Also, Suruchi *et al.*[28], recorded Pb concentration of 2.652mg/kg in vegetables, while Doherty *et al.*[29], reported 0.001mg/kg in vegetables in a farm within Iyana-Iba, Lagos, Nigeria.

The concentration levels of total Zn ranged: 0.1039±0.0520 to 0.2482±0.0529, 0.6638±0.1525 to 0.8773±0.1929, 0.3550±0.2078 to 2.9441±1.7382, 0.5195±0.3677 to 0.7533±0.2582 and 0.6205±0.2648 to 1.0361±0.6153 in yellow and red *Capsicum annuum* L. fruits, *Gongronema latifolium* leaves, *Solanum molegian* fruits, *Solanum aethiopicums* leaves and *Solanum aethiopicums* fruits respectively. The concentration levels of total Ni ranges: 0.2393±0.0592 to 0.3077±0.1026, 0.3419±0.2581 to 0.3761±0.1184, 0.2393±0.0592 to 0.2735±0.2135, 0.3077±0.1026 to 0.3761±0.2135 and 0.1026±0.0000 to 0.1709±0.1184 in yellow and red *Capsicum annuum* L. fruits, *Gongronema latifolium* leaves, *Solanum molegian* fruits, *Solanum aethiopicums* leaves and *Solanum aethiopicums* fruits respectively. Zinc concentration in red and yellow *Capscium annuum* L. fruits, *Gongronema latifolium* leaves, *Solanum melongen* fruits, *Solanum aethiopicum* fruits, and *Solanum aethiopicum* leaves in the six vegetables were within the WHO/FAO (Table 4) which pegged the limits to be 60mg/kg. Lente *et al.*[25] also reported Zn values in Accra, to be 10mg/kg. Zinc is an important mineral as a result of its exceptional biological and public health importance[30], but excessive ingestion can lead to an adverse health impact on humans[31]. Zinc can also reduce the concentration of high-density lipoproteins and immune function[32]. In developing countries, about two billion people are affected by zinc deficiency and are related to many diseases[33]. Zinc deficiency is implicated in about 800,000 children's death worldwide every year, causes delayed sexual maturation, growth retardation, diarrhoea in children, and infection vulnerability[17,30].

The concentration levels of total Cd ranges: 0.0130±0.00042 to 0.0377±0.0040, 0.0243±0.0125 to 0.0463±0.0246, 0.0313±0.0179 to 0.0703 to 0.0316, 0.0510±0.0157 to 0.0583±0.0332, 0.0110±0.0142 to 0.0377±0.0188 yellow and red *Capsicum annuum* L. fruits, *Gongronema latifolium* leaves, *Solanum molegen* fruits, *Solanum aethiopicums* leaves, and *Solanum aethiopicums* fruits respectively. Agneta *et al.*[27], reported Cd concentration of ≤10–123µg/kg (0.01–0.123mg/kg) dry weight in water spinach (*Ipomoea aquatica*) in Bangkok region of Thailand and this compares with the present result just like the Pb concentration. Kosak *et al.*[23], reported Ni, Pb, Zn, and Cd concentration of 0.2, 13, 38, and 1.5 mg/kg respectively in *Ipomoea pes-caprae* medicinal plant in Bang mor, South Thailand. The vegetable species with the highest accumulation of Cd was *Solanum melongen* fruits from farm A, with an average Cd content in leaves of 0.0703±0.0316mg/kg. The study showed that Cd concentration in some vegetables exceeded the WHO/FAO stipulated value of 0.02 mg/kg[20] but did not exceed 0.2 and 0.05mg/kg[34] leafy vegetables and fruiting vegetables respectively for the analyzed samples from different farms. Only *Solanum melongen* fruits from farm A exceeded WHO/FAO limits. Lente *et al.*[25] in Ghana, reported Cd values below the detectable limit of 0.006mg/kg in vegetables.

