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ASSESSMENT FOR THE LEVEL OF COPPER (Cu), LEAD (Pb), ZINC (Zn), MANGANESE (Mn), AND IRON (Fe) IN SOIL, CASSAVA ROOT AND ITS PEELS FROM KONDUGA TOWN, BORNO STATE, NIGERIA

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ABSTRACT
This research work is aimed at assessing the level of the metals; Copper (Cu), Lead (Pb), Zinc (Zn), Manganese (Mn), and Iron (Fe) in cassava roots, its peels as well as the soil that support the growth of the plant. To achieve this, samples of cassava roots and soil were collected from four different sites (farms) in Konduga town, Borno State Nigeria. Collection was made in the month of October to September 2014. The roots were washed with tap water peeled and sliced. These were then dried to a constant weight at room temperature, grounded to a fine particulate size, as well as the soil sample and sieved. These were then analyzed using Atomic Absorption Spectroscopy (AAS) following treatment with aqua-regia. The result obtained indicates that, the soil had the highest level of 42.306, 0.791, and 0.711(µg/g) for the metals, Fe, Cu, and Zn respectively. Manganese was found below detection limits, Pb had 0.235 (µg/g) whereas Cr had the least concentration of 0.013(µg/g). The root had the least concentration of 0.191 (µg/g) for Mn, whereas Fe, and Zn had the highest level of 2.936, and 0.725 µg/g respectively. The peels which is mostly not eaten by human in this part of the country (the north) had the highest level of 10.748, 0.923 and 0.713 µg/g for Fe, Zn, and Mn respectively. The levels observed for these elements were all found significantly different at ($P = 0.05$) according to the Tukey multiple comparison test. The metals; Cu, Cr, and Pb were found below detection limits in both the root and the peels. Cassava is not mostly consumed routinely as food in this part of the country (the northeast) but rather as a supplement; therefore the levels of these elements observed in the root indicates that, the root may not only be safe for consumption but the trace level of the metals may be helpful in the metabolic function of the body.

KEYWORDS: AAS, Environment, Heavy Metals, Pollution, Samples, Digestion, Human, Exposure.

INTRODUCTION
Nigeria, like any other African country, is an agrarian economy in which agriculture and agro-allied enterprises are the most popular source of income. It provides employment for up to 90% of the rural dwellers (World Bank, 1993). Nigeria is the largest producer of cassava in the world with about 45 million metric tons (FAO, 2008) and her cassava transformation has been reported as the most advanced in Africa. Cassava is grown throughout the tropic and could be regarded as the most important root crop, in terms of area cultivated and total production (Ano, 2003). It is a major food crop in Nigeria (Ogbe *et al*., 2007) strategically valued for its role in food security, poverty alleviation and as a source of raw materials for agro-allied industries with huge potential for the export market (Akinpelu *et al*., 2007). Cassava (*Manihot esculenta*) is the third most important food source in the tropics after cereal crops and is the staple food of at least 500 million people (Ceballos *et al*., 2004). It originates from South America and is believed to be brought to Africa in the 17th century. The roots of cassava became a staple food for many people since the late 19th and early 20th century (Hillocks, 2002). Not only cassava roots that are predominantly consumed but also the leaves are edible. It is often referred to as a food security crop (Barratt *et al*., 2006) for the following several reasons; firstly, the planting and harvesting time is flexible, which allows it to be harvested when really needed; secondly, because of the tolerance towards low soil fertility and water availability; and thirdly, the plants can be multiplied by vegetative propagation without the need for seeds, allowing farmers to continue to grow the crop without financial input (Hillocks, 2002). In Nigeria, cassava plays a very important role in food security; it has been observed that many Nigerians eat cassava products at least once a day (Ayankunbi *et al*., 1991). It is used mainly as a fresh food item, but is also processed into various food and non-food products, such as starch, flour, beverages, animal feeds, biofuels and textiles. It is traditionally processed before consumption into various products such as gari (roasted fermented granules) mostly in the east and southern part of Nigeria, fufu (dried fermented starch lour) predominantly eaten in the west, lafun (dried fermented lour), tapioca (unfermented roasted granules from starch) also mostly consumed in the east, and pupuru (smoked dried fermented balls) (Nweke, 1994). There are several thousand varieties of cassava and about 100 related wild species (Hershey *et al*., 1997), with hydrogen cyanide (HCN) contents of their roots ranging from 1-1550 parts per million (ppm) (Cardoso *et al*., 2005). Cassava plants

