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Evaluation of Heavy Metal Content of Green Leafy Vegetables Grown in Farms along Orogodo River in Agbor Metropolis, Delta State, Nigeria

*[1]Amitaye, A.N. and [2]Okwagi, P.
[1]Department of Chemistry, School of Basic Sciences, Nigeria Maritime University, Delta State, Nigeria
[2]Department of Chemistry, College of Education, Agbor, Delta State, Nigeria
*iupac.azuka@yahoo.co.uk

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ABSTRACT

Vegetables are good sources of essential vitamins and nutrients. Vegetables are vital component of family diet in Agbor metropolis hence, its high demand. Since plant materials are known to uptake heavy metals from environmental media (soil and water), it is therefore necessary to determine the levels of heavy metals in green leafy vegetables obtained from two farms: site 1 and 2, to ascertain the health risks associated with their consumption. Three (3) common leafy vegetables (pumpkin, Ujuju and water leaves) were selected based on their market demand and popularity among the residents. The vegetable samples were collected in the months of May, July and August 2017 and analysed for cadmium (Cd), lead (Pb), chromium (Cr) and nickel (Ni) using Atomic Absorption Spectrophotometer (AAS). The results of the determinations were in the range of 0.01 ± 0.01 to 0.09 ± 0.02 mg/kg, 0.11 ± 0.02 to 0.18 ± 0.03 mg/kg, 0.06± 0.02 to 0.21 ± 0.05 mg/kg, and 0.08 ± 0.02 to 1.34 ± 0.03 mg/kg for Cd, Pb, Ni, and Cr respectively. Water leaf plant had the highest amount of Cd (0.09 mg/kg and 0.07 mg/kg), Cr (1.34 mg/kg and 1.28 mg/kg), and Pb (0.18 mg/kg and 0.21 mg/kg) among the studied vegetables from sites 1 and 2 respectively. Cd, Pb, Cr, and Ni concentrations are below permissible limits by FAO/WHO. The hazard quotients associated with Cd, Pb, Cr, and Ni were below unity for adults and children indicating that all the vegetables are safe for human consumption.

1. INTRODUCTION

Heavy metals contamination and pollution have been reported in water (Amitaye, 2014), soil (Sharma, 2006), food (Wong, 1996) and food (Kalagbor and Ditri, 2014; Amitaye and Uche, 2016) and in the atmosphere (Manahan, 2005) at varying concentrations. Food stuff contamination by heavy metals has been reported in different parts of the world. Lead (Pb) levels of 0.01 ppm for beverage drink and 0.04 ppm for dairy product in Canada were reported by (Adraiano, 1984) while cadmium (Cd) level of 0.06 ppm and lead (Pb) level of 0.06 ppm for dairy products were reported in Poland (Pogorzelski et al., 1987). Cd level of 0.07 ppm and Pb level of 0.59 ppm in chicken eggs from Ibadan, Nigeria had been reported by (Fakayode and Olu-Owolabi, 2003). Also, trace levels of cadmium, lead, and nickel had been reported in chicken meat in Port Harcourt, Nigeria (Oforka et al., 2012). The contamination of these poultry products with heavy metals result from the type of feed brand and water the chickens consumed (Amitaye and Uche, 2017).

Plants species obtain nutrients either directly or indirectly from soil, and may uptake heavy metals along with nutrients if the soil had been contaminated and/or polluted with heavy metal(s) (Xiong, 2008; Amitaye and Uche, 2016, 2017). This has been confirmed from various studies on heavy metal uptake by plant species. Cadmium (Cd) was taken up by *Zea mays* seedlings cultivated in cadmium contaminated soil as reported by (Amitaye and Uche, 2017). However, the distribution of heavy metals in plants is modulated by factors such as metal concentration and the plant species (Amitaye and Uche, 2016). Empirical studies have revealed that some common vegetables are capable of accumulating high levels of metals from soil (Xiong, 2008; Uwah et al., 2009). Certain species of *Brassica oleracea* (cabbage) are hyper-accumulators of heavy metals in their edible tissues (Xiong, 2008). So, there is high propensity for man and other animals to become contaminated via consumption of contaminated food materials, especially of plant sources. It is therefore inevitable for human beings and other living organisms within a given ecosystem to get contaminated with heavy metals along their cycles of food chain (Okoye et al., 2011).

