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Heavy Metals Effect due to Contamination of Vegetables from Enyigba Lead Mine in Ebonyi State, Nigeria

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Abstract

The accumulation of As, Cd, Cr, Pb and Zn in soils and vegetables in the vicinity of Enyigba Lead mine were investigated using Particle Induced X-ray Emission (PIXE) spectrometry. Samples from Abakaliki served as control. The five edible vegetables studied include *Telfaria occidentalis* (fluted pumpkin); *Talinum triangulare* (water leaf); *Amaranthus hybridus* (Amaranth or pigweed); *Vernonia amygdalina* (bitter leaf); and *Solmun nigrum* (garden egg leaf). The metal concentrations in the soil decreased with depth which possibly suggests anthropogenic sources of contamination. The levels of Pb > Ni > Cd in Enyigba top soil was observed to be above the US-EPA Regulatory Limits in that order. Elevated concentrations of heavy metals were recorded in all the vegetable samples from Enyigba Lead mine and they exceeded those of Abakaliki. The results revealed that heavy metal values in the vegetable from Enyigba ranged from 0.035mg kg^{-1}- 0.400mg kg^{-1} (As), 0.001mg kg^{-1}-0.01mg kg^{-1}(Cd), 0.023mg kg^{-1}-0.273mg kg^{-1}(Cr), 0.105 mg kg^{-1}-0.826mg kg^{-1} (Pb), and 0.016mg kg^{-1}-0.174mg kg^{-1} (Zn); while those from Abakaliki were found to be 0.022mg kg^{-1}-0.280mg kg^{-1}(As), 0.002mg kg^{-1}-0.009mg kg^{-1}(Cd), 0.023 mg kg^{-1}-0.210 mg kg^{-1}(Cr), 0.091mg kg^{-1}-0.426mg kg^{-} (Pb) and 0.022mg kg^{-1}-0.144mg kg^{-1}(Zn). The levels of arsenic and lead in bitter leaf and garden egg leaf exceeded WHO Maximum Limit (WHO-ML = 0.1ppm for As and 0.3ppm for Pb). The variation in the parameters determined were found to be statistically significant ($p<0.05$) as determined by one way analysis of variance.

Keywords: heavy metal, vegetable, soil. Enyigba Pb-Zn mine

1. Introduction

Soil is one of the repositories for anthropogenic wastes. Biochemical processes can mobilize them to pollute water supplies and impact food chains. A major pathway of soil contamination is through atmospheric deposition of trace metal from point sources such as metaliferous mining, smelting and industrial activities. Other sources of contamination (non point) affect predominantly agricultural soils and they include inputs such as fertilizers, pesticides, sewage sludge, organic manures and composts (Singh, 2001). Uptake of metals is dependent on chemical form of the metals in the contaminated soil (Gundermann et al., 1995). Elevated levels of heavy metals in soils may lead to uptake by native and agronomic plants. Several studies have indicated that vegetables, particularly leafy crops, grown in heavy metals contaminated soils have higher concentrations of heavy metals than those grown in uncontaminated soil (Vousta et al., 1996). Some metals such as such as Fe, Zn and Cu are known to be essential in plant nutrition, however many other heavy metals do not play any significant role in a plants physiology. Plants growing in a polluted environment can accumulate toxic metals at high concentration causing serious risk to human health when consumed (Vahter et al., 2007). Some trace metals are very harmful because of their non-biodegradable nature, long biological half-lives and their potential to accumulate in different body parts. Many metals are extremely toxic because of their solubility in water and even in low concentrations, some trace metals have damaging effect to humans and animals because there is no mechanism for their elimination from the body (Reilly, 1980; Davies & White, 1981). Plants growing in a polluted environment can accumulate the toxic metals at high concentration causing serious risk to human health when consumed. Vegetables absorb and adsorb these metals from the ground as well as from the parts of vegetable exposed to air from polluted environment (Vousta et al., 1996). It has been reported that concentrations of Cd, Pb, Zn, Cu and Ni in different vegetables from industrialized areas were higher than those in non-industrialized areas in various parts of Turkey (Demirezen & Ahmet, 2006). This observation agrees with studies on Cd, Cu and Ni levels in vegetables from industrial and residential areas of Lagos City, Nigeria (Nwoko & Egunobi, 2002). Similar researches in Egypt (Radwan & Salama, 2006) and North Greece (Fytianos et al., 2001) revealed trace metals accumulated in vegetables and fruits grown in industrialized and urban areas than those in rural areas. In Nigeria, as in other tropical countries of Africa where the daily diet is dominated by starchy staple foods, vegetables are the cheapest and most readily available sources of important proteins, vitamins, minerals and essential amino acids. Few data exist on heavy metal concentration in many highly populated and industrialized cities in Nigeria. Recent research reported high level of heavy metals (Pb, Fe, Cu and Zn) and the long term effect of municipal waste disposal on soil properties and productivity of sites used for urban agriculture in Abakaliki, Nigeria. The accumulation of heavy metals including Pb, Ni, Cr, Cd and As in roots, stems and leaves of cocoyam (*Colocesia esculents*) and Cassava (*Mannihot esculent*) grown in polluted soil, an abandoned waste dump soils in Umuahia, Abia State Nigeria, has been reported (Okoronkwo et al., 2005). The concentration of Pb, Ni and Cd were observed to be significantly higher than Cr and As in the leaves and roots of the investigated plants. Furthermore, studies carried out on the Lead contamination of soils and vegetation in an abandoned battery factory site in Ibadan revealed that edible plants grown in polluted soils are susceptible to heavy metal uptake (Nwoko & Egunobi, 2002). The aim of this present study is to examine and obtain the current data and contamination statues of trace metals such as As, Cd, Cr, Pb and Zn in vegetables from anthropogenically active areas of Enyigba Pb-Zn Mine and Abakaliki Urban, using Particle Induced X-ray Emission (PIXE) spectrometric method.