are generally categorized as bitter or sweet, depending upon their cyanide content. The low-HCN, or sweet cassava, has less than 50 ppm of cyanogenic equivalents, while the high hydrogen cyanide (HCN) or bitter cassava has more than 100 ppm (Wilson and Dufour, 2002).. According to Adepoju *et al*. (2010), the food value of cassava is greatly compromised by its toxic hydrogen cyanide content. The sweet cassava can be cooked, boiled and sometimes eaten as they are, while the bitter cassava needs to be processed before being consumed. Most of the varieties found in the north are of the sweet type. It is eaten when cooked, parboiled and /or even row that is fresh. This is because it contains less or no cyanide. Heavy metal contamination of agricultural soils and crops has been regarded as a great environmental concern (Liu et al. 2005; Kachenko and Singh, 2006). Studies have shown that not only the ingestion or inhalation of contaminated particles, but also the ingestion of contaminated plants produce is another principal factor contributing to heavy metal exposure to animals and human. Soil is the primary sink of heavy metals in the atmosphere, hydrosphere and biota, and thus plays a fundamental role in the overall metal cycle in nature (Cao *et al*., 2010). Heavy metals in soil pose potential threats to the environment and can damage human health through various absorption pathways such as direct ingestion, inhalation, oral intake, and diet through the soil–food chain (Lu *et al*., 2011).. Heavy metal uptake via roots from contaminated soils and surface water, and direct deposition of contaminants from the atmosphere onto plant surfaces can lead to plant contamination. It has been recognized that food crops can be an important source of heavy metals for humans and animals (Dudka and Miller, 1999). In an effort by farmers to improve the fertility of low or non fertile soils to burst crop production, there have been cases of wrong applications of agrochemicals (chemical fertilizers, pesticides and herbicides) to crop. It was reported that the anthropogenic activities aimed at enhancing food production could facilitate the accumulation of undesirable substances in plants and affect the qualities of both soil and water resources adversely (NAAS, 2005). The wrong use of certain agro-chemicals in crop cultivations has been reported to account for about 50% of the free radical molecules available in our food, with potential adverse health effects following excessive ingestion. The health impacts of agricultural chemicals (pre and post emergence herbicides, insecticides and pesticides) used in cassava production are a function of their degree of accumulation in environmental sinks: soil, air, water, plants and the degree to which humans are exposed to them (Akinpelu *et al*., 2007).

Chronic intakes of heavy metals have damaging effects on human beings and other animals (Zheng *et al*., 2007). Trace heavy metals are significant in nutrition, either for their essential nature or their toxicity. Copper, iron and zinc for instance are known to be essential and may enter the food materials from soil through mineralization by crops, food processing or environmental contamination, as in the application of agricultural inputs, such as copper-based herbicides which are in common use in farms in some countries. Iron, copper, and zinc are essential metals for humans, since they play an important role in biological systems, but these essential heavy metals can produce toxic effects when their intake is excessively elevated (Zheng *et al*., 2007). Chromium, Copper and Zinc for instance, can cause non-carcinogenic hazardous such as neurologic involvement, headache and liver disease, when they exceed their safe threshold values (US EPA, 2000). In humans, prolonged excessive dietary intake of zinc can lead to deficiencies in iron and copper, nausea, vomiting, fever, headache, tiredness, electrolyte imbalance, anemia, lethargy and abdominal pain (American Medical Association, 1989). The consequence of high level of heavy metals in foods produce is of considerable concern nowadays because of their toxic effect to animals and human. Food safety is an important aspect of a nation's economic stability and due to previous reports on the degree of pollution of some other food items (Adekunle and Akinyemi, 2004), it has become imperative therefore to periodically, assess the levels of these heavy metals (such as Cu, Cd, Zn, Ni, Cr, Se, Hg, Pb, As and Fe) in our food crops and the entire environment in general to ascertain the risk posed by these metals to consumers. This research work therefore is aimed at determining the levels of the heavy metal pollutants; Cu, Zn, Cd, and Pb in Cassava root tubers from konduga town, of konduga Local Government Area of Borno state, Nigeria for safety reason.

