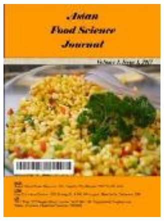

Asian Food Science Journal

2(4): 1-7, 2018; Article no.AFSJ.41561

Health Risk Assessment of Selected Trace Metals in Edible Vegetables Grown in Obudu Urban Area of Cross River State Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author AMA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author EIB managed the analyses of the study. Author NOV managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AFSJ/2018/41561
Editor(s):
(1) Abd Elmoneim Osman Elkhalifa, Professor, Department of Food Chemistry, Ahfad University for Women, Sudan.
Reviewers:
(1) Ewuzie, Ugochukwu, Abia State University, Nigeria.
(2) Taratisio Ndwiga, Moi University, Kenya.
(3) Ibrahim Bashiru, Sokoto State University, Nigeria.
Complete Peer review History: http://prh.sdiarticle3.com/review-history/25006

Original Research Article

Received 18th March 2018
Accepted 26th May 2018
Published 6th June 2018

ABSTRACT

Aim: Edible vegetables are consumed directly as food or medicine in Obudu urban area of Cross River State, yet they are sometimes grown in old wastes dumpsites where wastes containing trace metals may have been disposing of indiscriminately, with the view to tap the composted manure. The objective of this study was to assess the health risk of selected trace or heavy metals in this edible vegetables in the area.

Place and Duration of Study: Department of Chemistry Laboratory, University of Calabar, Calabar Nigeria, between January and March, and July and September 2016 for dry and rainy season respectively.

Methodology: Edible vegetable samples were collected at five different locations together with the soil samples where each vegetable was planted during the dry and rainy season of the year respectively. They were digested and their average Hg, Ni, Pb and Zn concentration was determined using the 210 VGP Buck scientific model Atomic Absorption Spectrometer (AAS). The health risk was assessed using the Target Hazard Quotients (THQ) values determined from AAS data.

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Results: These showed that the mean concentration of Pb in the soil in $mgkg^{-1}$ ranged from $0.011 - 0.033$ and $0.010 - 0.031$ for the rainy and dry season respectively, while that of Zn ranged from $0.165 - 0.635$ and $0.163 - 0.627$ for rainy and dry season respectively. Hg and Ni were considered string variables as they were not detected in the soil or vegetables. The average concentration of Pb and Zn accumulated by the vegetables in $mgkg^{-1}$ ranged from $0.005 - 0.023$ and $0.004 - 0.018$ for the rainy and dry season respectively, while that of Zn ranged from $0.017 - 0.074$ and $0.016 - 0.079$ for the rainy and dry season respectively. The trend of the average concentration of the metals in the soil and vegetables was in the order: Zn > Pb > Hg > Ni. The THQ values of Pb and Zn were in range 0.0018-0.0101 and 0.0001-0.0004 respectively, all less than 1.

Conclusion: From the results, there is some level of heavy or trace metal concentration present in the soil and the edible vegetables in the area but the amount is still low and within the permissible limit of WHO/FAO, and there is no health risk associated with the consumption of the vegetables as far as the studied metals are concerned for now.

Keywords: Risk assessment; trace metals; edible vegetables.

1. INTRODUCTION

Mercury (Hg), Nickel (Ni), Lead (Pb) and Zinc (Zn) belongs to a group of elements or metals called trace metals due to the fact that they occur in the earth crust in small or minute amounts. They are often referred to as heavy metals. A heavy metal is a metallic element that has a specific gravity of 5.0 or greater and is usually poisonous [1]. Heavy metals are widely recognized and related to the widespread contaminants of land and freshwater ecosystems. Many definitions have been opined for heavy metals based on density, atomic number/weight, chemical properties or toxicity. Though these metals or elements are useful in many ways and are of economic value to the society, they are also poisonous or toxic to animals or humans when taken in through food in high doses.

