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Heavy Metal Contents in Soil and Leaf with Relative Bioaccumulation Factor of Selected Locations at Awka, Nigeria

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ABSTRACT

Heavy metals are bioaccumulated and biotransferred by both natural and anthropogenic means. Heavy metal contamination in Soils and plants is one of the main issues in the entire globe which needed urgent attention because heavy metals above their normal limits are extremely hazardous to both plant and animals. Thus, this study was designed to evaluate the level of concentration of heavy metals in agricultural soils and vegetable (*Telfairia occidentalis*) grown on the soils in five different villages (Okpuno, Amawbia, Isu aniocha, Ifite-Awka and Amansea) within Awka capital territory, Anambra state, Nigeria. The samples of both the leaf and soil samples were collected from 5 different locations and were prepared, digested and the heavy metal concentration were determined using Atomic Absorption Spectroscopy (AAS 500 Model). The result obtained showed that the mean concentration of the toxic metals in the soil were in the decreasing order: Cr>As>Fe>Se>Ni>Hg>Pb>Cd, while the mean metal concentration in vegetable samples were in this decreasing order: Cr>Fe>Se>Ni>Cd>Pb>As>Hg. Chromium metal had the highest concentration in all the studied agricultural soils. Moreover, Cr metal also had the highest concentration in the vegetable samples in all locations except for that of Okpuno. The leaf samples had significant difference in the transfer factors of metals relative to the availability of same metals in the soil. The TF ranged from 0.000 to 9.98. The peak TF (9.98) of Se metal were observed in Amansea followed by 8.86 of Iron (Fe) obtained in Amawbia and the least (0.000) of Lead (Pb) were observed in Isu-Aniocha and also that of Nickel that were observed both in Ifite-Awka and Amansea. The study observed that the concentration of heavy metals in the sampled agricultural soils from different locations and the vegetable samples were lower than the WHO permissible limits except the mean concentration of Cd that were above the limit in vegetable samples and all the agricultural soils from the 5 different locations. This also suggests that at present, the health effect from the consumption of *Telfairia accidentalis* is very minimal in the sampled locations because of the low concentration of heavy metals in most of the sampled agricultural soils and vegetables. However, continuous exposure to these heavy metals to local residents in the sampled areas may cause serious health implications.

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Introduction

Environmental pollution by heavy metals is major global concern in the society today. These metals pose some serious health concerns to all living things including human beings in particular when accumulated in high concentration that is above body requirements [1]. Heavy metals contamination is found not only in agricultural soil, but also in living tissues and also most dangerous pollutants owning to their accumulation in crops [2]. Rapid industrialization and diverse anthropogenic activities have been a major cause of the increasing in the release of toxic metals into various environmental matrices [3]. Soils are also contaminated by toxic elements either by natural sources such as bedrock weathering, volcanic eruption and atmospheric deposition [4,5] or through anthropogenic sources such as waste deposits, agricultural inputs [6-8], Industrial and urban emissions, metallurgical processes, mining activities (Ahmed and Jianhua, 2014), gasoline combustion exhausts and lubricating oil spills from auto-mobile workshops and petrol filling, inappropriate waste management, fossil fuel combustion etc which in turn affects food quality [9]. Most heavy metals have generally high toxicity at low concentration, long residence times (often exceeding decades), and persistent bioavailability. [10]. They could also be dangerous to human health and ecosystem at low level due to their ubiquity, toxicity and persistence [11]. Human exposure to potential toxic elements is an issue of great concern [12]. Chronic dietary intake of metals/metalloids above their safe threshold for humans and animals may cause both carcinogenic and non-carcinogenic effects (Liu et al, 2013). Heavy metals such as Fe, Se, Cu, Zn, helps in many metabolic processes in the human body system. However, when their concentrations exceed certain limits, they may act as toxic metals [13]. Moreover, other metals such as Cd, As, Hg, Pb, etc have no known benefit to the body and are also toxic even at low concentration and there is no known homeostasis mechanism for them [14]. Mercury (as Methyl mercury) and Pb have most critical effects on nervous system, Cd have critical effects on several organs such as liver, lungs, kidney, bones, brain etc. while Arsenic (Inorganic forms) are classified as carcinogenic and also affects the skin, vascular and nervous system [13]. Pb, Cr, As, Cd can also cause a series of chronic effects and can also damage the nervous and immune systems as well as having health detrimental effects such as lung cancer, kidney and liver dysfunction and bone fractures thereby contributing to decreased human life expectancy by 9-10 years