EXPERIMENTAL DESIGN

Sample and sampling area

Samples of the soil and tubers of cassava (*Manihot esculenta*) grown on the same soil were randomly collected using standard procedure described by Radojevic and Bashkin (1999). Five different soil samples were collected at a depth of 0-30cm using soil auger. Samples were collected in three different farms lands from four different villages within the Konduga town, Konduga Local Government Area.

Physicochemical analysis of soil samples

Soil texture was determined by the Bouyoucos hydrometer method. The moisture content of soil was calculated by the weight difference before and after drying at 105 °C to a constant weight. The pH and electrical conductivity (EC) were measured after 20 min of vigorous mixed samples at 1: 2.5. Solid: deionized water ratio using digital meters [Elico, Model LI-120] with a combination pH electrode and a 1-cm platinum conductivity cell respectively. Cation exchange capacity was determined by summation method following the determination of exchangeable cations (USDA, 2004). Organic carbon was determined by using Walkley–Black method (Jackson, 1973).

Sample preparation and Analyses

The soil samples collected were homogenized, grounded, oven dried at 105ºC to a constant weight and sieved using a 2mm nylon sieve. Bunches of cassava tubers harvested from these sites were washed with distilled water, peeled, chopped in to pieces using a stainless steel knife, grounded and sieved. Approximately 2 g each of the grounded sample was weighed and placed in a 50 ml beaker. Twenty mills (20ml) of concentrated nitric acid was added and shaken vigorously. The beaker was heated gently on an electric heating plate placed in a fume cupboard till a clear solution was obtained. A dropwise addition of concentrated nitric acid was carried out to ensure that all the organic matter was digested. The digested samples were left to cool and then filtered through Whatman No. 42 filter paper. The resulting solutions were transferred into 50 ml graduated flask and made up to the mark with distilled water (Radojevic and Bashkin, 1999). Both the cassava roots, peel, and the soil extracts were analyzed using Atomic Absorption Spectrophotometer(AAS), SP Pye (1900) Unicam model connected to computer, for the level of the metals; copper (Cu), chromium (Cr), iron (Fe), zinc (Zn),manganese (Mn), and lead (Pb).

Statistical data handling

All statistical analyses were performed using SPSS 17 package. Mean concentration of the heavy metal determined were compared using One-way ANOVA, followed by multiple comparisons using Tukey test. A significance level of (p = 0.05) was used throughout the study.

RESULTS

The taxonomic classification of the soil (Table. 1) was sandy loam with pH of 6.78, EC of 89.40µS/cm. The high pH level of the soil is generally within the range for soil in the region; soil pH plays an important role in the sorption of heavy metals, it controls the solubility and hydrolysis of metal hydroxides, carbonates and phosphates and also influences ion-pair formation, solubility of organic matter, as well as surface charge of Fe, Mn and Al-oxides, organic matter and clay edges (Garba *et al*., 2012a).

TABLE 1: Physicochemical Properties of the Soil Samples

Soil Parameters	Values ±SD
Clay (%)	24.00 ±0.50
Sand (%)	66.00 ±0.24
Silt (%)	10.00 ±0.58
pH	6.78 ±0.06
OMC (%)	0.62 ±0.04
CEC (mol/100g soil)	4.74 ±0.01
EC (µS/cm)	89.40 ±0.04
Ca^{2+} (mol/kg)	0.60 ±0.05
Mg^{2+} (mol/kg)	5.00 ±0.90
Na^{+} (mol/kg)	0.34 ±0.09
K^{+} (mol/kg)	0.50 ±0.05

Measurements are averages of three replicates, CEC: Cation exchange capacity. EC: Electrical conductivity, OMC: Organic Matter Content, ±SD = Standard deviation.

TABLE 2: The Mean ±SD Concentration (µg/g) of the Heavy Metals: Cu, Cr, Fe, Mg, Mn, Pb, and Zn IN Soil and Cassava Roots Samples

Sample/ Element	Soil	Cassava root	Cassava Peel
Cu	0.791 ±.011	BDL	BDL
Cr	0.013 ±0.008	BDL	BDL
Fe	42.306 ±0.004	2.936 ±0.007	10.748 ±0.049
Zn	0.711 ±0.009	0.725 ±0.004	0.923 ±0.004
Mn	BDL	0.191 ±0.047	0.713 ±0.053
Pb	0.235 ±0.007	BDL	BDL

Difference between means were found not significantly at (P = 0.05) according to the Tukey multiple comparison test. Data are presented in mean ±SD = Standard deviation (n = 5), BDL = Below Detection Limit.