Odai *et al.*[35], conducted a study on vegetables grown within waste dump sites in Kumasi, and recorded high Cd levels (0.68 to 1.78mg/kg). Besides, Muchuweti *et al.*[36], recorded Cd (3.68 mg/kg) 18 times above EU standards in local vegetables irrigated with wastewater in Harare. Doherty *et al.*[29], reported Cd level of 0.001mg/kg in a farm in Egbeda area of Lagos Nigeria. Obviously, Cd has become a concern in agriculture as a result of its association with kidneys and bone damage, and its probable carcinogenic attribute[28]. Because Cd can be taken up via the alimentary tract; penetrate placenta during pregnancy, and harm the DNA membranes, it is unsafe. The increase in urinary excretion of Ca and its reduction in bone have been associated with Cd exposure which can lead to fatality[37]. Hence, Cd metal metabolism in the human body may persist from 16 to 33years, and it is associated with many health challenges of which abnormal urinary excretion of proteins and renal damages are observed[38].

Cobalt was undetectable in the majority of the vegetable samples except in yellow and red *Capsicum annuum* L. fruits, *Gongronema latifolium* leaves with a range of 0.0280±0.0071 to 0.0485±0.0346 and 0.0170±0.0127 to 0.0180±0.0141 mg/kg respectively. In the yellow and red *Capscium annuum* L. fruits group, Co concentrations ranged from 0.0280 ± 0.0071 to 0.0485 ± 0.0346mg/kg and it was below detection limits in yellow and red *Capscium annuum* L. in farm A and B respectively. The Co concentrations ranged from 0.017±0.0127 to 0.0180±0.0141mg/kg in Gongronema latifolium leaves. On the other hand, Co in *Solanum melongen* fruits and *Solanum aethiopicum* fruits and leaves were below the detection limit. The phytotoxicity of cobalt becomes obvious as concentration (mg/kg) ranges between 30 and 40, and hazard to animals is likely when concentrations exceed 60mg/kg[26]. Cobalt is an important trace element, which is a component of vitamin B12 precursor and it is applicable in the treatment of anemic patients[19,39]. Hence, the levels of concentration of cobalt determined in all the vegetables may not represent any potential risk.

The concentration levels of total Fe ranges: 1.3450±0.3252 to 7.0917±0.4409, 2.7306±0.3736 to 3.0568±0.3235, 1.6303± 0.3930 to 13.2460±1.3633, 4.4017±0.3235 to 5.4612±0.8847, 10.5968±0.6734 to 13.3683±1.2843 mg/kg in yellow and red *Capsicum annuum* L. fruits, *Gongronema latifolium* leaves, *Solanum molegen* fruits, S*olanum aethiopicums* leaves, and *Solanum aethiopicums* fruits respectively. Iron concentration levels in the six vegetables were within the WHO/FAO standard value of 56mg/kg[20]. *Solanum aethiopicum* and *Solanum melongen* fruits from farm A have the highest iron metal concentration of 13.3683±1.2843 and 13.2460±1.3633 mg/kg respectively. Excessive concentration of Fe in human can lead to its deposition in tissues, (Siderosis) in adrenals, liver, thyroid, pancreas and pituitary etc. according to Ametepey *et al.*[17].

The highest average content of Ni in all analyzed vegetable species was recorded in *Gongronema latifolium* and *Solanum aethiopicum* leaves, with concentration of 0.3761±0.1184 and 0.3761±0.2135mg/kg respectively, and the lowest content of Ni was recorded in *Solanum aethiopicum* farm A with concentration of 0.1026±0.0000 mg/kg. Yellow *Capscium annuum* L from farm A was below the detection limit. The levels of Ni determined in some vegetables exceeded the limit of 0.2mg/kg[40], but within FAO/WHO recommendation of 1.5mg/kg and maybe a potential health risk to monogastric animals if introduced to the vegetables.

Similar studies in some settlement showed the levels of toxic metals in ready to eat vegetables. For instance, a study was carried out by Okoro *et al.*[41] to evaluate the Cd, Ni, and Pb levels in vegetable *Solanum melongena* fruit, planted in farms close to waste dumpsite Emelogu, Abayi and Umuogele in Aba, Abia State, Nigeria. The report from Abayi showed Pb (0.03mg/kg), Ni (0.49mg/kg), Cd (0.05mg/kg), Emelogu Pb (0.01mg/kg), Cd (0.29mg/kg), Ni (0.001mg/kg) and Umuogele Pb (0.49mg/kg), Cd (0.25mg/kg) and Ni (0.24mg/kg). The level of trace metal from these farms showed that the concentration of the metal is within the permissible limit of FAO/WHO standard when compared to the lead concentration from farm B of our study.