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within the affected areas [15-17]. Globally, several studies on toxic metal contamination and pollution on agricultural soils and plants as well as its ecological and health risk assessments have been reported for many years [18,1,2,19-21]. Food is a major source of heavy metal intake by humans [9]. Vegetables absorb trace metals and accumulate them in their parts at amount high enough to cause health problems to both humans and animals that consumed the vegetables [22].

Heavy metal absorption by plants is dependent on multiple factors such as constituents of soils, capacity to exchange cations, organic matter, pH of soil, and species of plant and its age [17]. *Telfairia occidentalis* is a tropical edible greenish leafy vegetable that is grown in Nigeria and other Western African countries. It is commonly known as Fluted pumpkin leaf, Ugu in Igbo language, Okwukwo- wiri in Ikwerre language, Ikong-ubong in Efik but are mainly cultivated in Southeastern Nigeria and it is used primarily in soups and herbal medicine [23]. It contains nutrients like calcium, iron, potassium, manganese, vitamin C, A, B2, E. The leaves also contain oleic acid, alkaloids, tannins and linoleic acid which make it a local treatment in the treatment of infertility in both males and females [23]. In Awka metropolis, agricultural lands from different farmlands are of diverse sources, contents and properties. The extents of heavy metal contamination in different area of Awka, capital territory of Anambra state, southeast Nigeria are not well studied. The farmlands are suspected to be contaminated but never previously studied. The current study was aimed at determining the concentrations of heavy metals such as AS, Hg, Pb, Cd, Cr, Co, Se, and Fe in both different agricultural soils and vegetables (*Telfairia occidentalis*) that are grown on the soils within Awka metropolis. This study was designed to study the transfer factor of the toxic metals from the soil to the vegetable and health risk analysis.

Materials and Methods

Study Area

The selected study area is situated in Southeast Nigeria which lies between the mangrove forest and Guinea savanna. It is located at latitudes 6^0 12'25"N and Longitudes 7^0 04'04" E. The average highest annual rainfall is about 1952mm, while the mean daily temperature is 28^0c. Awka is the capital city of Anambra state, Southeast, Nigeria and it is strategically located midway between two major cities in Northern Igboland, Onitsha and Enugu. The city has an estimated population of 301,657 as of the 2006 Nigeria census and over 1.5 million as of 2018 estimate. The temperature in Awka is 27-30^0C between June and December but rises to 32-34^0C between January and April. The five study locations were selected within Awka capital territory as indicated in Figure 1. They were Okpuno, Amawbia, Ifite-Awka, Amansea and Isu-Aniocha. The province covered by the study area includes mainly villages and agricultural lands irrigated by ground water. The dwellers are mainly subsistence farmers and petite business owners that survive on agricultural produce. Significant foods cultivated in these regions were mainly cereals, legumes and vegetables. Fluted pumpkin leaves are an edible vegetable and predominant vegetable that are cultivated in these regions because of its medicinal, economic and health benefits. Continual plant cultivation and harvesting can primarily induce toxic metallic and non-metallic substances in agricultural soil leading to their uptake by plants. The potential toxic metal emission secondary sources were traffic emissions, domestic wastes, pollution from mechanic workshops and stagnant irrigated areas.