2. Area of Study

Abakaliki lies in the latitude of 6°19'N and Longitude of 8°05'S. Enyigba is located about 12 Km Southeast of Abakaliki (Microsoft Encarta, 2007). The prevailing climate conditions are high precipitation that exceeds evapotranspiration rates, high temperatures and humidity for more than half the year. Vegetation types are mangrove and freshwater swamp communities, rainforest, forest/savanna mosaic and derived savanna zone. Farming systems dominate in the region are yam and plantain crops, with oil palm bush and indigenous trees of nutritional, economic, medicinal and cultural importance. The Abakaliki Lead-Zinc is believed to be of hydrothermal origin emplaced at a low temperature of about 140°C and it is made up of primarily four lodes namely Ishiagu, Enyigba, Ameri and Ameka in the lower Benue Trough located in Ebonyi State (www//ngsa-ng.org/zinc (2007)).

Figure 1. Map of Nigeria showing the study area (Abakaliki), adapted from Microsoft Encarta (2007)

3. Material and Method

3.1 Sample Collection and Preparation

Soil samples (n=8) were collected at random 20m apart at 0-30 cm and 60-90 cm depth from four different points and pulled together composite samples. The former represents topsoil while the later represents subsoil samples. The samples were air-dried, ground mechanically and sieved to obtain < 2 mm fraction. 30 g sub-sample was drawn from the bulk (< 2 mm fraction) and reground to obtain < 200 µm fraction using laboratory mortar and pestle. Samples of edible portion of vegetable samples (n=20) included bitter leaf (*Vernonia amigdalina)*; Pumpkin leaf (*Telfaria occidentalis*); water leaf (*talinum triangulare*); Amaranthus *(Amaranthus hybridus)* and garden egg leaf (*solmun nigrum*) were randomly collected. The plant samples were put through a three step washing sequence (Reuter et al., 1983), air dried, weighed and placed in a dehydrator at approximately 80°C for 48 hours. The moisture and water droplets were removed with the help of blotting papers. The samples were pulverized into fine powdery form by the use of an agate mortar and pelletized by CAVER model manual palletizing machine.

3.2 Analysis of Soil and Plant Samples

The soil and plant samples were analyzed for heavy metal contents using similar procedure by (Olabanji et al., 1995). In this procedure, the target samples were irradiated in PIXE spectrometer for 3 minutes in a vacuum chamber with 3 MeV protons (beam currents of 10-70 nA and beam diameter of 4 mm). The X- rays generated from the target were measured with two Si/Li detectors and the corresponding metal concentration was ascertained by means of incorporated computer device.

