Original Research Article

HEALTH RISK ANALYSIS OF HEAVY METALS (Cr, Fe, Hg & Ni) IN EDIBLE VEGETABLES IN YALA URBAN AREA OF CROSS RIVER STATE, NIGERIA.

ABSTRACT

Aim: The aim of the study was to determine concentration of heavy metals in the soil and edible vegetables planted consumed Yala Urban Area of Cross River State, Nigeria, ascertained the level of metals contamination and the possible health risk or implication. **Sampling:** Forty eight (48) soil and edible vegetable samples (6 of each kind of the 8 vegetables) were collected randomly from Yala Urban Area of Cross River State. The eight vegetables considered for the study were *Amaranthus spp., Corchorus olitorius, Murraya koenigii, Ocimum grattissimum, Solanum melongena, Talinum triangulare, Telferia occidentalis* and *Vernonia amygdalina*. They were collected between January and March for dry season, and July and September for rainy season of the year. **Methodology:** The samples were digested and analyzed for the Cr, Fe, Hg and Ni (heavy metals) concentration using Flame Atomic Absorption Spectrometer (AAS) in the Chemistry Laboratory, University of Calabar. **Results:** The results showed that the mean concentration of the metals in the soil in $mgkg^{-1}$ ranged from (0.063 - 0.108) and (0.049 - 0.104) in rainy and dry seasons respectively for Cr, and (0.026 - 0.124) and (0.013 - 0.119) in rainy and dry season respectively for Fe. The mean concentration accumulated by the vegetables ranged from (0.037- 0.063) and (0.029 - 0.066) in rainy and dry season respectively for Cr and (0.012- 0.071) and (0.008- 0.086) in rainy and dry season respectively. Hg and Ni were neither detected in the soil nor in the vegetables. The trend of the metals in both the soil and vegetable was in the order: Cr > Fe> Hg> Ni. The Target Hazard Quotients were all less than 1, indicating no health risk. **Conclusion:** These results suggest that there is no significant difference between the amount of metals in the soil or that accumulated by the vegetables in rainy and dry seasons of the year. Also the amount of metals accumulated by most of the vegetables was directly proportional to the amount present in the soil where they are planted. These results indicate that the concentration of Cr, Fe, Hg and Ni in the soil and vegetables were still low and within the permissible limits of WHO/FAO. Thus, the consumption of the vegetables in the area may not pose any risk at the moment.

Keywords: Health risk analysis, Heavy metals, Consumption, Vegetables, Yala.

Introduction

A heavy metal has been described as a member of a loosely defined subset of elements that exhibit metallic properties (Wikipedia free encyclopedia). Examples of these elements are transition metals, some metalloids, lanthanides and actinides. According to Hardy [1], a heavy metal has a specific gravity of 5.0 or greater and is usually poisonous. The term heavy metal however, is often widely applied to include other potentially toxic elements even if they do not meet up with the apt chemical definition [1]. Chromium (Cr), Iron (Fe), Mercury (Hg) and Nickel (Ni) belong to this group of elements. Based on their toxic or poisonous effect at high doses and their contamination of food plants and animals when present in the soil or water environments, they have recently attracted the attention of many researchers worldwide as food safety and quality is a matter of public interest. Hence, several researchers have been carried out on heavy metals by researchers like Kanake [2, 3, 4, 5, 6, 7 & 8] etc. most of which were within the acceptable limits in their various localities to ascertain their food and environment quality/safety. Heavy metals are the major contaminating agents of our food and a problem of our environment [9].

Moreover, Khan [10] opined that the consumption of contaminated vegetables constitutes an important route for animal and human exposure to heavy metals. Halwell [11] earlier stated that the nutritional value of vegetables depends on the growing method and the quality of the soil because when vegetables are grown in contaminated soils, like those polluted with heavy metals; their nutritional value will be reduced as pollutants from the soil will be accumulated by the vegetables. Thus, vegetables should not be planted on soils contaminated with hazardous waste like heavy metals because they are nutritionally and medicinally valuable. Besides, the health of humans can be affected negatively when they consume these vegetables and accumulate these poisonous substances in high doses. Consequently, the aim of this study is to determine the concentration of some heavy metals (Cr, Fe, Hg and Ni) in the soil and edible vegetables in the study area (Yala) and ascertain the soil and vegetable quality with respect to heavy metal pollution.