The effects of high doses of some heavy metals have been enumerated to include low Intelligent Quotient (IQ) in children, brain, foetus, kidney and nervous system damages caused by lead, decreased body weight, heart and liver damage and skin irritation caused by Nickel, gingivitis, tremors, psychological changes and brain damages caused by copper etc. Zinc though needed in trace amount in living organisms causes damage to some biological systems and interfere with the body metabolism at excessive levels [2]. Therefore, the need to avoid human exposure to high levels of these metals is imperative, let alone taking in high doses of them into the body. Khan has opined that the consumption of contaminated food or vegetables is an important route of human and animal exposure [3]. Also, contaminated soils have resulted in the cultivation of contaminated vegetables or food crops [4,5,6]. It has also been stated that leafy vegetables accumulate much higher amounts of heavy metals as compared to other vegetables. This is because leafy vegetables have higher translocation and transpiration rates compared to the fruit vegetables where transfer of the metals from the root through the system and to the fruit is longer and results in lower accumulation than leafy vegetables in a given time [7]. Khair among other researchers has reported that heavy metal contamination is a major problem of our environment as the main contaminating agents of our food [8]. This is due to the fact that they are released often to sea, rivers, lakes and soil as waste from their numerous applications in industries and everyday use in the society. Thus, the increasing demand for food and its safety has attracted the attention of many researchers worldwide to the health risks associated with the consumption of contaminated vegetables that may contain pesticides, heavy metals such as Hg, Ni, Pb, Zn etc. and other toxins.

Obudu is one of the Local Government Areas of Cross River State, Nigeria with a population of about one hundred thousand people. The topography of the area by its location is characterized by mountainous landforms and hills, which makes it a good haven for quarrying activities. The people engage in both subsistence and commercial farming, cultivating yams, cassava, legumes, cocoa, rice, groundnuts, peas etc., in large quantity using herbicides, insecticide and fertilizers as the need arises. Also, as an urban area with small and medium scale enterprises, mechanic workshops, skill workers etc., the release of waste and scraps, containing some heavy metals into the environment is certainly possible. Moreover, the people also practice rotational waste-dump sites at their backyards around their premises where they plant edible vegetables in the old waste-dump sites with the aim of tapping the compost manure for a good yield. They do this without minding that wastes were dumped on these sites indiscriminately. This makes the vegetables grown in the area to be susceptible to contamination as the soil quality with respect to trace or heavy metals contamination is not known. For vegetables to be free of trace metals, the soil where they are planted should be free from metals contamination. Hence, there is need to determine the concentration of heavy or trace metals in the soil before planting or growing vegetables.

Consequently, this study is aimed at determining the Hg, Ni, Pb and Zn (heavy metals) concentration in edible vegetables in the area with the view to ascertain the health implication of their concentration in the soil and vegetables if any, so as to proffer possible solution and create awareness about such for the general good of the people in the area and the society at large.

2. MATERIALS AND METHODS

Sampling and sample pre-treatment: forty soil samples and vegetables were collected randomly at different locations within Obudu urban area and the closest neighbourhood. The soil samples were collected at the root level of the vegetables at the depth of the 12 to 15 cm, and at the same time the edible vegetables were collected and wrapped separately with identification labels before taking them to the laboratory.

The edible vegetables considered for this study in area which were planted in each of the forty soil samples include: *Amaranthus spp* (Green vegetable), *Corchorus Olitorius* (Ewedu), *Murraya koenigii* (Curry leaf), *Ocimium gratissimum* (Scent leaf), *Solanum melongena* (leaf eggplant), *Telfairia occidentals* (Pumpkin), *Talinum triangulare* (Water leaf), and *Vernonia amygdalina* (Bitter leaf). They are commonly used for food and medicinal purposes in the area. The samples were collected and analyzed between January and March for the dry season and between July and September for the rainy season.

The vegetable samples were washed with distilled water and oven-dried at 80-85°C for about 2hours. Each dried sample was milled into powder, sieved with 0.3mm sieve and stored in a labeled plastic jar with cap. The soil sample was also oven-dried, ground into find powder and homogenized with pestle and mortar sieve and stored in labelled plastic jars separately.

