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EVALUATION OF HEAVY METALS IN CONSUMABLE VEGETABLES IN AZARA TOWN OF NASARAWA STATE

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Abstract: **Environmental pollution due to mining activities has become a reoccurring incident in the world. This poses great health challenges to the victims through food/water contamination. Azara community has experienced increased mining activities due to presence of vast mineral resources, most of which are done locally using crude methods. This study investigated the presence of heavy metals (Cd, Pb, Cu, Ni, Mn and Fe) concentration in commonly consumed vegetables namely *Vernonia amygdalina*, *Cucumis reticulatus*, *Abelmuschuses culentus*, *Amaranthus dubius*, *Talinum fruticosum* and *Telfairia occidentalis* in Azara community, Nasarawa state, Nigeria. The vegetable samples were analyzed with Atomic Absorbtion Spectrophotometer Agilent FS240AA for heavy metals. All the samples collected from the study site showed detectable levels of some of the heavy metals analyzed except in *Talinum fruticosum*. The heavy metals were present at varying concentrations ranging from 0.016-9.654mg/kg. The concentration of Ni was found to be above the WHO permissible limit in all samples, level of Pb was above the permissible limit in all samples except for *Talinum fruticosum*, while Mn was above the limit in all except for *Telfairia occidentalis* and *Cucumis reticulatus*. The metal pollution index (MPI) was extremely high in *Talinum fruticosum* and *Abelmuschuses culentus* with 1.3and 1.1 respectively, while *Amaranthus dubius* and *Cucumis reticulatus* had MPI of slightly above average with 0.6858 and 0.69 respectively. The health risk index (HRI) of metals ranged from 0.00-0.326mg/kg for Cd; 0.481-2.927mg/kg for Pb; 0.01-0.209mg/kg for Cu; 0.42-1.596mg/kg for Ni; 0.23-0.64mg/kg for Mn and 0.001-0.04mg/kg for Fe, respectively. The estimated Health Risk Index (HRI) for Pb and Ni exceeded the limit in all except for *Talinum fruticosum* (Pb), *Telfairia occidentalis* (Ni), *Vernonia amygdalina* (Ni) for adults, *Cucumis reticulatus* and *Amaranthus dubius* (Ni). The result of the study indicated a likelihood of future health risk which may arise from heavy meatal toxicity due to elevated HRI and MPI.**

Keywords: **Metals, limit, mining, toxicity and pollution.**

I. INTRODUCTION

Heavy metals (HMs) are part of our daily life. All living and non-living things consist of chemicals and almost all manufactured products involve the use of chemicals. Many chemicals can, if properly handled, contribute to the improvement of our quality of life, health and well-being. But some HMs is extremely harmful and can impact on our health and environment negatively when improperly utilized (WHO, 2011). Heavy metals are described as metallic elements that have a density higher than that of water (Fergusson, 1990). They can also be defined as metals with atomic weight greater than sodium and can damage living tissues at low concentrations and tend to accumulate in the food chain. Over the years, there has been an increase in the ecological and global public health concern associated with environmental contamination by these metals (Tchounwou *et al.*, 2012). Notwithstanding the fact that these metals occur naturally, most pollution and exposure arise from man-made activities like mining and smelting operations, industrial activities, domestic and agricultural use of metals and metal-containing compounds (Fergusson, 1990).

The essential HMs plays some vital roles in biochemical and physiological functions in plants and animals. They are cofactors of several key enzymes and play important roles in various oxidation-reduction reactions (WHO, 1996). A typical example is the role of Cu as a cofactor for several oxidative enzymes like ferroxidases, peroxidases, catalase, dopamine β-monooxygenase and others (Stern, 2010). This makes it an essential metal that is integrated into several metalloenzymes involved in formation of hemoglobin, metabolism of carbohydrate and biosynthesis of catecholamine among others. The capability of Cu to shuffle between an oxidized state, Cu (II), and reduced state, Cu (I), is exploited by cuproenzymes associated with redox reactions. The toxicity of Cu is largely attributed to this characteristic as the reaction between Cu (II) and Cu (I) give rise to the generation of superoxide and hydroxyl radicals (Tchounwou *et al.*, 2008).