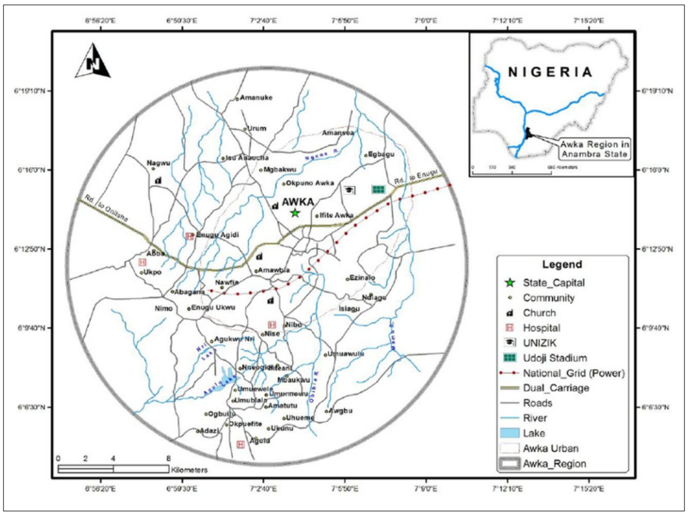

Figure 1: Map of Awka showing the study areas

Sample Collection

Soil and leafy vegetable sampling were carried out in December 2022. At each site, composite top soil samples of about 1kg were collected by mixing subsamples at depth of 0-20cm. Total of 35 samples were randomly collected with stainless steel auger. In like manner, 35 vegetable samples of approximately 0.5kg were randomly collected from the studied areas. The soil and plant samples were packed into separate polyethene bags and taken to laboratory for subsequent chemical analysis and treatment.

Chemical analysis: The soil sample were air-dried, ground and passed through 100-mesh sieve in order to remove debris. The leaves samples were washed to remove impurities, oven dried at 600C, ground and sieved. In the analysis, 1g of homogenized soil and vegetable samples were digested with 3ml HNO3, 9ml of 10M HCl in Teflon digestion vessel. The digested samples were added to different beakers and heated on electric hot plate at 1800C for about 3hrs, and allowed to cool at ambient temperature. The extracted clear sample solutions were transferred into 25ml volumetric flask and diluted to brim with distilled water. Prior to the chemical analysis, all vessels used were decontaminated using 10% nitric acid solution and rinsed further with distilled water. All the solutions prepared were subsequently assayed for potential toxic elements using Atomic Absorption Spectroscopy (AAS 500F Model by PG instruments Ltd, UK) equipped with air/acetylene flame were used. Analytical grade reagents were used all through. The metal standards were prepared from their respective salts and used for the calibration curve for the elemental determination. The limit of detection (LOD) and the limit of Quotation (LOQ) for the elements were calculated thrice the standard deviation for the digested blanks.

Bioaccumulation Factor (BAF): The metal transfer from soil to plants and associated plant contamination can be identified by Bio-accumulation factor indicator. BAF were calculated using this equation 1 [5].

$$BAF = C_{plant} / C_{soil}$$

Where C (mg/kg) is the potential toxic elements concentrations in plant and soil respectively

Discussion

The mean concentrations of heavy metals in both soil and vegetables in the studied locations are depicted in Table 1-5 with bioaccumulation factor presented in Table 6 and Figure 2. The mean concentration of the toxic metals in the soil were in the decreasing order: Cr>As>Fe>Se>Ni>Hg>Pb>Cd, while the mean metal concentration in vegetable samples were in this decreasing order: Cr>Fe>Se>Ni>Cd>Pb>As>Hg. Chromium metal had the highest concentration in all the studied agricultural soils. Moreover, Cr metal also had the highest concentration in the vegetable samples in all locations except for that of Okpuno and this can be attributed to various sources like application of pesticides and fertilizers that contains chromium, improper disposal of industrial waste near the locations and disposal of fossil fuels. Chromium (Cr) plays an important role in the metabolism of cholesterol, fat and glucose. It is needed in a minute concentration in the body. However, high concentration of Cr can be very toxic and carcinogenic [24]. Iron (Fe) is also one of the essential heavy metal in the body when it is in low concentration, however, excess concentration causes rapid rise in pulse rate and coagulation of blood, hypertension etc. In all the studied locations, the mean concentration of Fe for both the agricultural soil and the vegetable samples were recorded below the permissible WHO limit (20mg/kg). The mean concentration in the soil samples ranged from 0.028 to 0.833mg/kg, while that of vegetable samples ranged from 0.032 to 0.827mg/kg. Nickel (Ni) has been considered to be an important trace element for animal and human health [25].