Yala urban area is characterized with low land, plains and hills. The soil is well drain sandy loam in texture, which makes it suitable for agriculture. It has population of over 15 thousand people. Besides, the people are engaged in subsistence and commercial farming, growing rice, cassava, yam, cocoa in large quantities as well as vegetables for consumption as food and medicine. This often results in the use of insecticides, herbicides and other agrochemicals. By its location, it is a major link to the eastern and northern part of the country and most times experience heavy vehicular traffic. In addition, its major urban centre; Okpoma and the adjoining Okuku where Cross River University of Technology mini-campus is located have business centres, State and Local Government institutions among other urban features. Moreover, the inhabitants of the area practice rotational waste dump sites around their premises and later plant vegetables in old waste dump sites with a view to tap the compost manure for good yield even though wastes were disposed there indiscriminately. All these characteristics/features together with erosion during the rainy season make heavy metal contamination of the area inevitable. Hence, there is need to ascertain the edible vegetables and soil quality with respect to heavy metals pollution, and also evaluate the possible health risk associated their consumption.

Materials and Methods

Sampling and sample pre-treatment: forty eight soil samples and vegetables (with 6 of each vegetable) were collected randomly at different locations within Yala urban area at a distance of about 1km apart. The soil samples were collected at the root level of the vegetables at the depth of about 12 to 15 cm, using a hand trowel. At the same time, a handful of the edible vegetables were collected and wrapped separately with identification labels, and taken to the laboratory for further analysis. The edible vegetables considered for this study include: *Amaranthus spp* (Green vegetable), *Corchorus olitorius* (Ewedu), *Murraya koeningii* (Curry leaf), *Ocimium grattissimum* (scent leaf), *Solanum melongena* (egg plant leaf), *Telfairia occidentalis* (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 between January and March for the dry season and between July and September for the rainy season of the year. The vegetable samples were washed with distilled water and oven-dried at 80-85 ^{0}c for about 2 hours. Each dried sample was ground into powder, sieved with a 0.3 mm sieve and stored in a labeled plastic jar with cap. The soil sampled was also oven-dried, ground into powder and homogenized using pestle and mortar, sieved and stored in labeled plastic jars separately.

Digestion of samples: vegetable samples were digested following the procedure of one of the methods of the Association of Official Analytical Chemists (AOAC) as reported by Sobukola [12] thus: 1.0 g of each sample was put in a beaker and placed in a fume cupboard, 20 mL of concentrated (HCl), 10 mL of concentrated HNO_3 and 5 mL of H_2SO_4 were added. After digestion was complete, the beaker was heated in a fume cupboard for about 30 minutes. 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 of one of the methods of the Association of Official Analytical Chemists (AOAC) as reported by Akan [13] thus: 2.0 g of each soil sample powder was weighed into an acid washed beaker. 20 mL of aqua regia (mixture 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 supernatant liquid solution was used for heavy metal analysis.

Element Analysis: the soil and vegetable samples were analyzed for Cr, Fe, Hg and Ni using a VGP 210 BUCK Scientific Model of flame Atomic Absorption Spectrometer (AAS) at the following wavelengths: Cr (357.0 nm), Fe (248.0 nm), Hg (253.7 nm) and Ni (232.0 nm).

Calculations: the Target Hazard Quotient which is the ratio of the body intake dose of a pollutant to the reference dose was calculated thus:

$$THQ = \frac{DIVxCm}{RfDxB}$$

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 humans in kg, while RfD is the oral reference dose of the pollutant permissible and it is fixed by United States Environmental Protection Agency (US-EPA). **Note:** B is assumed by US-EPA to be 70kg for adult males and 60kg for adult females. For this study, 65kg (the average of 70kg and 60kg) was used for all adults, while the DIV was assumed to be 100g (0.1kg/day) per day. In some countries or places, up to 150 or 200g per day has been assumed especially for vegetarians. From the formula, THQ is a dimensionless parameter or ratio. According to US-EPA through Integrated Risk Information System-database IRIS [14], 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 RfD values for Cr, Fe, Hg and Ni from IRIS are 0.0003, 0.007, 0.001 and 0.01 $mgkg^{-1}$ respectively [14].