These metals have been known to alter cell organelles and components like cell membrane, mitochondrial, lysosome, endoplasmic reticulum, nuclei, and some enzymes associated with metabolism, detoxification, and damage repair (Wang & Shi, 2001). Several cell components like DNA and nuclear proteins interact with metal ions giving rise to DNA damage and conformational changes that result in cell cycle modulation, carcinogenesis or apoptosis (Chang *et al.*, 1996). Several studies have shown that reactive oxygen species (ROS) production and oxidative stress play a key role in the toxicity and carcinogenicity of metals such as Cd and Pb (Tcchounwou *et al.*, 2004). They are systemic toxicants that are known to initiate multiple organ damage at minimum level of exposure. However, each metal is known to have unique features and physicochemical properties that confer to its specific toxicological mechanisms of action (Tchounwou *et al.*, 2012).

Generally, mining has been known to be a major source of heavy metal pollution (Chaanda *et al.*, 2010) in the environment today, as such minerals generally contain both toxic and essential metals. Mining plays a significant role in income generation and employment among artisan miners in Nasarawa State of Nigeria. The known main mining sites are found at Azara, Aloshi, Akiri, Wuse and Keana. The exploitation of mineral resources at Azara has provided the inhabitants with a good source of income, supplementing farming. Notwithstanding, mining poses threats and hazards that is jeopardizing the environment by disrupting the ecosystem, which includes water bodies, wildlife, natural landscapes, agricultural lands, vegetation and economic trees (Ishaya *et al.*, 2018). Due to improper planning and negligence of mining regulations, an appreciable amount of environmental degradation and ecological damage occurs in almost every barite site in Azara-Awe as a result of increasing number of artisan miners in the state.

This research ascertained heavy metals such as: Cadmium (Cd), Lead (Pb), Copper (Cu), Nickel (Ni), Manganese (Mn) and Iron (Fe) content of locally grown vegetables consumed in three different areas of Azara Development Area of Nasarawa State, Nigeria and evaluated the potential health risk involved in the consumption of the vegetables.

II. MATERIALS AND METHODS

A. Location

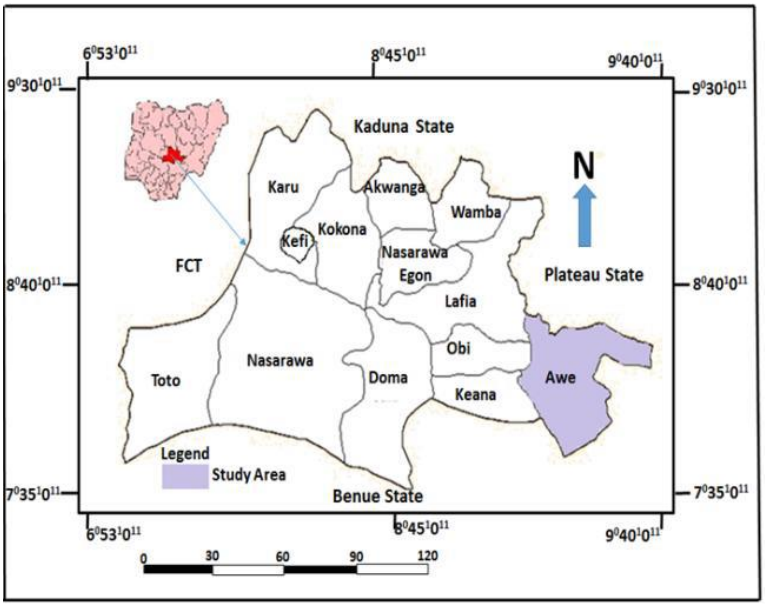

Figure 1: Map showing study area

The study area is situated within Azara district of Awe Local Government Council of Nasarawa State. It lies within latitude $8^0$18.3’ and $8^0$25.3’ and longitude $9^0$14.2’ and $9^0$20.2’ covering a total area of about 143km^2 on a map of scale 1:100,000 (Tanko *et al.*, 2015).

B. Sample Collection

Samples of the edible vegetables were randomly collected from various market vendors in the local market around the community around October, 2019.