Heavy metals are broadly classified into essential [copper (Cu), chromium (Cr), nickel (Ni), selenium (Se), and zinc (Zn)] and non-essential [cadmium (Cd), lead (Pb), mercury (Hg) metals (Alloway, 1995; Wagner and Boman, 2003). The non-essential metals are toxic and harmful to human health even at trace concentrations. The non-essential metals play no useful role in metabolic processes in plants and animals (Jarup et al., 1998). However, their relevance stem from their hazardous effects on biotics and the environment. These metals have long half-lives and can bioaccumulate in living systems to exert deleterious effects on man, plants and animals. For this, cases of disorders, and malfunctioning of organs due to metal toxicity have been reported in humans and other animals (Jarup et al., 1998). Decline in crop productivity indices have also been reported in some plant species such as *Zea mays* by Amitaye and Uche (2016, 2017).

Toxic metal ingestion by human can directly or indirectly damage the Deoxyribonucleic acid (DNA) which may result in cancer (Jacob et al., 2013). Also, birth defects as well as impaired organ functioning have been reported in human beings that consumed metal contaminated food materials (Ademoroti, 1996; Sharma, 2006). It is therefore important to monitor heavy metal distribution in food materials in order to ascertain their safety for human consumption.

As a veritable source of vitamins, protein, carbohydrate, dietary fibres, and minerals, leafy vegetables occupy a very important place in the human diet. Vegetables are the edible parts of herbaceous plants such as leaves, stems, roots, flowers, seeds, and fruits that are consumed raw or cooked as part of main dish or salad. Vegetables have good antioxidant activities hence, help in detoxification of the human body systems (Yargholi and Azimi, 2008). They are rich sources of vitamin C (Hough et al., 1982; Amitaye, 2017), carotenoids, and provitamin A (Asiwe, 2017). Also, they have hypoglycemic (sugar reducing) effect hence, essential for diabetics (Yargholi and Azimi, 2008). However, the preference for vegetables depends on gender, age, cultural background as well as the geographical location of consumers (Jansen-Van-Rensberg et al., 2004).

Like other plant materials, vegetables have the ability to uptake or absorb heavy metals through contaminated soil, irrigation water (Thilini et al., 2014) and metals deposited on plant surfaces exposed to the polluted environments (Sharma et al., 2009). Metal concentrations in four leafy vegetables sold in markets at Abraka town, Delta state have been investigated by Agbogidi and Erhenhi (2013) while Aiwonegbe and Ikhuoria (2007) have reported the levels of heavy metals in root and leafy vegetables grown in Benin city, Edo state.

The concentrations of heavy metals in fruits and leafy vegetables in Lagos were reported by Sobukola et al (2010).

Since no empirical studies has been done to ascertain heavy metal content of green leafy vegetables from Agbor metropolis, Delta state, this study is therefore, set out to determine the levels of cadmium, chromium, nickel, and lead in green leafy vegetables from some local farms and asses their hazard quotient for adult and children.

2. MATERIALS AND METHODS

2.1. Study Area

The Agbor metropolis is geographically located at latitude 6°16' North and longitude 6°9' East. The area is laterite-rich with good loamy soil for agricultural productions. Agbor metropolis is a densely populated with people from all works of life, including students from Delta State College of Education and the Delta State school of nursing (Anigboro et al., 2011). Majority of persons in the metropolis are farmers with some civil servants and traders. The topography is undulated with settlements within its sloppy and hilly axes. Because of good soil fertility, larger majority of populace are farmers. Also, green leafy vegetables are well sought after among residents in Agbor metropolis. Therefore, it is necessary to examine the vegetables for some common environmental contaminants such as heavy metals.