But high concentrations of Ni are very hazardous to human and animal health. The mean concentration of Ni in the leaf samples from the sampled locations ranged from 0.000 to 0.338mg/kg and those of agricultural soil samples ranged from 0.346mg/kg and are all below the WHO limits (10mg/kg). Arsenic (As) is one of the heavy metal that has no known functions or importance to human/animals. They are considered toxic even at low concentration. Soil samples from Amansea and Isu-Aniocha, Amawbia, and Okpuno had mean concentration of As that were below the WHO permissible limit for As (0.5mg/kg), other location like Ifite –Awka had the mean concentration of As (0.889mg/kg) that is above the WHO permissible limit and this may be due to proximity of the agricultural soil to dumpsites, fertilizer and pesticides applications etc. The leaf sample mean concentration of As ranged from 0.004 to 0.016mg/kg. Lead (Pb) is one of the hazardous heavy metals. The WHO permissible limit in plants is 2mg/kg. `The mean concentration of Pb in soil samples were recorded to range between 0.000 to 0.128mg/kg., and those of the vegetable samples ranged from 0.000 to 0.098mg/kg which are all within the permissible limit set by WHO. Selenium is an essential metal both to the soil, plants and humans. However, in excessive concentrations, it can be very hazardous metal. Se mean concentration in the vegetable samples ranged from 0.312 to 0.602mg/kg and those of the soil samples from different locations ranged from 0.036 to 0.455mg/kg which all aligned with the permissible limit by WHO (2mg/kg). Cadmium (Cd) is another toxic metal and its presence in high concentrations is very hazardous to human health. The soil samples from Amansea had their mean concentration of Cd (0.081mg/kg) above the recommended limit by WHO (0.02mg/kg), whereas other sample areas have their Cd mean concentrations below the WHO limit. In like manner, the value of the mean concentration of Cd in leaf samples in Amansea (0.162mg/kg) is above the WHO permissible limit in plants whereas, other location leaf samples ranged below the WHO limit. Mercury (Hg) is one of the most toxic heavy metals to humans. It can cause hazards in humans such as neurological and behavioral disorders, cancer etc. From the table 1, the mean concentration of Hg in leaf samples from different locations ranged from 0.014 to 0.042mg/kg which were below the WHO permissible limit in plants (0.5mg/kg) and the same can be said for soil samples from different locations which ranged from 0.007 to 0.197mg/kg. The Bioaccumulation Factor (BAF) expresses the bioavailability of a metal at a specific position on a species of plant and it can be calculated by dividing the metal content in the vegetable by the metal content in the soil [26,27].

The leaf samples had significant difference in the transfer factors of metals relative to the availability of same metals in the soil. The TF ranged from 0.000 to 9.98. The peak TF (9.98) of Se metal were observed in Amansea followed by 8.86 of Iron (Fe) obtained in Amawbia and the least (0.000) of Lead(Pb) were observed in Isu-Aniocha and also that of Nickel that were observed both in Ifite-Awka and Amansea. TF with value less than one may be due to the possibility that the soil is the main source of metal bioaccumulation in plants. However, when the value is above one, the total concentrations in the soil do not necessarily correspond to the metal bioavailability in the soil. It may be due to external anthropogenic factors/ sources of heavy metals to the plants. The bioavailability of heavy metals depends mainly on a number of physiochemical properties such as pH, organic matter contents, cation exchange capacity, soil textures, redox potentials etc. [28]. There were no absorption of Ni and Pb in the leaf samples from Amansea and Isu-Aniocha because Ni and Pb were not bioavailable in their soil samples. The same were also observed in the uptake of Ni in Ifite-Awka. Higher Transfer Coefficients reflects high soil content or greater capacity of plants to absorb metals in their tissues [29,30].

Table 1: Heavy metals concentrations in soil and vegetable samples from Okpuno in Awka South Local Government Area

Okpuno	Pb (ppm)	Cd (ppm)	Hg (ppm)	Ni (ppm)	As (ppm)	Cr (ppm)	Fe (ppm)	Se (ppm)
Soil	0.063	0.008	0.007	0.187	0.287	0.675	0.228	0.228
Leaf	0.092	0.006	0.022	0.098	0.011	0.170	0.824	0.356

Table 2: Heavy metals concentrations in soil and vegetables samples from Ifite-Awka in Awka South Local Government Area