Six vegetables, namely, Bitter leaf (*Vernonia amygdalina*), Melon (*Cucumis reticulatus*), Okro(*Abelmuschuses culentus*), Spinach (*Amaranthus dubius*), Water leaf (*Talinum fruticosum*), Fluted pumpkin leaf (*Telfairia occidentalis*) were selected. All samples were collected and stored in polythene bags according to their type and brought to the laboratory for preparation and treatment.

C. Sample Preparation

Samples were washed with distilled water to eliminate suspended particles. The samples were dried under shed on sheet of papers to eliminate excess moisture. Once dried, each sample was weighed and oven dried at 50°C. Each oven dried sample was ground in a mortar until it could pass through a 120µm sieve. The samples were stored in clean, dry, high density bottles with screw caps.

D. Sample Analysis

Two (2) grams of each sample was weighed into a china dish and charred in a furnace at 550^{0}C. The samples were cooled in a dessicator, weighed and transferred to a 20ml flask, followed by wet digestion with HNO_3:$HClO_4$ (2:1) on a sand bath for 2-3 hours. 10ml of HCl was added to the solution. The solution was filtered and diluted with deionized water (Hussain *et al.*, 2011).Estimation of heavy metals was conducted using Agilent FS240AA Atomic Absorption Spectrophotometer (AAS) according to the method of American Public Health Association (APHA)(1998) at CHESCO, Abuja.

E. Preparation of Reference Solutions

A series of standard metal solutions in the optimum concentration range were prepared. The reference solutions were prepared daily by diluting the single stock element solutions with deionized water containing 1.5 mL concentrated nitric acid/litre. A calibration blank was prepared using all the reagents except for the metal stock solutions. Calibration curve for each metal was prepared by plotting the absorbance of standards versus their concentrations.

F. Metal Pollution Index (MPI)

To examine the overall heavy metal concentrations of vegetables, the metal pollution index (MPI) was computed. This index was obtained by calculating the geometrical mean of concentrations of all the metals in the vegetables (Okereke *et al.*, 2016).

$MPI\ (mgkg^{-1}) =$

$(Cf_1 \times Cf_2 \times \ldots\ldots \times Cfn)^{1/n}$

Where, Cf_n = concentration of metal, n in the sample

G. Daily Intake of Metals (DIM)

The daily intake of metals (DIM) was determined by the following equation:

Daily intake of metal (DIM) = (Concentration of metal (mg/kg) × Daily food intake)/ (Average body weight)

The average adult and child body weights were considered to be 55.9 and 25 kg respectively, while average daily vegetable intakes for adults and children were considered to be 0.345 and 0.232 kg/person/day, respectively (Okereke *et al.*, 2016).

H. Health Risk Index (HRI)

The health risk index (HRI) was calculated from the ratio of estimated daily intake of test vegetables and oral reference doses. Oral reference doses were 0.0035, 0.001, 0.04, 0.14, 0.7 and 0.02 mg kg^{-1} day^{-1} for Pb, Cd, Cu, Mn, Fe and Ni, respectively.

Estimated exposure is obtained by dividing the daily intake of heavy metals by their safe limits. An index of more than 1 is considered to be risky for human health.

Health risk index (HRI) = DIM/RfD

Where DIM is daily intake of metal and RfD is the reference oral dose for each metal.

I. Statistical Analysis

All analyses were performed in triplicate. Results were expressed as means ± standard deviation (SD). The data was analysed using One-way Analysis of variance (SPSS v.21) statistical method. Significant difference was taken at 5% level of confidence ($P<0.05$)

III. RESULTS

The mean concentrations of heavy metals found in vegetables sampled from the local market in Azara Development Area, Nasarawa state, are presented in Table 1 below. It can be seen that the mean concentration of Cd in *A. esculentus*, 0.026 mg/kg is significantly lower than the WHO permissible limit of 0.2 mg/kg. Also, in *T. occidentalis*, *V. amygdalina*, *C. reticulatus and A. cruentus* with mean concentrations of Cd as 0.035, 0.026, 0.012 and 0.016 mg/kg respectively are all significantly lower than the WHO permissible limit of 0.2 mg/kg. However, concentration of this element was not detected in *T. fruticosum* (Table 1).