Statistical Analysis: The data collected was analyzed using SPSS version 20. The data were expressed in terms of descriptive statistics and figures were presented with mean values of triplicates. Significance test was also computed using paired t-test at $P < 0.05$ for dry and rainy season data in order to check whether there was any significant difference.

Results: The mean heavy metal concentration in $mgkg^{-1}$ (dry weight) in the soil and vegetables during the rainy and dry season have been presented in Tables 1 and 2 respectively, while the Target Hazard Quotients of the vegetables have been presented in Tables 4 and 5 for the both seasons. WHO/FAO permissible limits for the metals in soil, vegetables and medicinal plants are presented in Table 3.

Table 1: Mean concentration of Cd, Co, Cr, & Fe in mgkg^{-1} (dry weight) in the soil and vegetables during the rainy season in Obudu.

Vegetable	Cr	Fe	Hg	Ni
Amarathus spp	0.042±0.003	0.022±0.005	ND	ND
Soil	0.069±0.011	0.033±0.004	ND	ND
Corchorus olitorius	0.052±0.008	0.038±0.010	ND	ND
Soil	0.069±0.017	0.075±0.019	ND	ND
Murraya koenigii	0.054±0.004	0.017±0.003	ND	ND
Soil	0.063±0.014	0.027±0.004	ND	ND
Ocimumgratissimum	0.040±0.006	0.029±0.011	ND	ND
Soil	0.071±0.012	0.056±0.014	ND	ND
Solanum melongena	0.050±0.009	0.019±0.003	ND	ND
Soil	0.064±0.004	0.026±0.004	ND	ND
Talinum triangulare	0.037±0.007	0.071±0.019	ND	ND
Soil	0.084±0.027	0.124±0.014	ND	ND
Telferia occidentalis	0.063±0.022	0.029±0.011	ND	ND
Soil	0.108±0.004	0.056±0.012	ND	ND
Vernoniaamygdalina	0.072±0.012	0.012±0.002	ND	ND
Soil	0.105±0.036	0.026±0.004	ND	ND

Values reported in mean ± SD format with N=3, ND – Not Detected.

Table 2: Mean concentration of Cd, Co, Cr, & Fe in $mgkg^{-1}$ (dry weight) in the soil and vegetables during the dry season in Obudu.

Vegetable	Cr	Fe	Hg	Ni
Amarathus spp	0.035±0.005	0.019±0.001	ND	ND
Soil	0.066±0.013	0.030±0.002	ND	ND
Corchorus olitorius	0.048±0.008	0.036±0.010	ND	ND
Soil	0.070±0.019	0.072±0.019	ND	ND
Murraya koenigii	0.049±0.002	0.015±0.004	ND	ND
Soil	0.058±0.014	0.024±0.005	ND	ND
Ocimum grattissimum	0.037±0.005	0.025±0.009	ND	ND
Soil	0.066±0.011	0.052±0.007	ND	ND
Solanum melongena	0.046±0.008	0.015±0.004	ND	ND
Soil	0.060±0.012	0.027±0.003	ND	ND
Talinum triangulare	0.034±0.006	0.086±0.014	ND	ND
Soil	0.079±0.021	0.119±0.012	ND	ND
Telferia occidentalis	0.029±0.011	0.059±0.020	ND	ND
Soil	0.049±0.003	0.099±0.015	ND	ND
Vernonia amygdalina	0.066±0.011	0.008±0.002	ND	ND
Soil	0.104±0.026	0.013±0.005	ND	ND

ND- Not Detected, Values in mean ± SD format with N=3

Table 3: WHO permissible limits of heavy metals in soil, vegetables and medicinal plants in $mgkg^{-1}$.

Metal	Soil	Vegetables	Med. plants
Cr	**100**	**0.1-0.2**	**1.5**
Fe	**100**	**7.0**	**20**
Hg	**1.0**	**0.03**	**-**
Ni	**35**	**0.1**	**10**

Source: [15, 16 & 17]

Table 4: Target Hazard Quotients (THQ) of heavy metals in edible vegetables in Yala Urban area of Northern Cross River State in rainy season.