It has been reported that cassava tolerates soils within a wide pH range (4.0 to pH 8.0) but the best pH range for growing cassava is 5.5–6.5 (Titus *et al*., 2011). The soil had moderately low organic matter content (0.62%) and relatively low cation exchange capacity (CEC) (4.74 mol/100g soil). CEC measures the ability of soils to allow for easy exchange of cations between its surface and solutions (Garba *et al*., 2012b). Human exposure to toxic heavy metals (such as chromium, iron, copper and zinc) is known to be responsible for many human health problems. Contaminated foods have been identified as one of the major source of such heavy metals to man (Ward, 1995). Contamination of food may also take place during harvesting, transportation, storage, processing and/or preparation. Table 2 above shows the natural heavy metal content of the soil, the peeled cassava root, and the peels of the cassava roots observed in this study. With the exception of manganese (Mn) all the heavy metals determined were detected in the soil samples. Iron (Fe) has the highest value of 42.306µg/g, followed by copper (Cu) 0.791µg/g, then Zn (0.711µg/g and lead (Pb) 0.235µg/g. Chromium (Cr) has the least value of 0.013µg/g and it has been indicated that the toxic level of Cr in soil is around 2-50 µg/g (Bergmann, 1992), whereas manganese (Mn) was found below detection limit. The level of the metals in the soil could be attributed to the remoteness of the farms to the places of high anthropogenic activities. Occurrence of heavy metals in soils is a consequence of industrialization, particularly in soils of urban areas which show higher levels of heavy metals than those in their rural counterpart (Lavado *et al*., 1998).

In the peeled cassava root, iron (Fe) has the highest value of 2.938µg/g, zinc had 0.725µg/g, and 0.186µg/g was observed for manganese whereas the metals; Cu, Cr, and Pb were found below detection limits. Report has it that Zn is more actively mobilized than Cu from roots to shoots (Barrg and Clark, 1998). In the peels, iron (Fe) has the highest value of 10.748µg/g, followed by zinc and Mn with the values 0.923 and 0.713µg/g respectively. Chamber and Sidle (1991) found that plant metal levels were highly variable when related to soil metal levels. The heavy metals; Cu, Cr, and Pb, in this study were all found below detection limits. The sources of heavy metals in plants are their growth media (air, soil, nutrients) from which heavy metals are taken up by roots or foliage. Therefore the concentration of metals in plant tissue is a function of the metal content in the growing environment.

TABLE 3: Concentration (µg/g) of the heavy metals; Cu, Cr, Zn, Mn, and Pb observed in cassava roots of this study and some studies done elsewhere worldwide

Elements/Place of study	Cu	Cr	Zn	Mn	Pb	Fe	(Reference)
Konduga (Nigeria)	BD	BDL	0.725	0.191	BDL	2.936	This study
Otukpo (Nigeria)	0.053	0.023	0.318	....	0.522	0.438	(Abba *et al*., 2013)
Ohimini(Nigeria)	0.057	0.026	0.344	....	0.511	0.410	(Abba *et al*., 2013)
Katsina-Ala(Nigeria)	0.054	0.025	0.361	....	0.548	0.389	(Abba *et al*., 2013)
Ugheli (Nigeria)	......	12.63	....	....	1.200	......	(Nwajei, 2009)
Kumasi (Ghana)	0.862	....	22.258	......	......	29.908	(Apau *et al*., 2014)