The mean concentration of Pb in *A. esculentus*, 1.09 mg/kg was significantly higher than the permissible limit of 0.3 mg/kg. The Pb contents of *T. occidentalis*, *V. amygdalina*, *C. reticulatus* and *A. cruenthus*, 0.764, 0.731, 0.63 and 1.104 mg/kg respectively are all significantly higher than the WHO permissible limit of 0.3mg/kg. But, the mean concentration of Pb in *T. fruticosum*, 0.273 mg/kg is within the permissible limit of 0.3 mg/kg (Table 1).

The mean concentration of Cu in *A. esculentus*, *T. occidentalis*, *V. amygdalina*, *T. fruticosum*, *C. reticulatus* and *A. cruenthus* were 0.66, 0.283, 0.424, 0.409, 0.901 and 0.464 mg/kg respectively. The result showed that the concentrations of the mineral element in these vegetables were within the WHO permissible limit of 2.00 mg/kg (Table 1).

The mean Ni concentration of 3.44, 1.745, 2.631, 3.305, 1.857 and 1.36 mg/kg were recorded for *A. esculentus*, *T. occidentalis*, *V. amygdalina*, *T. fruticosum*, *C. reticulatus* and *A. cruenthus*, respectively. The result showed that the concentration of the element in the vegetables were higher than the WHO permissible levels of Ni in food sample (Table 1).

The mean concentration of Mn in *A. esculentus*, *V. amygdalina*, *T. fruticosum and A. cruenthus* were 9.654, 7.658, 7.667 and 7.817mg/kg respectively. The result showed that the concentration of the mineral element in these vegetables were higher than the permissible limit of 6.64 mg/kg. However, the Mn content of *T. occidentalis* and *C. reticulatus*, 5.74 and 5.212mg/kg respectively are both with the permissible limit of 6.64 mg/kg (Table 1).

The mean concentration of Fe in *A. esculentus*, *T. occidentalis*, *V. amygdalina*, *C. reticulatus and A. cruentus* were 3.041, 0.123, 0.126, 1.642 and 1.202 mg/kg respectively. The result showed that the concentration of this metal is within WHO permissible limit of 4.8mg/kg. However, concentration of this metal was not detectable in *T. fruticosum* (Table 1).

Table 1: Mean concentrations of vegetable samples/WHO permissible limit of heavy metals in vegetables.

Vegetables	Cd (mg/kg)	Pb (mg/kg)	Cu (mg/kg)	Ni (mg/kg)	Mn (mg/kg)	Fe (mg/kg)
A. esculentus	0.03 ± 0.002^{a}	1.09 ± 0.008^{e}	0.66 ± 0.014^{c}	3.44 ± 0.005^{g}	9.65 ± 0.065^{f}	3.04 ± 0.035^{d}
T. occidentalis	0.04 ± 0.003^{a}	0.76 ± 0.006^{d}	0.28 ± 0.005^{a}	1.75 ± 0.002^{c}	5.74 ± 0.034^{b}	0.12 ± 0.009^{a}
V. amygdalina	0.03 ± 0.003^{a}	0.73 ± 0.006^{d}	0.42 ± 0.009^{b}	2.63 ± 0.007^{e}	7.66 ± 0.036^{d}	0.13 ± 0.023^{a}
T. fruticosum	ND	0.27 ± 0.004^{b}	0.41 ± 0.007^{b}	3.31 ± 0.006^{f}	7.67 ± 0.027^{d}	ND
C. reticulatus	0.01 ± 0.003^{a}	0.63 ± 0.003^{c}	0.90 ± 0.005^{d}	1.86 ± 0.002^{d}	5.21 ± 0.033^{a}	1.64 ± 0.013^{c}
A. cruentus	0.02 ± 0.004^{a}	1.10 ± 0.004^{e}	0.46 ± 0.008^{b}	1.36 ± 0.004^{b}	7.82 ± 0.035^{e}	1.20 ± 0.011^{b}
WHO limit	0.2^{a}	0.3^{b}	2.00^{e}	1.3^{a}	6.64^{c}	4.8^{e}

Results are expressed in Means ± SD (n=4). Mean values with different letters are considered significant at $p < 0.05$.