Also, Gaya *et al.*[39], carried out a similar study in *Gongronema latifolium* leaves, red and yellow *Capscium annuum* L. fruits. They found out that mean concentration of Cd, Cr, Co, Fe, Ni, Pb and Zn for *Gongronema latifolium* leaves was 5.317±0.022, 2.533±0.011, 8.333±0.034, 12.500±0.083, 4.333±0.008, 6.450±0.032, 2.167±0.022 mg/kg respectively. Yellow *Capscium annuum* L. fruits 4.600±0.024, 4.700±0.019, 5.567±0.051, 13.883±0.048, 4.333±0.008, 3.067±0.006 and 2.517±0.013 mg/kg respectively as well. Red *Capscium annuum* L. fruits 6.033±0.013, 4.700±0.019, 5.550±0.019, 13.900±0.127, 3.417±0.014, 4.717±0.023 and 3.983±0.013 mg/kg respectively. The level of metals contamination in Gaya *et al.*[39] study is higher when compared to this work. These showed that the farms were these vegetables are grown have not been greatly contaminated.

Table 5 presents the hazard quotient and total hazard index of the PTEs. The intake of contaminated vegetables with a substantial number of trace metals could be harmful to human health. The health effect from the average daily dose was ascertained using the mean concentration of metals in the various vegetables from different farm locations.

Table 4. Concentration of trace metals in the studied vegetables (mg/kg)

Sample code	Chromium	Lead	Zinc	Nickel	Cadmium	Cobalt	Iron
UA	0.1361 ± 0.1348	0.2500 ± 0.0000	0.6638 ± 0.1525	0.3761 ± 0.1184	0.0463 ± 0.0246	0.0170 ± 0.0127	2.7306 ± 0.3736
UB	0.0778 ± 0.0337	0.3750 ± 0.1768	0.8773 ± 0.1929	0.3419 ± 0.2581	0.0243 ± 0.0125	0.0180 ± 0.0141	3.0568 ± 0.3235
SMSA	0.1167 ± 0.0584	ND	0.3550 ± 0.2078	0.2735 ± 0.2135	0.0703 ± 0.0316	ND	13.2460 ± 1.3633
SMSB	0.1556 ± 0.1215	0.3750 ± 0.1768	2.9441 ± 1.7382	0.2393 ± 0.0592	0.0313 ± 0.0179	ND	1.6303 ± 0.3930
SALA	0.1167 ± 0.0584	0.3750 ± 0.1768	0.7533 ± 0.2582	0.3077 ± 0.1026	0.0510 ± 0.0157	ND	5.4612 ± 0.8847
SAAS	0.1750 ± 0.1543	ND	1.0361 ± 0.6153	0.1026 ± 0.0000	0.0110 ± 0.0142	ND	13.3683 ± 1.2843
SALB	0.0778 ± 0.0337	0.4167 ± 0.1443	0.5195 ± 0.3677	0.3761 ± 0.2135	0.0583 ± 0.0332	ND	4.4017 ± 0.3235
SABS	0.1556 ± 0.0337	ND	0.6205 ± 0.2648	0.1709 ± 0.1184	0.0377 ± 0.0188	ND	10.5968 ± 0.6734
RPA	ND	ND	0.2482± 0.0529	0.3077± 0.1026	0.0377± 0.0040	0.0485± 0.0346	7.0917± 0.4409
RPB	0.1363± 0.0335	0.4167± 0.0113	0.1241± 0.0786	0.2393± 0.0592	0.0290± 0.0100	ND	2.4453± 0.5329
YPA	0.1165± 0.0827	0.6667± 0.1443	0.1414± 0.0499	0.3077± 0.1026	0.0340± 0.0042	ND	1.7120± ± 0.4409
YPB	0.0292± 0.0412	0.2500± 0.0000	0.1039± 0.0520	ND	0.0130± 0.0042	0.0280± 0.0071	1.3450± 0.3252
WHO/ FAO(mg/ kg) max limit	2.3[b]	5.0[a]	60[a]	1.5[a]	0.2[a]	0.05-0.1[f]	56[b]

