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Concentration of Some Heavy Metals (Cd, Co, Fe & Hg) in Soil and Edible Vegetables in Ogoja Urban Area of Cross River State, Nigeria

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Abstract

The concentration of heavy metals (Cd,Co,Fe & Hg) in soil and some edible vegetables was determined during the rainy and dry seasons of the year, using Atomic Absorption Spectrometer (AAS) after the samples were digested. Forty samples of the eight edible vegetables and forty soil samples, where they were planted, were also collected at the root level of the vegetables. The eight most common edible vegetables considered were *Telfairia occidentalis, Amaranthus spp*, *Corchorus olitorius*, *Ocimum grattissimu*m (scent leaf), *Solanum melongena* (yellow garden egg leaf), *Talinum triangulare*, *Murraya koenigi* and *Vernonia amygdalina*. The result of the analysis revealed that Co and Hg were stringed variables as they were not detected in the soil or vegetables in both seasons of the year. Cd ranged from 0.005-0.043 $mgkg^{-1}$ in the soil and 0.005-0.042 $mgkg^{-1}$ for rainy and dry season respectively while Fe ranged from (0.015-0.051) $mgkg^{-1}$ and (0.019-0.050) $mgkg^{-1}$ for rainy and dry season respectively. The mean concentration of Cd accumulated by the vegetable ranged from 0.005-0.010 mgkg-^{1} in both seasons, while that of Fe ranged from (0.013-0.034) $mgkg^{-1}$ and (0.009-0.033) $mgkg^{-1}$ for rainy and dry seasons respectively. From the data, it shows that Fe was more in the soil than Cd, and it was also accumulated by the vegetables more than Cd. The metal's concentration in the vegetables is still low and within the permissible limits of FAO/WHO. The amount of metal accumulated is directly proportional to that in the soil. There is no significant difference between the results of the dry and rainy season. There is need to maintain this low level of heavy metals in the soil and vegetables through adequate awareness on the proper disposal of waste and environmental monitoring/evaluation by relevant agencies of the state.

Keywords: Heavy Metals, Concentration, Soil, Edible Vegetables

Introduction

Heavy metals' contamination of the environment has become a serious concerned to researchers world-wide, due to its effects on humans, plants and animals' health. Hardy et al. (2008) defined a heavy metal as a metal that has a specific gravity of 5.0 or higher, and it is usually poisonous. Heavy metals are a subset of elements that exhibit metallic properties, and these metals mainly include the transition metals, some metalloids, lanthanides and actinides (Wikipedia Free encyclopedia). Heavy metals are the major contaminating agents of our food. Contamination of seeds, plants and plant products at significant levels with toxic chemical elements due to contaminated soil and water, has been observed as a result of release of these toxicants into the sea, rivers, lakes and irrigation channels (Abdollatif et al., 2007; Khair, 2009). A vegetable is an edible plant or its part, intended for cooking or eating raw. Vegetables contain a great variety of other phytochemicals, some of which possess antioxidants, antibacterial, antifungal, antiviral and anticarcinogenic properties. They are eaten in a variety of ways as part of our main meals and as snacks. Their nutritional value ranges from little protein or fat to varying amounts of vitamins like Vitamin A, K and B6, provitamins, dietary minerals, fibre and carbohydrates (Wikipedia Free Encyclopedia). Therefore, vegetables are very significant to the health of man based on their nutritional and medicinal values. Smith (1996) stated that the growing of vegetables within and at the edges of cities is an aged-long practice. Most of these cultivated soils are contaminated with heavy metals resulting mainly from vehicular emissions, pesticides and fertilizers application, industrial effluents and other anthropogenic activities. These have resulted in the growth of contaminated vegetables (Jackson and Alloway (1993; Rattan et al., 2005; Sanayei et al., 2009). The consumption of contaminated vegetables constitutes an important route of animal and human exposure to heavy metals (Khan et al., 2009).

Ogoja is one of the Local Government Areas of Cross River State, with its administrative headquarters in Igoli, extending to Abakpa. This makes it almost a city as it is populated with Government Agencies, banks, schools, tertiary institutions, small and medium scale industries etc. It is also a place through which vehicles and people travelling to Northern Nigeria from Calabar metropolis, the Cross River State capital, pass through. This also makes it to have an appreciable amount of vehicular traffic.