The Metal Pollution Index (MPI) is a reliable and accurate method of rating that provides the composite influence of individual metal on the overall quality of a substance. The rating is a value between zero and one, reflecting the relative importance of individual quality considerations (Majhi and Biswal, 2016). The MPI of the vegetables in this study is presented in figure 2 below. Of all the vegetables studied, *T. fruticosum* and *A. esculentus* showed a very high MPI with 1.3 and 1.1 respectively, indicating a very high degree of metal pollution in both vegetables making them unfit for consumption. Meanwhile, *C. reticulatus* and *A. cruentus* have MPI of slightly above average with 0.691 and 0.6858 respectively, showing a high metal pollution in both vegetables making them unsafe for consumption. Finally, *T. occidentalis* and *V. amygdalina* showed an average MPI of 0.459 and 0.523 respectively, showing mild metal pollution in both vegetables. The high MPI of the vegetables in the present study suggests that the consumption of these vegetables pose a risk to human health due to high accumulation of heavy metals in the edible parts of these vegetables.

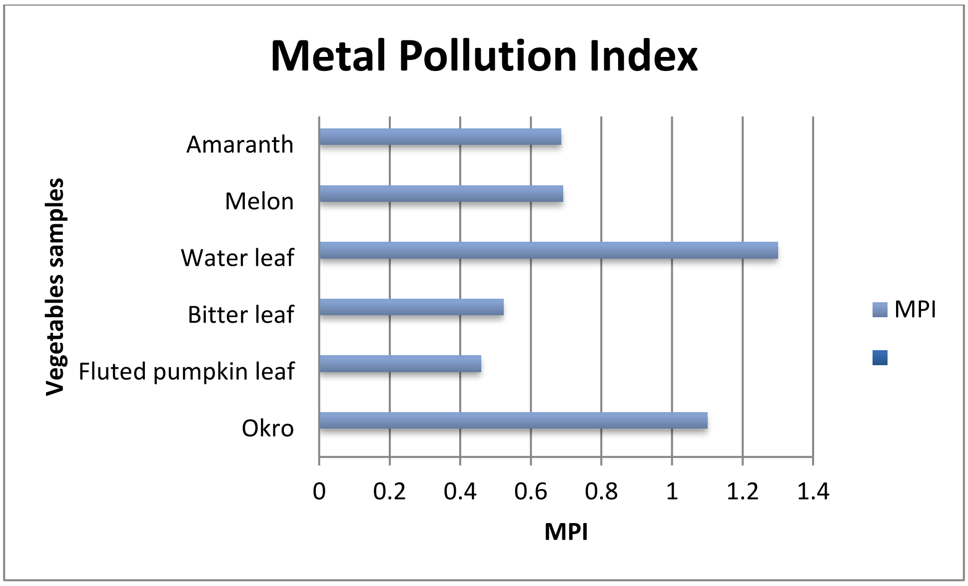

Figure 2: Metal Pollution Index of the vegetable samples.

The Health Risk Index (HRI) expresses the probability of a health effect to occur under defined circumstances and exposure to a certain hazard. Risks are estimated using data and mathematical models and the rating is on a scale of zero to one (0-1) (Bregendahl *et al.*, 2017). For adults, the HRI of Cd were all very low with 0.162 in *A. esculentus*, 0.217 in *T. occidentalis*, 0.161 in *V. amygdalina*, 0.075 in *C. reticulatus* and 0.098 in *A. cruenthus*. For children, the HRI of Cd were also low with 0.244 in *A. esculentus*, 0.326 in *T. occidentalis*, 0.241 in *V. amygdalina*, 0.112 in *C. reticulatus* and 0.148 in *A. cruenthus.*

For Pb, the HRI for adults were 1.922 for *A. esculentus*, 1.347 for *T. occidentalis*, 1.289 for *V. amygdalina*, 1.112 for *C. reticulatus* and 1.946 for *A. cruenthus*; which are all higher than 1 except for *T. fruticosum* with HRI of 0.4812. For children, the HRI of Pb were relatively higher than that of adults with 2.891 for *A. esculentus*, 2.025 for *T. occidentalis*, 1.938 for *V. amygdalina*, 1.673 for *C. reticulatus*, 2.927 for *A. cruenthus* and 0.724 in *T. fructosum*. This implies that there is a great threat of Pb toxicity from the consumption of these vegetables with children at greater risk.