Ifite-Awka	Pb (ppm)	Cd (ppm)	Hg (ppm)	Ni (ppm)	As (ppm)	Cr (ppm)	Fe (ppm)	Se (ppm)
Soil	0.089	0.003	0.015	0.346	0.889	1.807	0.605	0.381
Leaf	0.092	0.018	0.031	0.000	0.011	0.984	0.827	0.318

Table 3: Heavy metals concentrations in soil and vegetables samples from Amawbia in Awka South Local Government Area

Ifite-Awka	Pb (ppm)	Cd (ppm)	Hg (ppm)	Ni (ppm)	As (ppm)	Cr (ppm)	Fe (ppm)	Se (ppm)
Soil	0.061	0.002	0.009	0.273	0.448	1.007	0.070	0.455
Leaf	0.092	0.009	0.036	0.210	0.043	1.900	0.620	0.421

Table 4: Heavy metals concentrations in soil and vegetables samples from Amansea in Awka North Local Government Area

Ifite-Awka	Pb (ppm)	Cd (ppm)	Hg (ppm)	Ni (ppm)	As (ppm)	Cr (ppm)	Fe (ppm)	Se (ppm)
Soil	0.128	0.081	0.197	0.338	0.009	0.266	0.029	0.056
Leaf	0.098	0.162	0.014	0.000	0.004	1.040	0.046	0.559

Table 5: Heavy metals concentrations in soil and vegetables samples from Isu-Aniocha in Awka North Local Government Area

Ifite-Awka	Pb (ppm)	Cd (ppm)	Hg (ppm)	Ni (ppm)	As (ppm)	Cr (ppm)	Fe (ppm)	Se (ppm)
Soil	0.094	0.010	0.036	0.279	0.045	1.327	0.833	0.162
Leaf	0.000	0.011	0.042	0.015	0.016	1.447	0.032	0.602

Table 6: Bioaccumulation factor of the vegetable samples relative to their soil sources

	Bioaccumulation Factors							
	Pb	Cd	Hg	Ni	As	Cr	Fe	Se
Okpuno	1.46	0.75	3.14	0.52	0.04	0.25	3.61	1.56
Ifite-Awka	0.80	6.00	2.07	0.00	0.01	0.54	1.37	0.83
Amawbia	1.51	4.50	4.00	0.77	0.10	1.89	8.86	0.93
Amansea	0.77	2.00	0.07	0.00	0.44	3.91	1.59	9.98
Isu-Aniocha	0.00	1.10	1.17	0.05	0.36	1.09	0.04	3.72

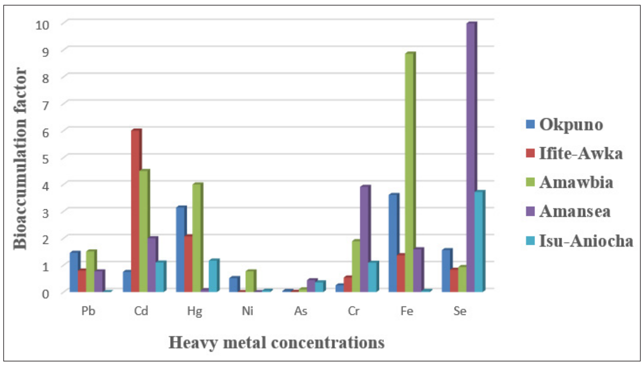

Figure 2: Bioaccumulation factor selected heavy metals at different studied areas

Conclusion

The study was focused on the determination of the mean concentrations of heavy metals in soil and vegetables (*Telfairia accidentalis*) grown on the sample soils locations in 5 different villages with Awka capital territory, Anambra, Southeast, Nigeria. The study observed that the concentration of heavy metals in the sampled agricultural soils from different locations and the vegetable samples were lower than the WHO permissible limits except the mean concentration of Cd that were above the limit in vegetable samples and all the agricultural soils from the 5 different locations. In addition, the concentration of heavy metals is more in some vegetable samples from different sampled location when compared to their subsequent soil samples. This may suggest that the absorption and retention of metals by the vegetable tissues are very high, and other anthropogenic sources of heavy metals may asw well be the cause of it. At present, the health effect from the consumption of *Telfairia accidentalis* is very minimal because of the low concentration of heavy metals in most of the sampled agricultural soils and vegetables. However, continuous exposure to these heavy metals to local residents in the sampled areas may cause serious health implications.

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