The population of the people is about 120,000 people and it lies between latitude 6^0 39'and 7^0 34'N and longitude north of the equator 8^0 47' and 8^0 51' E. The area is characterized with hills, undulations, plains and streams. The people in their culture, like most Africans, practice rotational waste dumpsites within their premises or backyards. They later plant vegetables in old waste dumpsites with the view of tapping the compost manure from these dumpsites for their vegetable plants in order to improve the yield, yet indiscriminate waste are disposed in these dumpsites. Besides, 70% of the population engages in farming, growing rice, cassava, Yam and maize in subsistence and commercial quantity, making use of fertilizers, herbicides and other agrochemicals, as the need arises. All these activities make the release of heavy metals into the environment inevitable. Thus, there is need to investigate heavy metal concentration of the soil and vegetables consumed in this area to ascertain the environmental and vegetable quality in this regard to see whether the level of contamination, if any, is within the permissible limit of WHO or other regulatory agencies.

Materials and Methods.

Sampling and sample pre-treatment: forty soil samples and vegetables were collected randomly at different locations within Ogoja urban area and the closest neighborhood. The soil samples were collected at the root level of the vegetables at the depth of about 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 which were considered for this study and were planted in each of the forty soil samples include: *Amaranthus spp* (Green vegetable), *Corchorus olitorius* (Ewedu), *Murraya koeningii* (Curry leaf), Ocimium *grattissimum* (scent leaf), *Solanum melongena* (eggplant leaf), *Telfairia occidentalis* (pumpkin), *Talinum, triangulare* (water leaf) and *Vernonia amygdalina* (Bitter leaf). They collectively form a set of vegetables which are commonly used for food and for 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. The vegetable samples were washed with distilled water and oven-dried at 80-85^{0}c for about 2hours. Each dried sample was ground into powder, sieved with 0.3 mm sieve and stored in a labeled plastic jar with cap. The soil that was sampled was also oven-dried, ground into find powder and homogenized with pestle and mortar, sieved and stored in labeled plastic jars separately.

Digestion of samples: vegetable samples were digested following the procedure of Sobukola, et al. (2010). Thus, 1.0_g of each sample was placed in a beaker and 20cm^3 of concentrated (HCl), 10 cm^3 of concentrated HNO_3 and 5cm$_3$ of $H_2SO_{4,}$ were added. After volatiles were removed, 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 100cm^3 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 Akan et al. (2010). Thus, 2.0g of each soil sample powder was weighed into an acid washed beaker. 20cm^3 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. Then, the beaker was removed, allowed to cool, washed together with the watch glass using de-ionized water into a volumetric flask, and it made-up to 100cm^3 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 Cd, Co, Fe and Hg using Atomic Absorption Spectrometer (AAS) at the following wavelengths. Cd (228.9nm), Co (240.7nm), Fe (248.0nm) and Hg (253.7nm).

Calculations: the bioaccumulation ratio which is the ratio of the concentration of the heavy metal or pollutants in the vegetable shoot or leaf to its concentration in the soil (where the vegetable is planted), was calculated, thus:

Bioaccumulation Ratio = $\frac{C_m \text{ in plant}}{C_m \text{ in soil}}$

Cm in plant is the concentration of heavy metal (pollutant) in vegetable or plant, while Cm in soil is the concentration of the same metal in the soil.

Statistical Analysis: The data collected was analyzed using SPSS version 2.0. The data were expressed in terms of descriptive statistics and figures were presented with mean values of triplicates. The significance's test was computed using pair samples T-test at $P < 0.05$ for dry and rainy season data in order check the variation.

Results: The concentration of Cd, Co, Fe and Hg in the soil, and the eight vegetables for both the rainy and dry seasons, are presented in Tables 1 and 2 respectively.