Table 1. Mean concentrations (mg kg^{-1}) of heavy metals in soil of Enyigba lead Mine and Abakaliki Urban and their pollution indices

	Enyigba (Mean pH = 6.5±0.29)				Abakaliki (Mean pH = 6.8±0.38)				
Metal	Topsoil	PI	Subsoil	PI	Topsoil	PI	Subsoil	PI	US-EPA*
As	4.8	0.06	2.12±1.6	0.03	2.84±1.4	0.4	ND	-	75
Cd	126.0±42	1.5	28.8±6.2	0.34	3.4±1.2	0.04	0.18±0.2	0.00	85
Cr	1212.2±141.2	0.40	922.2±12.2	0.31	1054.2±18.6	0.35	916±8.4	0.31	3000
Pb	1116.8±43.2	2.7	91.7±16.7	0.22	122.2±22.2	0.30	0.21±0.1	0.00	420
Zn	995.2±82.4	0.13	322.0±62.4	O.O4	69.8±22.2	0.01	42.4±16.1	0.00	7500

* Values refer to metal concentration in typical soils (Miroslav & Vladimir, 1999), PI = Pollution index.

Table 2. Mean concentrations (mg kg^{-1}) of heavy metals in vegetables from Enyigba Lead Mines

Parameter Samples	As (mg kg^{-1})	Cd (mg kg^{-1})	Cr (mg kg^{-1})	Pb (mg kg^{-1}	Zn (mg kg^{-1})
Telfaria occidentalis (Fluted pumpkin leaf)	0.067±0.02	0.003±0.01	0.050±0.02	0.206±0.21	0.029±0.02
talinum triangulare (Water leaf)	0.400±0.06	0.011±0.02	0.273±0.42	0.112±0.12	0.174±0.14
Amaranthus hybridus (Pig weed)	0.035±0.01	0.001±0.01	0.023±0.02	0.105±0.13	0.016±0.01
Vernonia amigdalina (Bitter leaf)	0.166±0.03	0.007±0.01	0.116±0.01	0.511±0.38	0.074±0.02
solmun nigrum (Garden egg leaf)	0.268±0.02	0.012±0.01	0.178±0.03	0.826±0.42	0.123±0.12
WHO-ML*	0.10	0.10	0.05	0.30	100.00

*Values refer to Maximum Limit of World Health Organization (CODEX, 2001)

Table 3. Mean concentrations (mg/kg) of heavy metals in vegetables from Abakaliki Urban

Parameter Samples	As (mg kg-1)	Cd (mg kg-1)	Cr (mg kg-1)	Pb (mg kg-1	Zn (mg kg-1)
Telfaria occidentalis (Fluted pumpkin leaf)	0.036±0.02	0.002±0.01	0.038±0.02	0.202±0.21	0.022±0.02
talinum triangulare (Water leaf)	0.280±0.04	0.009±0.02	0.210±0.28	0.101±0.12	0.144±0.10
Amaranthus hybridus (Pig weed)	0.022±0.01	0.006±0.01	0.023±0.01	0.091±0.13	0.012±0.01
Vernonia amigdalina (Bitter leaf)	0.128±0. 02	0.007±0.01	0.122±0.01	0.421±0.28	0.072±0.02
solmun nigrum (Garden egg leaf)	0.194±0.02	0.009±0.02	0.142±0.02	0.426±0.32	0.110±0.10
WHO-ML*	0.10	0.10	0.05	0.30	100.00

*Values refer to Maximum Limit of World Health Organization (CODEX, 2001)