Two sites under vegetable cultivation were selected on the basis of proximity to main market and scale of vegetable productions. Both sites are situated in the Northern part of Agbor metropolis and also, less than 1 km from the Orogodo river. Site 1 is along Agbor-Asaba road while site 2 is along the new Agbor-Abraka road, just by Musa slaughter. Site 2 is about 2 km downstream from site 1.

2.2. Sample Collection

Three (3) green leafy vegetables were selected based on their market demand and popularity among residents in Agbor metropolis. The three samples are Ujuju (*Myrianthus arboreus)*) Pumpkin (*Telfairia occindentalis*) and water leaves (*Talinum triangulare*). The samples were collected in the months of May, July and August 2017. The samples were collected separately in triplicate. They were brought to the laboratory and wrapped in absorbent paper after sufficient washing with distilled water and initial air-drying. The samples were treated and digested at Chemistry Laboratory, Delta State College of Education, Agbor. Extraction and determination of metals were done in the Post Graduate Laboratory, Department of Chemistry, University of Benin, Edo state by standard methods (APHA, 1998).

2.3. Sample Treatment and Metal Determination

The vegetables were cut with a sterile knife into leafy and stem portions. Subsamples (each of 1 kg) of the leafy parts were processed for analysis by the dry-ashing method. The samples were first oven-dried at 105 °C for 8-hours until the leaves brittle. The dried leaves were then powdered manually in a mortar. The powdered samples (14g each), with three replicates taken for each vegetable, were correctly weighed and placed in a silica crucible, and few drops of concentrated nitric acid (HNO_3) were added to the sample to increase ashing rate. The dry-ashing process was performed in a muffle furnace by gradual increase of the temperature up to 550 °C and holding at this temperature for 6-hours (Crosby, 1977). The ash was allowed to cool in desiccators. The cooled ash was then rinsed with 3 M hydrochloric acid. The ash suspension was filtered into a 50 ml volumetric flask through Whatman No. filter paper, and the volume was made up to the mark with 3M hydrochloric acid. The filtrate (each of the samples) was extracted to obtain individual metals and then measured using standard hollow cathode lamps for Pb, Ni, Cd and Cr of an Atomic Absorption Spectrophotometer (Bulk Scientific VAP 210) (Hough et al., 1982). The detection limit of the analytical method for each metal was calculated as being triple the standard deviation of a series of measurements for each solution, the concentration of which is distinctly detectable above the background level (Elbagermi et al., 2012).

2.4. Analyses

2.4.1. Metal pollution index (MPI)

Assessment of overall load of heavy metals in each vegetable growing at each site was made by computing the metal pollution index (Usero et al., 1997). It was calculated as the geometric mean of concentration of all heavy metals in the edible portion of plant, as expressed in Equation 1.

$$\text{MPI (mg/kg)} = (C_1 \times C_2 \times C_3)^{1/n} \quad (1)$$

Where Cn = Concentration of heavy metal n in sample

2.4.2. Hazard quotient

The risk associated with consumption of contaminated food can be assessed using hazard quotient (US EPA, 1989). Hazard quotient for adults (male and female) and children (below 3years) associated with the intake of metals along with vegetables from experimental sites was assessed using Equation 2:

$$\text{Hazard quotient (HQ)} = \frac{D \times C_{metal}}{RfD \times BO} \quad (2)$$

Where:

D = Daily intake of food (kg/day)
C_{metal} = Concentration of metal (mg/kg)
RfD = Reference oral dose of metal (mg/kg of body weight/day)
BO = Body weight (kg)

For the present study, daily requirement or intake of vegetables was taken as 0.1 kg for adults, as this is the minimum vegetable requirement for a balanced diet. Daily intake of vegetables for children below 3 years was taken as 0.005 kg (National Institute of Nutrition, 2011). The average body weight for adult male was taken as 55 kg and average body weight of female as 45 kg and of children (below 3 years) is 12 kg (Indian Council of Medical Research, 2010).