DISCUSSION

In all the samples analyzed (the soil, peeled root, and the peels), the soil sample was found to contain all the heavy metals in different concentrations. Iron (Fe) and zinc (Zn) were observed at relatively higher level compared to the other elements. The level of Fe and Zn observed in the cassava root of this study was found far less than what was observed in cassava root from markets in the Kumasi Metropolis (Table 3), (Apau *et al*., 2014). It was also found much greater than the levels of Fe and Zn observed in Otukpo, Ohimini, and Katsina-Ala (Table 3) as reported by Abba *et al.* (2013). The heavy metals; Cu, Cr, and Pb were all found below detection limit in peeled cassava of this study. In contrary the levels: 0.862, 0.057, and 0.053µg/g were observed in descending order for Cu from Kumasi, Ohimini, and Otukpo, respectively (Apau *et al*., 2014; Abba *et al*., 2013). These areas are places of high anthropogenic activity (such as high traffic density, industries and incessant power plants). According to numerous studies, the pollution sources of heavy metals in environment are mainly derived from anthropogenic sources. In urban soils and urban road dusts, the anthropogenic sources of heavy metals include traffic emission (vehicle exhaust particles, tire wear particles, weathered street surface particles, brake lining wear particles), industrial emission (power plants, coal combustion, metallurgical industry, auto repair shop, chemical plant *etc*.), domestic emission, weathering of building and pavement surface, atmospheric deposit and so on (Morton-Bermea *et al*., 2009). It has been proven that, any plant found growing in heavy metal contaminated soil usually increases their heavy metal tissue concentration (Orrono and Lavado, 2009).

It has been reported that the differences in metal contents present in food samples depended on the physical and chemical nature of the soil and absorption capacity of each metal by the plant, which is altered by various factors like environmental and human interference, and the nature of the plant (Zurera *et al*., 1989). Most of the cassava farms are found in remote areas (villages) therefore the farms are far away from places of high anthropogenic activities. More so, in this part of the country cassava production is about the cheapest because; it has minimum cost of production. With or without fertilizer, cassava grows and produces tubers enough to go round the family. Therefore less or no fertilizers were used on the farmland to enhanced soil fertility talk less of being contaminated. Reports has it that, the anthropogenic sources of heavy metals in agricultural soils include mining, smelting, waste disposal, urban effluent, vehicle exhausts, sewage sludge, pesticides, fertilizers application and so on (Yang *et al*., 2009). Of all the heavy metals analyzed, iron was found in abundant in both the pericarp and mesocarp of the cassava roots followed by Zinc. It has been envisaged that, iron and zinc are usually present in soil in adequate to excess amounts, and a plant can improve its iron and zinc uptake by using strategies to solubilize the iron and zinc present in the soil (Rengel, 2001). As with humans and other animals, iron and zinc are essential for plant health and proper growth and development. Thus, plant foods are significant sources of iron and zinc for humans. Iron is a catalyst in chlorophyll formation, is a component of ferredoxin, and is present in several peroxidase, catalase, and cytochrome oxidase enzymes (Strachan, 2010). Cassava roots are the chief source of some important minerals like zinc, magnesium, copper, iron and manganese (Ikegwuonu, 2013).

CONCLUSION

Consumption of cassava roots and sometimes the leaves in Nigeria is always on the increase especially in the rural areas. These could be due to the cheapness in its production. Cassava is not mostly consumed routine as food in this part of the country (the northeast) but as a supplement; therefore the levels of these elements (Fe, Zn, and Mn) observed in the root may not only be safe for consumption but helpful to the body.

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REFERENCES

Abah J., Ubwa S.T., Audu S.I. and Malu S.P. (2013) Assessment of the Levels of Some Trace Metals in Soils and Roots of Cassava Grown Under Usage of

Agrochemicals in Some Parts of Benue State, Nigeria. Res. J. Chem. Sci. Vol. 3(5), 63-70.

Adekunle, I. M. and Akinyemi, M. F. (2004) "Lead levels of certain consumer products in Nigeria: a case study of smoked fish foods from Abeokuta". Food and Chemical Toxicology, 42, 1463 – 1468.

Adepoju, O.T., Adekola, Y.G., Mustapha, S.O. and Ogunola, S.I. (2010) Effect of processing methods on nutrient retention and contribution of cassava *(manihot spp)* to nutrient intake of Nigerian consumers. Afr. J. Food Agric. Nutr. Dev. 10(2), 2099-2111.

Akinpelu A.O., Amamgbo E.F., Olojede A.O. and Oyekale A.S. (2011) Health implications of cassava production and consumption, Journal of Agriculture and Social Research, 11(1), 118-125.