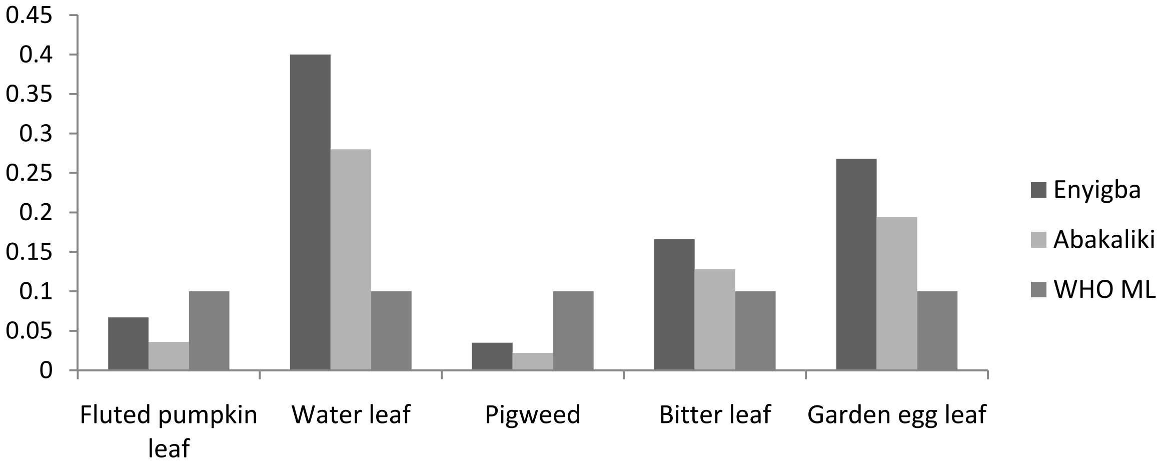

Figure 1. Arsenic distribution in the vegetables

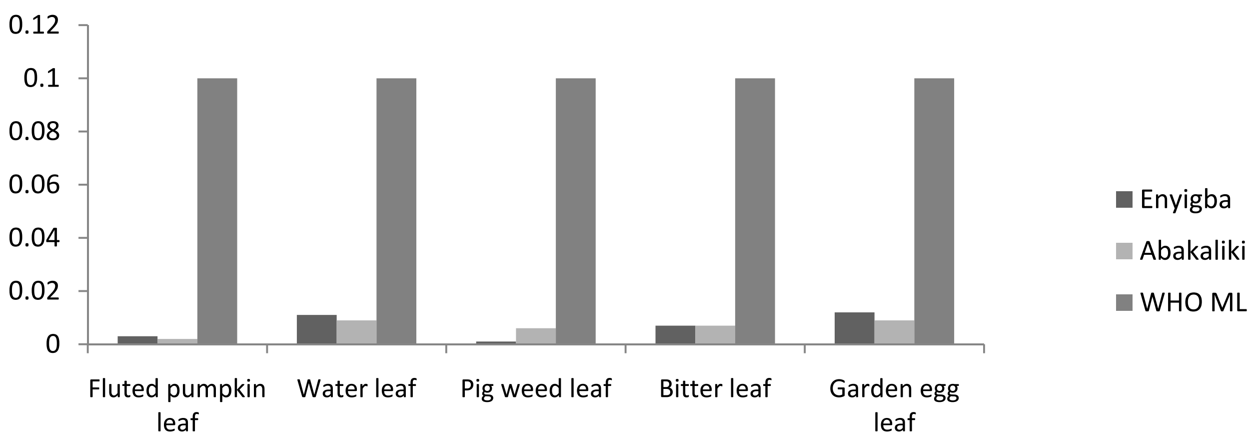

Figure 2. Cadmium distribution in the vegetables

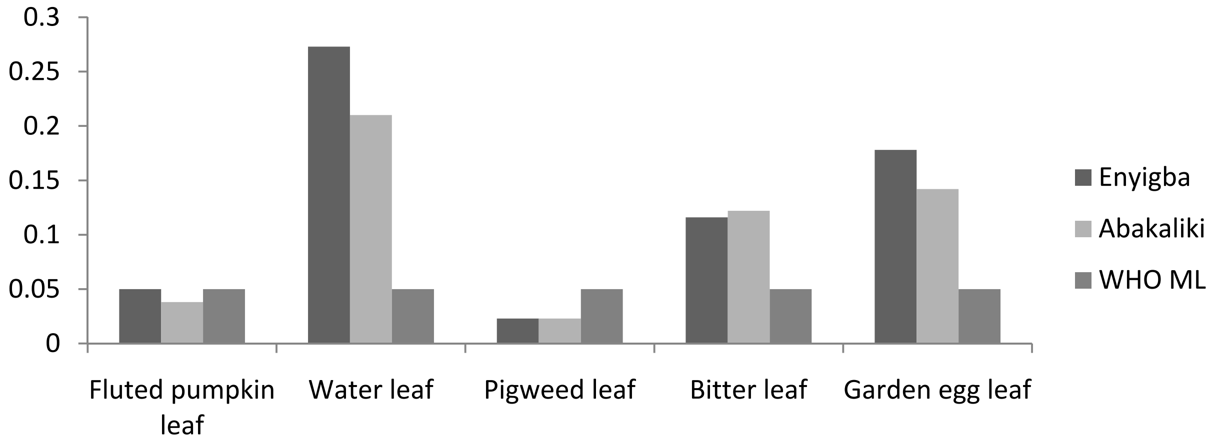

Figure 3. Chromium distribution in the vegetables

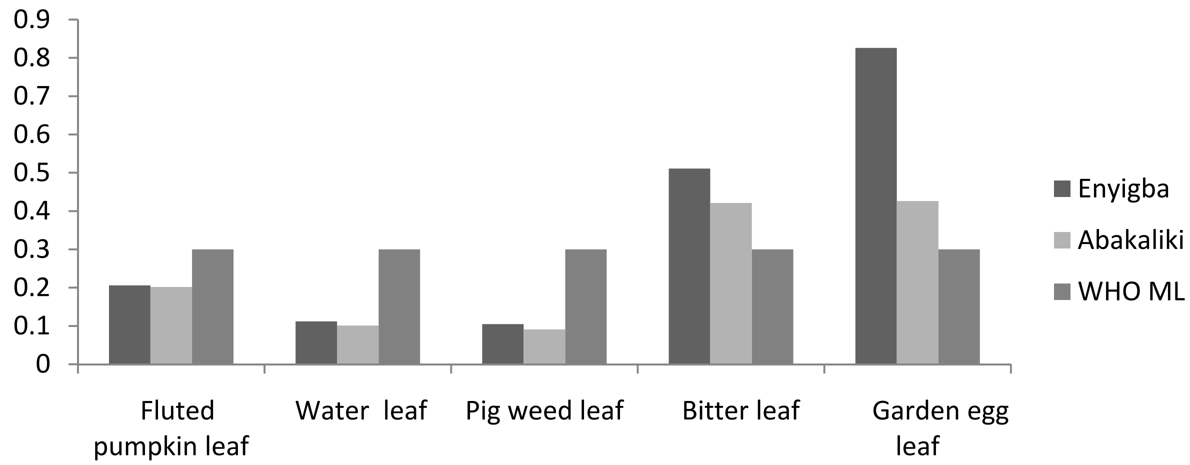

Figure 4. Lead distribution in the vegetables

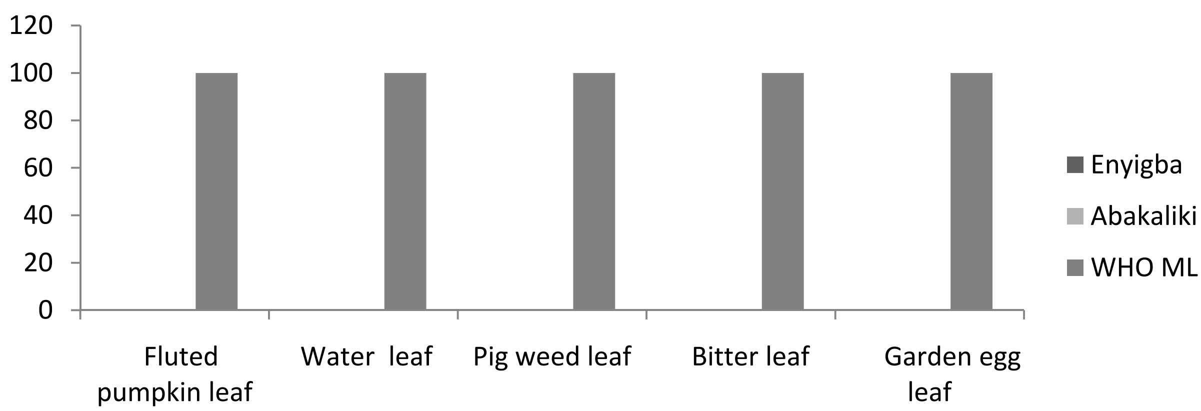

Figure 5. Zinc distribution in the vegetables

4. Discussion

4.1 Arsenic

Tables 1, 2 and 3 present the concentrations of arsenic in the investigated soil and vegetables. Concentration of As in vegetables from Enyigba lead mine was found to be significantly higher than those of Abakaliki Urban. Figure 1 revealed that arsenic in water leaf, bitter leaf and garden egg leaf from both Enyigba and Abakaliki exceeded WHO Maximum Limit (WHO ML) which is 0.1 mg kg^{-1}. High level of arsenic was observed in water leaf (quadruple) and garden egg leaf (twice) when compared to WHO standard. Alan et al. (2003), reported high concentration of arsenic in different vegetables grown in Bangladesh which was high enough to cause clinical problems both to animals and human beings consuming these metal rich vegetables. Consumption of the affected vegetables will certainly result to health consequences which include kidney and liver damage, gastrointestinal effect, peripheral neuropathy, Skin lesion, Lung cancer and death.