Where ND = not detected, UA is the *Gongronema latifolium* leaves from farm A, UB is the *Gongronema latifolium* leaves from farm B, SMSA = *Solanum melongen* fruits from farm A, SMSB = *Solanum melongen* fruits from farm B, SALA = *Solanum aethiopicum* leaves from farm A, SAAS = *Solanum aethiopicum* fruits from farm A, SALB = *Solanum aethiopicum* leaves from farm B. SABS = *Solanum aethiopicum* fruits from farm B, RPA is red *Capsicum annuum* L. seeds from farm A, RPB is red *Capsicum annuum* L. seeds from farm B, YPA is yellow *Capsicum annuum* L. seeds from farms and YPB is the yellow *Capsicum annuum* L. seeds from farm B. [b]PMTDI (mg/day): provisional maximum tolerable daily intakes[42],Agency for toxic substance disease registry[19]; aWHO/FAO[20] and Indian standard.

Table 5 . Consumption rate, HQ and THI of PTEs of the vegetable samples

Sample	Variables	Cr	Pb	Zn	Ni	Cd	Co	Fe	THI
RPA	ADDa	-	-	0.00018	0.00022	0.00003	0.00003	0.00507	
	ADDc	-	-	0.00078	0.00096	0.00012	0.00015	0.02216	
	HQa	-	-	0.0006	0.011	0.03	0.003	0.0072	0.052
	HQc	-	-	0.0026	0.0048	0.12	0.015	0.032	0.174
RPB	ADDa	0.00009	0.00010	0.00009	0.00017	0.00002	-	0.00175	
	ADDc	0.00043	0.00046	0.00039	0.00075	0.00009	-	0.00767	
	HQa	0.0225	0.0262	0.0003	0.0375	0.02	-	0.0025	0.109
	HQc	0.0108	0.1146	0.0013	0.0373	0.09	-	0.011	0.265
YPA	ADDa	0.00008	0.00048	0.0001	0.00022	0.00002	-	0.00122	
	ADDc	0.00036	0.00208	0.00044	0.00096	0.00011	-	0.00535	
	HQa	0.02	0.012	0.0015	0.011	0.0243	-	0.0017	0.071
	HQc	0.09	0.0521	0.0049	0.0481	0.1063	-	0.0076	0.309
YPB	ADDa	0.00002	0.00018	0.00007	-	0.00001	0.00002	0.00096	
	ADDc	0.00009	0.00078	0.00032	-	0.00004	0.00009	0.0042	
	HQa	0.005	0.045	0.0002	-	0.01	0.002	0.0014	0.064
	HQc	0.0228	0.1953	0.0011	-	0.04	0.009	0.006	0.274
UA	ADDa	0.0001	0.0002	0.0005	0.0003	0.00003	0.00001	0.00195	
	ADDc	0.0004	0.0008	0.0021	0.0012	0.00014	0.00005	0.00853	
	HQa	0.025	0.05	0.002	0.015	0.03	0.01	0.003	0.135
	HQc	0.1	0.2	0.007	0.06	0.014	0.05	0.012	0.443
UB	ADDa	0.00006	0.00027	0.00063	0.00024	0.00002	0.00001	0.00218	
	ADDc	0.00024	0.00117	0.00274	0.00107	0.00008	0.00005	0.00955	
	HQa	0.015	0.068	0.0021	0.012	0.02	0.001	0.003	0.14
	HQc	0.06	0.293	0.009	0.054	0.08	0.005	0.0014	0.502
SMSA	ADDa	0.00037	-	0.00112	0.00086	0.00022	-	0.04163	
	ADDc	0.0016	-	0.0049	0.00376	0.00097	-	0.1821	
	HQa	0.092	-	0.004	0.043	0.22	-	0.059	0.418
	HQc	0.400	-	0.016	0.188	0.97	-	0.260	1.834
SMSB	ADDa	0.00049	0.00118	0.00925	0.00075	0.0001	-	0.00512	
	ADDc	0.00214	0.00516	0.04048	0.00329	0.00043	-	0.22416	
	HQa	0.123	0.03	0.031	0.038	0.10	-	0.007	0.329
	HQc	0.054	1.289	0.135	0.165	0.43	-	0.320	2.393
SALA	ADDa	0.00025	0.0008	0.00161	0.00066	0.00011	-	0.0117	
	ADDc	0.00109	0.00352	0.00706	0.00288	0.00049	-	0.0512	
	HQa	0.063	0.2	0.005	0.033	0.11	-	0.017	0.428
	HQc	0.273	0.88	0.024	0.144	0.49	-	0.073	1.884
SALB	ADDa	0.00017	0.00089	0.00161	0.00081	0.00012	-	0.00943	
	ADDc	0.00073	0.00391	0.00706	0.00353	0.00055	-	0.04127	
	HQa	0.042	0.223	0.005	0.041	0.12	-	0.014	0.445
	HQc	0.183	0.978	0.024	0.018	0.55	-	0.059	1.812