American Medical Association (1998) Home Medical Encyclopedia, Volume Two, I - Z Clayman, M.D., Charles B.; Charles B. Clayman, M.D. (Edited by) Published by Random House, New York, p. 1184

Ano A.O., (2003) Studies on the effect of liming on the yield of two cassava cultivars, NRCRI Annual Report 2003, p. 9,

Apau, J., Acheampong, A., Appiah, J.A. and Ansong, E. (2014) Levels and Health Risk Assessment of Heavy Metals in Tubers from Markets in the Kumasi Metropolis, Ghana. International Journal of Science and Technology Volume 3 No. 9, 534-539.

Ayankunbi, M. A, Keshinro, O.O and Egele, P. (1991) Effect of methods of preparation on the nutrient composition of some cassava products- Gari (Eba) Lafun, and *Fufu*. Food Chemistry, 41,349-354.

Barratt, N., Chitundu, D., Dover, O., Elsinga1, J., Eriksson, S., Guma, L., Haggblade, M., Haggblade, S., Henn, T.O., Locke, F.R., O'Donnell, C., Smith, C. and Stevens, T. (2006) Cassava as drought insurance: Food security implications of cassava trials in Central Zambia. *Agrekon*, Vol 45, No 1, 106-123.

Barrg, S.A.S. and Clark (1998) Problems of interpreting the relationship between the amounts of lead and Zinc in plants and soil on metalliferous wastes. N. Phytol., 81, 773-783.

Bergmann, W**.** (1992) "Nutritional disorders of plants", Gustav Fisher, New York, USA, p237

Cao, H. B., Chen, J.J., Zhang, J., Zhang, H., Qiao, L. and Men, Y. (2010)Heavy metals in rice and garden vegetables and their potential health risks to inhabitants in the vicinity of an industrial zone in Jiangsu, China. J Environ Sci., 22(11), 1792–9.

Cardoso, A.P., Mirione, E., Ernesto, M., Massaza, F., Cliff, J., Haque, M.R. and Bradbury, J.H. (2005) Processing of cassava roots to remove cyanogens. *Journal of Food Composition and Analysis*, 18, 451–460.

Ceballos, H., Iglesias, A.C., Perez, J.C. and Dixon, A. (2004) Cassava breeding: opportunities and challenges. *Plant. Mol. Biol*., 56, 506–516.

Chambers, J. and Sidle, R. (1991) Fate of heavy metals in an abandoned lead-zinc tailings pond and vegetation. Journal of Environmental Quality, 20, 745-758.

Dudka, S. & Miller, W.P. (1999) Accumulation of potentially toxic elements in plants and their transfer to human food chain. Journal of Environmental Science and Health. Part. B, Pesticides, Food Contaminants, and Agricultural Wastes, 34, 681–708.

FAO (2008) Corporate document repository; the impact of HIV/AIDS on the agricultural sector

//www.fao.org /DOCREP/005/Y4636E/y4636e05.htm,

Garba, S.T., Maina, H.M., Oseamehon, S.A. and Barminas, J.T. (2012a) Inhibitory side Effects of the Metals: Copper, Cadmium, Chromium, and Nickel on seed Germination and Growth of *Eleusine indica. International Research Journal of Basic and Applied Science Vol. 4, No.1,* 14-22.

Garba, S.T., Maina, H.M., Oseamehon, S.A. and Barminas, J.T. (2012b) Uptake, Transport, Re-Translocation and ETDA-Chelation of the Metals: Cu, Cd, Cr, Co and Zn in *Pennisetum pedicellatum.* International Journal of Environmental Sciences: Vol.1 No.2, 70-76.

Hershey, C., Henry, G., Best, R. and Iglesias, C. (1997). *Cassava in Latin America and the Caribbean*.

Hillocks RJ (2002) Cassava in Africa. in: R.J. Hillocks, J.M. Thresh, A. Bellotti (Eds.) Cassava: Biology, Production and Utilization. CABI publishing, Wallingford, UK 26.

Ikegwuonu, N. C. (2013) Cassava Production as an Enterprise. Training Pamphlet, by Small Holders Foundation, Nigeria.

Jackson, M. L. (1973) Soil chemical analysis . Printice Hall. Inc., Englewood Clifs, N.J. Library of congress , USA.