For Cu, the HRI for adults were 0.01 for *A. esculentus*, 0.044 for *T. occidentalis*, 0.065 for *V. amygdalina*, 0.063 for *T. fructosum*, 0.139 for *C. reticulatus* and 0.072 for *Amaranthus cruenthus*. For children, the HRI were 0.153 for *A. esculentus*, 0.066 for *T. occidentalis*, 0.098 for *V. amygdalina*, 0.095 for *Talinum fructosum*, 0.209 for *C. reticulatus* and 0.108 for *A. cruenthus*. They were all less than 1 implying that there is no risk of Cu toxicity.

Similarly, in Ni, the HRI for adult was 1.062 *A. esculentus* and 1.02 for *T. fruticosum,* which are both higher than 1 indicating a very high potential health risk. The HRI of Ni in *V. amygdalina* was 0.812, melon 0.573 and *T. occidentalis* 0.5385 which are all above average indicating a potential health risk. While the HRI of Ni in *A. cruentus* was 0.42, which is below average. For children, the HRI of Ni were 1.596 in *A. esculentus*, 1.534 in *T. fruticosum* and 1.221 in *V. amygdalina*, which are all above 1, indicating a very high health risk. The HRI of Ni in *T. occidentalis*, *C. reticulatus* and *A. cruentus* are all above average with the values 0.81, 0.8162 and 0.631 respectively indicating a potential health risk.

The HRI of Mn for adults was all below average with 0.426 in *A. esculentus*, 0.253 in *T. occidentalis*, 0.338 in *V. amygdalina*, 0.338 in *T. fructosum*, 0.23 in *C. reticulatus* and 0.345 in *A. cruentus* thereby posing no health risks. But, for children, it is slightly different as the HRI appeared to be on the average or slightly above average in *A. esculentus* (0.6399), *A. cruentus* (0.518), *T. fruticosum* (0.5082) and *V. amygdalina* (0.5076). The slightly above average HRI shows a potential health risk from Mn poisoning due to bioaccumulation. However, *T. occidentalis* and *C. reticulatus* with HRI of 0.38 and 0.346 respectively pose no threat to the health of the consumers.

For Fe, the HRI of both adults and children were all insignificant with 0.027 for adults and 0.04 for children in *A. esculentus*, 0.001 for adults and 0.002 for children in *T. occidentalis*, 0.001 for adults and 0.002 for children in *V. amygdalina*, 0.015 for adults and 0.022 for children in *C. reticulatus* and 0.01 for adults and 0.016 for children in *A. cruentus*.

Table 2: Health risk index (HRI) of heavy metals in both adults and children

Age/Sample	Cd	Pb	Cu	Ni	Mn	Fe
Adult(Okro)	0.162	1.922**	0.01	1.062**	0.426	0.027
Children	0.244	2.891**	0.153	1.596**	0.640	0.040
Adult(Fluted	0.217	1.347**	0.044	0.539*	0.253	0.001
Children(Pumpkin leaf)	0.326	2.025**	0.066	0.810*	0.380	0.002
Adult(Bitter leaf)	0.161	1.289**	0.065	0.812*	0.338	0.001
Children	0.241	1.938**	0.098	1.221**	0.508	0.002
Adult(Water leaf)	-	0.481	0.063	1.02**	0.338	-
Children	-	0.724*	0.095	1.534**	0.508	-
Adult(Melon)	0.075	1.112**	0.139	0.573*	0.23	0.015
Children	0.112	1.673**	0.209	0.862*	0.346	0.022
Adult(Amaranth)	0.098	1.946**	0.072	0.42	0.345	0.010
Children	0.148	2.927**	0.108	0.631*	0.518*	0.016

*indicates values above average.