SAAS	ADDa	0.0002	-	0.00118	0.00012	0.00001	-	0.01528	
	ADDc	0.00109	-	0.00518	0.00051	0.00006	-	0.06684	
	HQa	0.05	-	0.004	0.001	0.01	-	0.022	0.087
	HQc	0.273	-	0.017	0.026	0.06	-	0.096	0.472
SABS	ADDa	0.00018	-	0.00070	0.0002	0.00004	-	0.01211	
	ADDc	0.00078	-	0.00307	0.0008	0.00019	-	0.05298	
	HQa	0.045	-	0.002	0.01	0.04	-	0.017	0.114
	HQc	0.195	-	0.01	0.043	0.19	-	0.076	0.514

Where – = not detected ADD = Estimated daily intake, HQa = hazard quotient for adult, HQc = hazard quotient for children

The HQs were < 1 for both adult and children in all the vegetables indicating the tolerable level of non-carcinogenic adverse health impact, except Pb HQs value for children in Solanum melongen fruits from farm B. Therefore, concerns about the prolonged consumption of the vegetables is not expected in respect of potential health risk apart from Solanum melongen fruits in farm B. When the HQ > 1, there is anxiety for potential health risk. Hence, there is a potential health risk for children when they consume 0.22kg/day of Solanum melongen fruits from farm B.

The Hazard Index (HI) values of the trace metals studied ranged from 0.09 to 0.44mg/kg for adults and 0.17 to 2.39mg/kg for children that were below and above 1, indicating an acceptable and unacceptable level of non-carcinogenic adverse health effect respectively. Hence, HI recorded in Nsukka farms indicated the contribution of trace metals can lead to aggregate risk through consumption of vegetables like Solanum aethiopicum leaves and Solanum melongen fruits by children from all the farms respectively. These high HI values for all trace metals observed in Solanum aethiopicum leaves and Solanum melongen fruits have great potential to pose a health risk to the children. The difference in THQ values for adults and children is usually attributable to the differences in the intake of the trace metals, body mass, and exposure duration. However, vegetable intake is just a proportion of food consumed or supplementary food that may include fish[43], meat[44,45], rice[46], and tobacco[47] that are consumed can also contribute and (or) increase amounts of trace metals.

4. Conclusion

Predominantly, concentrations of the trace metals in the various ready to eat vegetables were all within the allowable values of WHO/FAO. Samples from Opanda area are more contaminated by these PTEs and this could be due to the vehicular movement along Nsukka-Onitsha Road which passed through farm A. However, the separate HQ values were all < 1 for adults and children from all the farms, except the Pb concentration for children in Solanum melongen fruits. The increase in the Pb contamination could be from the combustion of leaded fuel by automobiles plying Nsukka-Onitsha highway. The THI for children in all the vegetables were less < 1, except for SMSA, SMSB, SALA, and SALB indicating no non-carcinogenic adverse risk when consumed by adults but not children. Finally, the hazard risk assessment of the ready to eat vegetables in Nsukka area indicated no risk for adult and moderate for children. Standing on the observations aforementioned, it is therefore suggested that since Nsukka is a pre-urban area that deals with farming, measures, and control should always be implemented to make sure that the level of trace metal in the vegetable will not exceed WHO/FAO permissible limit.

5. Conflict of Interest

There are no conflicts of interest.

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