Lavado, R.S., Rodriguez, M.G. Scheiner, J.D., Taboada, M.A., Rubio, G. Alvarez, R., Alaconada, M. and Zubillaga, M.S. (1998) Heavy metals in soils of Argentina: Comparison between urban and agricultural soils. Communication in Soil Science and Plant Analysis 29, 1913-1917.

Liu, Y. S., Gao, Y., Wang, K. W., Mai, X. H., Chen, G. D. and Xu, T. W. (2005) Etiologic study on alimentary tract malignant tumor in villages of high occurrence. China Tropical Medicine, 5, 1139–1141 (in Chinese).

Lu, Y., Yin W., Huang, L.B., Zhang, G. L. and Zhao, Y.G. (2011) Assessment of bioaccessibility and exposure risk of arsenic and lead in urban soils of Guangzhou City, China. Environ Geochem Health; 33, 93–102.

Morton-Bermea, O., Hernández-Álvarez, V., González-Hernández, G., Romero, F., Lozano, R. and Beramendi-Orosco, L.E. (2009) Assessment of heavy metal pollution in urban topsoils from the metropolitan area of Mexico City, Journal of Geochemical Exploration 101, 218–224.

NAAS (2005) Policy options for efficient nitrogen use, Policy paper no. 33. *National Academy of Agricultural Science,* New Delhi, 1-4.

Nwajei, G.E. (2009). Trace element in soils and vegetation in the vicinity of Shell Petroleum company operation area in Ughelli, Delta State of Nigeria.American Journal of Sustainable Agriculture 3(3), 374- 378.

Nweke, F.I. (1994) Processing potentials for cassava production growth. COSCA Working paper No. 3. Collaborative Study of Cassava in Africa, IITA, Ibadan, Nigeria.

Ogbe F.O., Emehute, J.K.U. and Legg, J. (2007) Screening of cassava varieties for whitefly populations, NRCRI Annual Report 2007, 30-33

Orrono, D.I. & Lavado, R.S. (2009) Heavy metal accumulation in *Pelargonium hortorum*: Effects on growth and development. International Journal of Experimental Botany, 78, 75-82

Radojevic, M. & Bashkin, V. (1999) Practical environmental analysis. The Royal Society of Chemistry London, pp. 287-361

Rengel, Z. (2001) Genotypic differences in micronutrient use efficiency in crops. Commun. soil. sci. plant anal. 32, 1163-1186.

Strachan, S. (2010) Trace elements. Current Anaesthesis and Critical Care 21, 44-48.

Titus P., Lawrence J. and Seesahai A., (2011) Commercial cassava production, technical bulletin, www.cardi.org/.../ 2011/.../commercial-cassava-production-technical Accessed10/02/2013.

USDA (2004) Natural resources conservation service: soil survey laboratory methods manual, soil survey investigation report no. 42 version 4.0. natural resources conservation service, 700.

USEPA (2000) Supplementary guidance for conducting health risk assessment of chemical mixtures, Risk Assessment Forum Technical Panel; [EPA/630/R-00/002].

Yang, P., Mao, R. Shao, H. and Gao, Y. (2009) The spatial variability of heavy metal distribution in the suburban farmland of Taihang Piedmont Plain, China, C. R. Biologies 332, 558–566.

Ward, C.L., Omura, S. & Kopito, R.R. (1995) Degradation of CFTR by the ubiquitin-proteasome pathway. *Cell* 83, 121-127.

Wilson, W.M. & Dufour, D.L. **(**2002) Why “bitter” cassava? The productivity of “bitter” and “sweet” cassava in a Tukanoan Indian settlement in the Northwest Amazon. *Economic Botany* 56(1), 49-57.

World Bank, (1993) A strategy to develop agriculture and a focus for the World Bank, World Bank technical paper no. 203, Africa technical department series, 1-10,

Zheng, N., Wang, Q. C., Zheng, D. M. (2007) Health risk of Hg, Pb, Cd, Zn, and Cu to the inhabitants around Huludao Zinc Plant in China via consumption of vegetables. Sci Total Environ., 383,81–9.

Zurera-Cosano, G., Moreno-Rojas, R., Salmeron-Egea, J., and Lora, R.P. (1989) Heavy metal uptake from greenhouse border soils for edible vegetables. J. Sci. Food Agric., 49, 307–314.