Vegetables	Cr	Fe	Hg	Ni

Amaranthus spp.	0.215	0.005	ND	ND
Corchorus olitorius	0.267	0.008	ND	ND
Solanum melongen	0.277	0.004	ND	ND
Murraya koenigii	0.205	0.006	ND	ND
Ocimumgrattissimum	0.256	0.004	ND	ND
Talinum triangulare	0.190	0.016	ND	ND
Telfairia occidentalis	0.323	0.006	ND	ND
Vernoniasamygdalina	0.369	0.003	ND	ND

Table 5: Target Hazard Quotients (THQ) of heavy metals in edible vegetables in Yala Urban area of Northern Cross River State in dry season

Vegetable	**Cr**	**Fe**	**Hg**	**Ni**
Amaranthus spp.	0.180	0.004	ND	ND

Corchorus olitorius	0.246	0.008	ND	ND
Murraya koenigii	0.251	0.003	ND	ND
Ocimum grattissimum	0.190	0.006	ND	ND
Solanum melongena	0.236	0.003	ND	ND
Talinum triangulare	0.174	0.019	ND	ND
Telfairia occidentalis	0.149	0.013	ND	ND
Vernonia amygdalina	0.339	0.003	ND	ND

Discussions: The results in Tables 1 and 2 showed that the mean concentration of the metals in the soil in $mgkg^{-1}$ ranged from (0.063-0.108) and (0.049-0.104) in rainy and dry seasons respectively for Cr, and (0.026-0.124) and (0.013-0.119) in rainy and dry season respectively for Fe. The mean concentration accumulated by the vegetables ranged from (0.037-0.063) and (0.029-0.066) in rainy and dry season respectively for Cr, and (0.012-0.071) and (0.008-0.086) in rainy and dry season respectively. Hg and Ni were neither detected in the soil nor in the vegetables in both seasons. The results also indicate that there is no significant difference between the concentration of metals in the soil and that accumulated by the vegetables in the rainy and dry season of the year. The availability of heavy metals in the soil for plants accumulation depends on several factors like P^H, soil texture, the chemical form of the metal etc. It has been proven by several researchers that the solubility of the cationic forms of the metals in the soil solution increases as the soil P^H decreases, and they become readily available for plants to accumulate [18, 19, 20, & 21]. Thus, acidic soils favour the accumulation of metals by vegetables than neutral or alkaline soils. The accumulation of Cr and Fe by plants is also higher in acidic soils due to their availability in such soils among other factors [22]. An earlier research in the study area by Free Library [23] has shown that the soil is quite acidic and porous with a pH range of 4 to 6. However, the concentration of Cr and Fe in the soil and that already accumulated by the edible vegetables is still very low and within the permissible limits of WHO/FAO as shown in Table 3. Besides, Hg and Ni were not detected in the soil or the vegetables. Therefore efforts has to be made by relevant government agencies to maintain this low concentration of the metals in the study area through public awareness of the effects of pollution and a periodic environmental monitoring and assessment of the metals concentration in the area.

Target hazard quotients: The results in Tables 3 and 4 reveals the Target Hazard Quotients (THQ) of the heavy metals in the edible vegetables in the study area (Yala) for the rainy and seasons respectively. These results indicate that the THQ values for Cr and Fe which were detected in the vegetables are far less than 1 for all vegetables in both seasons, especially Fe. This implies that the heavy metals concentration in the edible vegetables is not posing any risk and there is no potential health risk associated with their consumption for now.

According to US-EPA/IRIS [14], it is only THQ values greater than 1 that shows there is potential health risk associated with the consumption of food or vegetables contaminated with a certain pollutant or heavy metal. Thus, the THQ values also agreed with the fact that the mean concentrations of these metals in the vegetables are still low and within the permissible limits of WHO/FAO.

CONCLUSION

The results of this study have shown that there is some level of Cr and Fe in the soil, which have been accumulated by the edible vegetables in the area. The concentrations of Hg and Ni were not detected in the area and seem negligible at the moment. The level of the metals present in the soil and vegetable are still very low and within the permissible limits of WHO/FAO. Thus, the concentration of these metals in the edible vegetables may not pose any health risk at the moment.

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