**indicates values above 1.

IV. DISCUSSION

The effect of heavy metal uptake by vegetables cannot be underscored as vegetables make up an important portion of human diet and are consumed in large quantity. They are great sources of vitamins, minerals and fiber, and also possess high antioxidant properties. Nevertheless, consumption of heavy metal poisoned vegetables will not only eliminate the proposed nutrients but also, pose a great risk to human health. Therefore, food poisoning by heavy metals is a very vital aspect of food safety (Elbagermi *et al.*, 2012). There are so many factors that introduce heavy metals to the food chain: agricultural practices like the use of various kinds of fertilizers, insecticides and pesticides; industrialization; disposal of untreated waste; irrigation with waste water; cultivating along dumpsites and anthropogenic activities like mining, rock weathering, erosion etc. In this study, the main source of heavy metals is the mining activities carried out in the community. All the plant samples analyzed contained detectable levels of the heavy metals except for water leaf that had a non-detectable amount of Cd and Fe.

With the exception of water leaf, all the samples taken from Azara exceeded the WHO maximum permissible limit for Pb (0.3mg/kg) in vegetables. Also, the HRI of Pb in all the vegetable samples was significantly above 1 in both adults and children except for Water leaf. This proves that Pb is a major pollutant in the food chain of Azara in accordance to the findings of Okereke et al., (2016); Arora *et al.*, (2008); WHO (2007b), Pb has been found to occur in the food chain globally, causing environmental and food safety challenges. Pb poisoning causes wide range of deleterious health issues that vary in age, gender, health status of the individual and time of exposure. Acute exposure to Pb induces brain damage, kidney damage, and gastrointestinal diseases, while chronic exposure may cause adverse effects on the blood, central nervous system, blood pressure, kidneys, and vitamin D metabolism (Flora *et al.*, 2006).

In adults, Pb affects the reproductive system of both genders by altering the male gametes resulting in sperm abnormalities and decreased sexual desire as well as sterility and causing abnormal ovarian cycles and menstrual disorders in addition to spontaneous abortion in women. Groups at risk include infants, children and women of reproductive age (in terms of the lead exposure of the fetus and of the nursing infant during lactation). Children are more vulnerable to Pb poisoning as their HRI appear to be greater than that of adults by over 45% and also they are more exposed to the metal as their behavior and lifestyle (e.g. more hand-to-mouth activities, being physically closer to ground level, and more time spent outdoors) and even based on per kilogram of body weight, children drink more fluids, eat more food and breathe more air than adults. Also, gastrointestinal absorption of Pb is much higher in children. All of which result in additional Pb exposures compared with adults (WHO, 2007). Children remain vulnerable due to the developmental status of their brains and nervous systems, as well as their incomplete blood-brain barrier development (ATSDR, 2005b). The neurodevelopmental effects have been observed in children exposed to Pb both in utero and post natal levels at rather low levels. The developing brain is sensitive to maternal exposure of Pb (Skerfving, 2005). Pb impairs learning and memory in the brain by inhibiting the N-methyl-d-aspartate receptor (NMDAR) and block neurotransmission by inhibiting neurotransmitter release, block the neuronal voltage-gated calcium (Ca^{2+}) channels (VGCCs) and reduce the expression of brain-derived neurotrophic factor (BDNF) (Engwa *et al.*, 2016). Also, there is mobilization of Pb from the maternal skeleton (accumulated from childhood onwards) during lactation, and there is also excretion of Pb in the breast milk. Hence, the breastfed infant can be exposed, and its sensitive brain affected. Pb toxicity has also been associated with inhibited heme synthesis (WHO, 2007b). Pb^{2+} replaces Fe^{2+} in reactions of ferrochelatase and ALA dehydratase in heme synthesis, thereby resulting in Pb-induced anemia (Chiu *et al.*, 2013). Pb has been classified as a carcinogen by IARC. Pb-induced carcinogenic process is suggested to cause DNA damage, alter DNA repair system and cellular tumor regulatory genes through the generation of ROS (Silbergeld *et al.*, 2000).