4.2 Cadmium

The pollution index (PI) of cadmium in soil of Enyigba lead mine was 1.5 which indicates that the soil was polluted with As (Miroslav & Vladimir, 1999). Cadmium is a mobile element, easily absorbed by roots and transported to shoots where it is uniformly distributed in plant (Sekara et al., 2005). The concentrations of Cd in all the investigated vegetables from Enyigba and Abakaliki were below WHO ML which is 0.1 mg kg^{-1} (Tables 2 and 3, Figure 2). Highest concentration of Cd was observed in Enyigba mine Garden egg leaf and water leaf. Consumption of these vegetables will not result to cadmium related health problems. Cd contaminated vegetables are known to result to bone fracture, diarrhea, stomach pains and severe vomiting, reproductive failure, damage of central nervous system and DNA, in addition to cancer development.

4.3 Chromium

Cr in water leaf, garden egg leaf and bitter leaf significantly exceeded the WHO-ML (0.05 mg kg^{-1}) even though its PI in the soil was <1 (Table 1, 2 and 3, Figure 3). Consumption of the affected vegetables will certainly result to health consequences which include kidney and liver damage, skin rashes, stomach upset and ulcer, respiratory problems and lung cancer and alteration of genetic materials.

4.4 Lead

Lead is the main cause for concern in terms of contamination of vegetables in Enyigba lead Mine by heavy metals. Lead is toxic and can be harmful to plants, though the plants usually show ability to accumulate large amounts of lead without visible changes in their appearance or yield. In many plants, Pb accumulation can exceed several hundred times the threshold of maximum level permissible for human (Wierzbicka, 1995). From this present work, high PI (2.5) of Pb, was observed for lead in the soils of Enyigba lead mine (Table 1). Pb in garden egg leaf and bitter leaf exceeded the WHO ML which is 0.3 mg kg^{-1} although it was less in fluted pumpkin, water leaf and pig leaf (Tables 1 and 2, Figure 4). Consumption of these vegetables will certainly result to health consequences. Todd (1996) emphasized that most of the accumulated Lead is sequestered in the bones and teeth. This causes brittle bones and weakness in the wrists and fingers. Lead that is stored in bones can re-enter the blood stream during periods of increased bone mineral recycling (i.e., pregnancy, lactation, menopause, advancing age, etc.). Mobilized lead can be redeposited in the soft tissues of the body and can cause musculoskeletal, renal, ocular, immunological, neurological, reproductive, and developmental effects (ATSDR, 1999).

4.5 Zinc

Among all metals, Zn is the least toxic and an essential element in the human diet as it is required to maintain the proper functions of the immune system, normal brain activity and is fundamental in the growth and development of the foetus. Zinc deficiency in the diet may be more detrimental to human health than too much Zinc in the diet (Nair et al., 1997). Although the average daily intake of Zinc is 7-16.3 mg Zn/day, the recommended dietary allowance for it is 15 mg Zn/day for men and 12 mg Zn/day for women (ATSDR, 1994). On the contrary, the high concentration of Zinc in vegetables may decrease in sense of smell and taste, slows down healing process of wound, skin sore and loss of appetite. Zinc shortage also causes birth defect and anaemia, stomach cramps and vomiting and Skin irritation etc. The acceptable limit for human consumption of Zn is 150 mg kg^{-1}. During present study, the concentration of Zn was found high garden egg leaf and water leaf, while low concentration of Zn was observed in pig weed and pumpkin leaves (Tables 2 and 3, Figure 5). Levels of Zn in vegetables were far below WHO ML which is f 100 mg kg^{-1}.

5. Conclussion

The results of the study revealed that bitter leaf and garden egg leaf accumulated As, Cr and Pb above the WHO M Ls. Water leaf also accumulated As and Cr above the WHO ML but the level of lead was within the acceptable limit of WHO. These three vegetables are in high demand in Abakaliki and other areas within the locality because they are part of daily staple food. Continuous consumption of these vegetables will inevitably result to health consequences. There is a need for regular evaluation of trace metals in these vegetables by Federal and State protection agencies. The studied plants can be used for environmental monitoring based on metal loads.

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