3. RESULTS AND DISCUSSION

The results showed that all the studied metals were present at varying levels in the vegetables. The levels of metal contamination ranged from 0.01 to 1.34 mg/kg in the vegetables. The results are comparable to those reported at some markets in Lagos state. The heavy metals in the vegetables (from Lagos) fall in the range of 0.09 ± 0.01 to 0.21 ± 0.06 mg/kg for Pb; 0.03 ± 0.01 to 0.09 ± 0.01 mg/kg for Cd; and 0.02 ± 0.01 to 0.07 ±0.01mg/kg for Ni (Sobukola et al., 2010).The concentrations of Nickel (0.19 mg/kg) and lead (0.13 mg/kg) in spinach from some selected markets in Benin city as reported by (Aiwonegbe and Ikhuoria, 2007) were also comparable to those obtained in the present study; though the cadmium concentration (0.12 mg/kg) in the spinach was much greater compared to the value obtained in the present study (0.01-0.09 mg/kg).

Table 1: Mean concentration of heavy metals and the metal pollution index of green leafy vegetable from site 1

Vegetable type	Mean metal concentration (mg/kg)				Metal pollution index
	Chromium (Cr)	Cadmium (Cd)	Lead (Pb)	Nickel (Ni)	(mg/kg)
Pumpkin leaf (*Telfairia Occindentalis)*	0.08± 0.02	0.04± 0.01	0.13± 0.02	0.18± 0.03	0.093
Water leaf *(Talinum triangulare)*	1.28± 0.02	0.07± 0.01	0.21± 0.02	0.08± 0.01	0.197
Ujuju leaf *(Myrianthus arboreus)*	1.10± 0.02	0.01± 0.01	0.14 ± 0.01	0.06± 0.02	0.098
WHO/FAO permissible limits	2.30	0.02	0.03	4.00	0.273

Table 2: Mean concentration of heavy metals and the metal pollution index of green leafy vegetable from site 2

Vegetable type	Mean metal concentration (mg/kg)				Metal pollution index
	Chromium (Cr)	Cadmium (Cd)	Lead (Pb)	Nickel (Ni)	(mg/kg)
Pumpkin leaf (*Telfairia Occindentalis)*	1.00± 0.01	0.05± 0.01	0.11± 0.02	0.21± 0.05	0.184
Water leaf *(Talinum triangulare)*	1.34± 0.03	0.09± 0.02	0.18± 0.03	0.10± 0.02	0.216
Ujuju leaf *(Myrianthus arboreus)*	1.21± 0.01	0.01± 0.01	0.12± 0.02	0.10± 0.03	0.110
WHO/FAO permissible limits	2.30	0.02	0.03	4.00	0.273

Uptake and distribution of heavy metals by some plant species have been reported by Amitaye and Uche (2016). The different levels of metal in the vegetables revealed their varied uptake efficiencies and distribution. The variation in uptake of metals with respect to different vegetables is because of difference in morphology, variation in translocation of aqueous solution in plant, difference in physiological indices of different crops (Sharma et al., 2016). Water leaf had the highest amount of Cd (0.07 mg/kg and 0.09 mg/kg), Cr (1.34 mg/kg and 1.28 mg/kg), and Pb (0.18 mg/kg and 0.21mg/kg) among the studied vegetables from sites 1 and 2 respectively. The nickel content of pumpkin leaf plant was the highest with values of 0.18 mg/kg and 0.21 mg/kg at sites 1 and 2 respectively. It shows that water leaf plant has greater propensity to uptake chromium, cadmium, and lead than pumpkin and Ujuju leaf plants. This implies that Water leaf has good uptake efficiency for chromium, cadmium, and lead. All these contributed to the high metal pollution index of water leafy plant (Tables 1 and 2). The uptake pattern of heavy metals by vegetables was found to be similar in the two sites. In the two sites, the uptake of metals exhibited the following trend: Cr > Pb > Ni > Cd. This trend was found to be different from previous studies investigating heavy metals in vegetables (Arora et al., 2008; Singh et al., 2010; Sharma et al., 2016).