Table. 1: Mean heavy metal concentration ($mgkg^{-1}$ dry weight) in soil and vegetables during the rainy season in Ogoja

Vegetables	Cd	Co	Fe	Hg
Amarathus spp	0.010± 0.002	ND	0.018 ± 0.003	ND
Soil	0.026± 0.005	ND	0.026 ± 0.010	ND
Corchorus olitorius	0.019± 0.002	ND	0.017 ± 0.004	ND
olitocorchorius rius	0.043± 0.003	ND	0.025 ± 0.006	ND
Soil				
murraya koenigii	0.018± 0.001	ND	0.014 ± 0.003	ND
soil	0.034± 0.012	ND	0.030 ± 0.007	ND
Occimum	ND	ND	0.015 ± 0.002	0.002
grattissimum	0.005± 0.003	ND	0.021 ± 0.005	
soil				
Solanun melongena	0.006±0.002	ND	0.024±0.004	ND
Soil	0.013±0.004	ND	0.015±0.002	ND
Talinum traingulare	ND	ND	0.008 ± 0.004	ND
Soil	0.005± 0.001	ND	0.031 ± 0.002	ND
Telfaira occidentalis	0.012± 0.001	ND	0.034 ± 0.004	ND
Soil	0.028± 0.003	ND	0.051 ± 0.004	ND
Vernonia amygdatina	0.010± 0.002	ND	0.051 ± 0.004	ND
Soil	0.019± 0.002	ND	0.013 ±0.004	ND

Note: ND = Not Detected and values reported in mean x S.D with N = 3.

Table 2: Mean concentration heavy metals in ($mgkg^{-1}$ dry weight) in soil and vegetables during the dry season in Ogoja

Vegetables	Cd	Co	Fe	Hg
Amaranthas spp	0.010± 0.002	ND	0.021 ± 0.002	ND
Soil	0.022± 0.003	ND	0.027 ± 0.002	ND
Corchorius olitorius	0.016± 0.001	ND	0.017 ± 0.004	ND

soil	0.042± 0.004	ND	0.021 ± 0.003	ND
Murraya koenigu	0.009± 0.001	ND	0.012 ± 0.003	ND
soil	0.027± 0.006	ND	0.028 ± 0.002	ND
Ocimum	ND	ND	0.014 ± 0.003	ND
grattissimum	0.007± 0.003	ND	0.021 ± 0.002	0.003 ± 0.001
soil				
Solanun melongena	0.005±0.003	ND	0.018±0.008	ND
Soil	0.011±0.003	ND	0.028±0.002	ND
Talinum triangulare	ND	ND	0.009 ± 0.002	ND
Soil	0.005± 0.002	ND	0.020 ± 0.002	ND
Telfaira occidentalis	0.011± 0.002	ND	0.033 ±0.007	ND
Soil	0.027± 0.002	ND	0.050 ± 0.003	0.002 ± 0.001
Vernonia	0.007± 0.002	ND	0.009 ± 0.004	ND
amygdalina	0.018± 0.002	ND	0.019 ± 0.002	ND
Soil				

Note: ND = Not Detected and values reported in mean ± SD with N = 3.

Table: 3 Bioaccumulation ratios of heavy metals in vegetates during rainy season

Metal	*Amaranthus Spp*	*Corchorus olitorius*	*Murraya koenigii*	*Ocimum grattissimum*	*Solanum melongena*	*Talinum Triangulare*	*Telfaira occidentalis*	*Vernonia amygdalina*
Cd	0.385	0.442	0.529	ND	0.462	ND	0.428	0.526
Co	ND	ND	ND	ND	ND	ND	ND	ND
Fe	0.692	0.680	0.467	0.714	0.774	0.533	0.667	0.591
Hg	ND	ND	ND	ND	ND	ND	ND	ND

Note: ND= Not Detected

Table 4: Bioaccumulation ratios of heavy metals in vegetables in dry season

Metal	*Amaranthus Spp*	*Corchorus olitorius*	*Murraya koenigii*	*Ocimum grattissimum*	*Solanum melongena*	*Talinum Triangulare*	*Telfaira occidentalis*	*Vernonia amygdalina*
Cd	0.455	0.381	0.333	ND	0.455	ND	0.407	0.389
Co	ND	ND	ND	ND	ND	ND	ND	ND
Fe	0.778	0.810	0.429	0.667	0.643	0.450	0.660	0.474
Hg	ND	ND	ND	ND	ND	ND	ND	ND

Note: ND = Not Detected

Discussion

The results in Tables 1 and 2 shows that there is a certain level of heavy metals' concentration in the study area, especially Cd and Fe; Co and Hg, were not detected in the soil or the vegetables. There is no significant difference between the heavy metals' concentration, both in the soil and in the vegetable for both seasons. This indicates that the sources of heavy metals may sometimes not be from air pollution sources like vehicular emissions or irrigation water sources used during the dry season. Rather, it shows that their sources may also be from other anthropogenic sources like indiscriminate disposal of waste-containing metals, industrial wastes and leachate from auto mechanic workshops which are often transported by erosion during rainy season among other means and are made available for accumulation by the vegetables planted near these sources or those planted directly on old waste-dumpsites with the aim of taping compost manure for increased yield. However, the concentration of heavy metals in the area is still within the permissible limit of WHO, especially for Cd and Fe, which the limits are 0.1mgkg^{-1}.