Digestion of samples: vegetable samples were digested following the procedure reported by [9] thus: 1.0 g of each sample was placed in a beaker and 20 mL of concentrated (HCl), 10 mL of concentrated HNO_3 and 5 mL of H_2SO_4 were added. After volatiles was removed, the beaker was heated in a fume cupboard for about 30minutes. The digested sample was removed and allowed to cool. DE-ionized water was added to the digest and made up to 100 mL in a volumetric flask. The solution was stirred and filtered to obtain the supernatant liquid ready for heavy metals analysis. Similarly, the soil samples were digested following the procedure used by [10] thus: 2.0 g of each soil sample powder was weighed into an acid-washed beaker. 20 mL of the aqua region (mixtures of HCl and HNO_3, in the ratio 3:1) was added to the sample in the beaker. The beaker was covered with a clean dry watch glass and heated at 90% for about 2 hours; the beaker was removed, allowed to cool, washed together with the watch glass using de-ionized water into a volumetric flask and made-up to 100 mL solution. The solution was filtered and the supernatant liquid solution was used for heavy metal determination.

Element determination: The soil and vegetable samples were analyzed for Hg, Ni, Pband Zn using the 210 VGP Buck scientific model of Atomic Absorption Spectrometer (AAS) at the following wavelengths. Hg (253.7 nm), Ni (232.0 nm), Pb (283.3 nm), and Zn (213.1 nm).

Calculations: The Target Hazard quotient which is the ration of the body intake does of a pollutant to the reference dose was calculated thus:

$$\mathrm{THQ} = \frac{DIV\ x\ Cm}{RfD\ x\ B}$$

Where DIV is the daily intake of vegetable in (kg/day), Cm is the concentration of pollutant (heavy metal) in the vegetable in $mgKg^{-1}$, B is the average body weight of human in kg and R_fD is the oral reference dose which is generally accepted and it is the permissible oral dose fixed by the US-EPA. Note: B is assumed by US-EPA to be 70 kg for adult males and 60kg for adult females. For this study, 65 kg (the average of 70 kg and 60 kg) for all adults, was used while the DIV was assumed to be 100 g (0.1kg/day) per day. In some countries or places, up to 150 or 200 g per day have been assumed especially for vegetarians. From the formula, THQ is a dimensionless parameter or ratio. According to US-EPA through [11], if THQ is less than 1 (THQ<1), it shows that there is no potential health risk associated with the pollutant. But if THQ>1, there is a health risk associated with the pollutant (heavy metal) at that moment. The R_fD for Hg, Ni, Pb and Zn from [11] are 0.003, 0.01, 0.0035 and 0.0300 $mgkg^{-1}$ respectively.

Statistical analysis: The data collected were analyzed using SPSS version 20. The data were also expressed in term of descriptive statistics and values were presented with mean values of triplicates. The significance test was computed using pair sample T-test at P<0.05 for dry and rainy seasons data.

3. RESULTS

The mean concentration of Hi, Ni, Pb and Zn in the soil and vegetables in Obudu Urban Area in the rainy and dry seasons are presented in Tables 1 and 2 respectively, while the Target Harzard Quotients for both seasons are reported in Tables 3 and 4 respectively.

Table 1. Mean concentration of Hi, Ni, Pb and Zn in the soil and vegetables in Obudu in rainy season in $mgk\xi^{-1}$(dry weight)

Vegetables	Hg	Ni	Pb	Zn
Amaranthus spp	ND	ND	0.023 ± 0.006	0.030 ± 0.016
Soil	0.001 ± 0.001	ND	0.033 ± 0.004	0.165 ± 0.060
Corchorus olitorius	ND	ND	0.011 ± 0.004	0.017 ± 0.012
Soil	0.002 ± 0.001	ND	0.024 ± 0.007	0.175 ± 0.017
Murraya koenigii	ND	ND	0.015 ± 0.009	0.041 ± 0.016
Soil	0.001 ± 0.001	ND	0.022 ± 0.013	0.415 ± 0.021
Ocimum grattissimum	ND	ND	0.007 ± 0.003	0.029 ± 0.015
Soil	ND	ND	0.012 ± 0.005	0.550 ± 0.002
Solanum melongena	ND	ND	0.015 ± 0.006	0.032 ± 0.008
Soil	ND	ND	0.025 ± 0.004	0.437 ± 0.082
Talinum triangulare	ND	ND	0.005 ± 0.002	0.033 ± 0.022
Soil	ND	ND	0.011 ± 0.002	0.366 ± 0.012
Telferia occidentalis	ND	ND	0.009 ± 0.001	0.062 ± 0.009
Soil	ND	ND	0.016 ± 0.011	0.635 ± 0.011
Vernonia amygdalina	ND	ND	0.011 ± 0.003	0.074 ± 0.018
Soil	ND	ND	0.017 ± 0.012	0.442 ± 0.017