From the result of this study, it was noted that the HRI of Ni is relatively high and above 1 in Okro and Water leaf for both adults and children, and also in Bitter leaf for children. This signifies a health risk of Ni poisoning in Azara from the consumption of these vegetables. The most common noncancerous effect of exposure to Ni compounds like Ni oxide and Ni sulphate is lung inflammation (Dal *et al.*, 2016). Ni compounds have been classified as human carcinogens based on evidence of carcinogenicity from studies in humans, including epidemiological and mechanistic studies. Research has shown that metallic Ni possess carcinogenic properties as it solubilizes in the body to release ionic Ni, an active genotoxic and carcinogenic form of Ni (National Toxicology Program, 2016). Ni, as a carcinogen, has various carcinogenic mechanisms which include regulation of transcription factors, controlled expression of certain genes and generation of free radicals. Ni has been shown to be involved in regulating the expression of specific long non-coding RNAs, certain mRNAs and microRNAs. Ni has the ability to promote methylation of promoter and induce the down regulation of maternally expressed gene 3 (MEG3) thereby up-regulating hypoxia-inducible factor-1α, two proteins which are known to be implicated in carcinogenesis (Engwa *et al.*, 2019). It has also been demonstrated that Ni can generate free radicals, which contributes to carcinogenic processes (Zambelli *et al*., 2016).

Another metal of interest is Mn; this is due to its slightly high HRI in vegetables like Okro, Bitter leaf, Water leaf and African spinach gotten from Azara in children. It can be said that they pose no health risk currently, but with the case of biomagnification (or bioaccumulation), it is a different scenario altogether. Bioaccumulation, in ecology and biology according to Aprile & De Bellis (2020), is the process whereby the accumulation of toxic substances in living beings increases in concentration following a rise in the trophic level. Biomagnification is also described as the concentration increase of a pollutant in biological organism overtime. In Azara, mining activities are still ongoing as it serves as the only source of livelihood of the inhabitants during dry season (in the absence of farming). This implies that the concentration of these metals in the vegetables will keep increasing with every farming season as rain washes off the metals from the mines to the agricultural lands and streams (used for irrigation). All these factors will contribute to the increase of the already moderately high metal, thereby causing a potential health risk to the inhabitants of the community. Mn toxicity is not to be ignored as it is a neurotoxin. According to Klos *et al.* (2007), Manganism, a neurological disease similar to Parkinson's disease is as a result of Mn toxicity. Results from the studies of O'Neal *et al*. (2014), shows that excess Mn accumulates in the femur, tibia, humerus and parietal bones. Another effect of Mn toxicity is at cellular level, where it accumulates and inhibits ATP synthesis.

From this study, it is observed that the concentration of heavy metals (Cd, Pb, Cu, Ni, Mn and Fe) of vegetables consumed in Azara Community of Nasarawa state are not high enough to cause acute poisoning, implying that consumers of these vegetables do not show symptoms of poisoning currently. But, applying the theory of bioaccumulation and biomagnification, they will show symptoms of chronic heavy metal poisoning in the near future, with reference to Pb and Ni as their concentration exceeds WHO permissible limit. This is because the concentrations of Pb and Ni are high enough to cause chronic poisoning and also, due to their non-biodegradable nature, the rate of excretion does not match the rate of intake, thereby, promoting gradual accumulation in the body system and damage of organs leading to gradual health deterioration unknown to the individual. This proves that there will be major health challenges like Anemia, children with neurodevelopmental defects, bone diseases like osteomalacia, failure of organs like liver, kidney and brain, and then cancer; for the inhabitants of Azara community in the near future if nothing is done to arrest this issue of heavy metal toxicity in Agricultural produce.

V. CONCLUSION

It cannot be said that nature's gift to man is poisonous, it depends on man's activities with the gifts. In this case, the improper means of mining mineral resources in Azara Development Area of Nasarawa State would lead to contamination of food by heavy metals from the mining sites. The food chain (soil-plant-human) pathway is recognized as the major pathway for human exposure to heavy metal pollution. These metals accumulate in plant tissues and transferred to humans when consumed. The non-biodegradable nature of the metals, life span and their slow elimination from the human system contribute to their bioaccumulation in various tissues posing great health risks in the future as their concentration is not high enough to cause acute poisoning. Therefore, there is great need to improve the quality of mining activities in the area to reduce the rate of environmental pollution due to crude means of mining. Also, regular monitoring of the metal pollution in farmlands and farm produce of the study area is vital to ensure the health of the consumers.

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