Corchorus olitorius accumulated the highest level of Cd (0.019mgkg-t) at the soil level of 0.043mgkg^{-1} in rainy season and 0.016mgkg-t of Cd at the soil level of 0.043mgkg^{-1} in the dry season Solanum melongena accumulated the lowest level of Cd (0.006mgkg^{-1}) at the soil level of 0.013mgkg^{-1} in the rainy season and 0.005mgkg^{-1} of Cd at the soil level of 0.011mgkg^{-1} in the dry season. *Ocimum grattissimum* and *Talinum triangulare* could not accumulate detectable levels of Cd in both seasons at soil level of 0.005mgkg^{-1}. The concentration of Co in the soil and that accumulated by the vegetables was not detected in both seasons. This shows that it was still negligible or insignificant in the environment. *Telfaira occidentalis* accumulated the highest amount of Fe (0.034mgkg^{-1}) at the soil concentration of 0.051mgkg^{-1} in the rainy season and 0.033mgkg^{-1} of Fe at the soil level of 0.050mgkg^{-1} in the dry season while *Talinum triangulare* accumulated the lowest amount of Fe (0.008mgkg^{-1}) with a soil concentration of 0.015mgkg^{-1} in the rainy reason and 0.009mgkg^{-1} at a soil concentration of 0.020mgkg^{-1}. Hg amount in the soil and that accumulated by the vegetables was not detected in both seasons. These results revealed that the concentration of metals accumulated by the vegetables in both seasons were directly proportional to the concentration present in the soil where the vegetables were planted. The bioaccumulation data in Tables 3 and 4, shows that all vegetables in the current study accumulated less than 50% of Cd present in the soil, except *Murraya koenigii* and *Vernonia amygdalina* during the rainy season while in the dry season, all vegetables accumulated Cd less than 50% in the soil.

For Fe, all vegetables accumulated more than 50% of Fe in the soil in the rainy season, except *Muraya Koenigii* while in dry season; all the vegetables accumulated more than 50% of the soil concentration of Fe, except *Muraya Koenigii* and *Vernonia anygdalina*. This shows that the chemical form of Fe in the soil was more available to the vegetables than that of Cd. This also shows that the bioavailability of metals to plants depends on certain factors like soil PH, soil texture or porosity and the degree of metal mobility in the soil. Ngole (2011) has reported that the concentration of most metals like Mn, Fe, Zn etc, increases in solution with a decrease in soil PH (i.e increase in soil acidity) and soil PH is the greatest determinant of the solubility and mobility of metals like Cr, Pb and Zn. Based on previous researches in the study area (Ogoja), especially the Free Library (2014), it was reported that the soil in Ogoja and its environs is porous, sandy, leached in most places due to high rainfall and that the soil PH ranges between 4.0 to 6.0 in most places. This shows that the soil is quite acidic and could be favorable for heavy metals mobility and uptake by plants or vegetables, depending on their concentration in the soil. However, the variation of these factors from place to place could be responsible for the differences in their bioaccumulation ratios in different vegetables.

Conclusion

From results of the study, it has been observed that the area under the current study has been contaminated by the presence of some heavy metals to some extent, and the edible vegetables in the area have accumulated some of these heavy metals, especially Cd and Fe but the concentration is still low and within the permissible limits of FAO/WHO. A major source of these heavy metals is from anthropogenic activities like indiscriminate disposal of wastes containing heavy metals quarrying activities, fertilizer, insecticides, herbicides application. The observation made in the current study is that there is no significant difference between the results of the rainy season and the dry season to attribute some of the courses to air pollution sources like vehicular emissions or even irrigation water in dry season.

Though the level of heavy metals (Cd, Co, Fe & Hg) in the soil and vegetables is still low, efforts have to be made by stakeholders and all concerned persons in the area to maintain this low level by adopting environmental best practices and creating awareness of the health hazards associated with heavy metals being accumulated by humans and animals at high concentrations through food or vegetables grown on contaminated soils.

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