Note: Values reported in Mean $\pm$SD format, with N=3, ND = Not Detected

Table 2. Mean concentration of Hg, Ni, Pb and Zn in soil and vegetables in Obudu in the dry season in $mgk\xi^{-1}$(dry weight)

Vegetables	Hg	Ni	Pb	Zn
Amaranthus spp	ND	ND	0.018 ± 0.004	0.027 ± 0.014
Soil	ND	ND	0.031 ± 0.003	0.163 ± 0.061
Corchorus olitorius	ND	ND	0.009 ± 0.003	0.016 ± 0.008
Soil	ND	ND	0.022 ± 0.006	0.173 ± 0.015
Murraya koenigii	ND	ND	0.013 ± 0.004	0.039 ± 0.012
Soil	ND	ND	0.019 ± 0.013	0.410 ± 0.017
Ocimum grattissimum	ND	ND	0.005 ± 0.003	0.027 ± 0.013
Soil	ND	ND	0.011 ± 0.004	0.549 ± 0.010
Solanum melongena	ND	ND	0.010 ± 0.005	0.029 ± 0.008
Soil	ND	ND	0.018 ± 0.002	0.435 ± 0.065
Talinum triangulare	ND	ND	0.004 ± 0.002	0.022 ± 0.010
Soil	ND	ND	0.010 ± 0.004	0.362 ± 0.012
Telferia occidentalis	ND	ND	0.009 ± 0.004	0.079 ± 0.019
Soil	ND	ND	0.013 ± 0.006	0.627 ± 0.020
Vernonia amygdalina	ND	ND	ND	0.069 ± 0.020
Soil	ND	ND	ND	0.435 ± 0.023

Note: Values reported in Mean $\pm$SD, with N=3, ND= Not Detected

Table 3. Target Hazard Quotients (THQ) of Hg, Ni, Pb and Zn in edible vegetables in Obudu during the rainy season

Vegetables	Hg	Ni	Pb	Zn
Amaranthus spp	Nil	Nil	0.0101	0.0002
Corchorus olitorius	Nil	Nil	0.0048	0.0001
Murraya koenigii	Nil	Nil	0.0066	0.0002
Ocimum grattissimum	Nil	Nil	0.0031	0.0001
Solanum melongena	Nil	Nil	0.0066	0.0002
Talinum triangulare	Nil	Nil	0.0022	0.0002
Telferia occidentalis	Nil	Nil	0.0040	0.0003
Vernonia amygdalina	Nil	Nil	0.0048	0.0004

Note: Hg & Ni are string variables because they were not detected in the vegetable

Table 4. Target Hazard Quotients (THQ) of Hg, Ni, Pb and Zn in edible vegetables in Obudu during the dry season

Vegetables	Hg	Ni	Pb	Zn
Amaranthus spp	Nil	Nil	0.0079	0.0001
Corchorus olitorius	Nil	Nil	0.0040	0.0001
Murraya koenigii	Nil	Nil	0.0057	0.0002
Ocimum grattissimum	Nil	Nil	0.0022	0.0001
Solanum melongena	Nil	Nil	0.0044	0.0002
Talinum triangulare	Nil	Nil	0.0018	0.0001
Telferia occidentalis	Nil	Nil	0.0040	0.0004
Vernonia amygdalina	Nil	Nil	Nil	0.0004

4. DISCUSSION

The data in Tables 1 and 2 revealed that there is some level of Pb and Zn contamination both in soil and in the vegetables in the study area out of the four heavy metals considered in this study. Hg and Ni were not detected in the soil or in the edible vegetable samples, showing that their concentration in the soil is still insignificant to be available for the vegetables to accumulate. Thus, Hg and Ni are considered string variables in the data. The results also showed that the highest amount of Pb accumulated by the vegetables was (0.023 $mgkg^{-1}$ and 0.018 $mgkg^{-1}$ for the rainy and dry season respectively by *Amaranthus spp.,* at the soil level of 0.033 and 0.006 – 0.031 $mgkg^{-1}$for the rainy and dry season respectively. The lowest amount of Pb accumulated was 0.005 and 0.004 $mgkg^{-1}$ by *Talinum triangulare* for the rainy and dry season respectively at the soil concentration of 0.011 and 0.010 $mgkg^{-1}$ for rainy and dry season respectively.