On the other hand, Ujuju leaf plant had the lowest uptake potential for cadmium from both sites. The pumpkin leaf was also contaminated with Cd, Pb, Ni and Cr but the levels of these metals in all the studied vegetable are below the allowable limits set by FAO/WHO (1999). Therefore, these vegetables are safe for consumption in the short run. These plants might take up heavy metals by absorption from airborne deposits on the parts of the plants exposed to the air from the polluted environment (Elbagermi et al., 2012) as well as from irrigation with contaminated water (Al-Jassir et al., 2005).

Metal pollution in the vegetable samples was estimated using metal pollution index. The MPI of these vegetables (from sites 1 and 2) are similar and the value obtained was less than unity and the World Health

Organisation's MPI value (0.273mg/kg) for the studied metals (Tables 1 and 2). However, the MPI of vegetables from site 2 (which is downstream from an abattoir) was greater than the MPI of vegetables from site 1. The MPI of water leaf plant was found to be maximum. The general trend of pollution index from sites 1 and 2 was water leaf > pumpkin leaf >Ujuju leaf.

Table 3: Hazard quotient of cadmium, lead, chromium and nickel of different leafy vegetables from site 1

Vegetable	Man				Woman				Children			
	Cd	Pb	Cr	Ni	Cd	Pb	Cr	Ni	Cd	Pb	Cr	Ni
Water leaf	0.127	0.095	0.387	0.007	0.150	0.116	0.474	0.008	0.029	0.022	0.080	0.003
Pumpkin leaf	0.072	0.059	0.024	0.016	0.080	0.072	0.030	0.020	0.016	0.014	0.005	0.004
Ujuju leaf	0.018	0.063	0.300	0.005	0.020	0.070	0.407	0.006	0.004	0.015	0.076	0.001

Table 4: Hazard quotient of cadmium, lead, chromium and nickel of different leafy vegetables from site 2

Vegetable	Man				Woman				Children			
	Cd	Pb	Cr	Ni	Cd	Pb	Cr	Ni	Cd	Pb	Cr	Ni
Water leaf	0.163	0.081	0.406	0.009	0.200	0.100	0.496	0.001	0.038	0.019	0.093	0.002
Pumpkin leaf	0.090	0.050	0.300	0.019	0.100	0.061	0.370	0.023	0.021	0.011	0.069	0.004
Ujuju leaf	0.018	0.054	0.360	0.009	0.020	0.060	0.448	0.010	0.004	0.013	0.084	0.002

The health risk associated with any pollutant depends on the degree of exposure and absorption by human body (Sharma et al., 2016). Hazard quotient was used to ascertain the level of risk associated with particular pollutant. If the hazard quotient is less than unity (1), the risk associated with exposure of heavy metal is negligible but if the level of hazard quotient is greater than unity, the heavy metal may pose serious health hazards. Hazard quotient of cadmium was found to be maximum in water leaf samples from both studied sites for the vegetables. The hazard quotient of chromium was the highest among the studied metals hence the propensity for chromium poisoning would be more likely than other metals. All the hazard quotients associated with Cd, Pb, Cr, and Ni was below unity in all the vegetable samples for adults and children (Tables 3 and 4) and as such pose no serious health hazards. Thus, these vegetables are safe for consumption.

4. CONCLUSION

Based on the results, the following conclusions were made:

i. That the concentrations of the metals of interest were below the permissible limits set by FAO/WHO in all the vegetable samples analysed.

ii. The health risk associated with Cd, Pb, Ni, and Cr in water leaf, pumpkin leaf and Ujuju leaf plants is negligible.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

6. ACKNOWLEDGEMENT

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