The highest amount of Zn accumulated was $0.074\, mgkg^{-1}$ by *Vernonia amygdalina* in rainy season and $0.079\, mgkg^{-1}$ by Telferia occidentalis in dry season, at the soil level of $0.042\ and\ 0.627\, mgkg^{-1}$ for the rainy and dry season respectively. On the other hand, the lowest amount of Zn accumulated was $0.017\ mgkg^{-1}$ and 0.016 by corchorus olitorius in the rainy and dry seasons respectively at the soil concentration of $0.175\ and\ 0.173 mgkg^{-1}$for rainy and dry seasons respectively. The average concentration of the metals in the vegetables and the soil generally was in the order; Zn > Pb > Hg > Ni.

The implication of this results is that there is no significant difference between the metals concentration in the soil and that accumulated by the vegetables for both seasons, indicating that the source of these metals in the environment may not be from air pollution sources like vehicular emissions or irrigation water sources during the dry season. Therefore, their source may be from other anthropogenic activities like indiscriminate disposal of waste containing heavy metals, industrial sewage, leachate from auto mechanic workshops or quarrying sites which are transported to the vegetable gardens during the rainy season by erosion. However, the concentration of the metals in the soil are still low and that accumulated by the edible vegetables in the study area is also low and within the permissible limit of FAO/WHO which is $0.1 mgkg^{-1}$ for the metals.

The availability of metals in the soil for plants accumulation depends on many factors like PH, soil texture or porosity etc. Several researchers have supported the fact that the solubility of cationic forms of metals in the soil solution increases as the P^H decreases and this make the metals readily available for plants to accumulate. The chemical form and solubility of metals in the soil can also determine their availability in the soil for plants accumulation [12,13,14]. The availability of Zn to plants in the soil depends on its chemical form in the soil and the dynamic equilibrium among its different forms or fractions present [15,16].

The results in Tables 3 and 4 showed the Target Hazard Quotients (THQ) of the metals in edible vegetables in the study area for the rainy and dry season respectively. The results indicate that the THQ values of Pb and Zn in the vegetables ranged from 0.0018 to 0.0101 and 0.0001 to 0.0004 respectively, and were far less than 1 in both seasons. This reveal that the metals concentration, especially Pb and Zn in the vegetables is not posing any health risk at the moment and there is no potential health risk associated with their consumption for now. It is only THQ values greater than 1 that indicates there is health risk associated with the consumption of food or vegetables contaminated with a particular pollutant or heavy metal [11]. Therefore, the THQ values agree with the fact that the average concentrations of Pb, Zn, Hg and Ni in the vegetables in the study area are still low and within the permissible limits of FAO/WHO.

5. CONCLUSION

The data of this study have shown that Obudu Urban Area is contaminated with some heavy metals especially Pb and Zn at a very low concentration at the moment. The source of these metals may be from anthropogenic activities like indiscriminate disposal of water, quarrying activities, and probably vehicular emissions or immigration water sources in dry season among others. In addition, edible vegetables in the area have also accumulated some of these heavy metals, but at a low concentration that is still within the permissible limit of WHO and there is no health risk associated with their consumption for now. These is because the mean concentration of Pb and Zn in the vegetables were less than 0.1 $mgkg^{-1}$ and their THQ values were less than 1. Thus, one can recommend that the relevant government agencies like the State Ministry of Environment should monitor and evaluate the metal levels of the environment at regular intervals of 5 to 10 years and also advise the public, that growing vegetables in the soil where waste are disposed indiscriminately or old waste-dump sites may contaminate the vegetable and make them unsafe for food.

ACKNOWLEDGEMENT

I sincerely express my deepest gratitude to God Almighty, and Pastor Francis of the Department of Botany, University of Calabar, Calabar, for assisting us in finding the botanical names of the vegetables used for the study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://prh.sdiarticle3.com/review-history/25006