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Full Length Research Paper

Assessment of trace metal levels in commonly used vegetables sold at selected Markets in Ghana

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Trace metal levels were assessed in edible parts of thirteen (13) common vegetables sold at seven (7) selected markets; Kumasi, Asante-Mampong, Obuasi, Nkenkesu, Akomadan, Daboase and Nobekwaw in Ghana. The vegetable samples were analysed for Pb, Fe, Zn and Cu using Atomic Absorption Spectrophotometry. The concentration of Pb registered in *Lactuca sativa* (1.82 mg/kg), *Daucus carota* (1.72 mg/kg), *Solanum melongena* (1.44 mg/kg) and *Cucumis sativus* (1.37 mg/kg) all from Obuasi were above the FAO/WHO MPL of 0.3 mg/kg. The mean concentrations of Zn in the vegetable samples were all below the FAO/WHO MPL of 100 mg/kg with the exception of *Piper nigrum* from Kumasi which recorded a mean Zn value of 298.78 mg/kg. The highest mean Fe concentration of 698.79 mg/kg was registered in *Lycopersicum esculentus,* above the WHO/FAO MPL for Fe of 425 mg/kg. The mean concentration of Cu recorded for all the vegetables were below the FAO/WHO MPL of 73 mg/kg for Cu. The overall mean concentration of trace metals in the vegetables analysed appeared to be within safe limits laid down by FAO/WHO.

Key Words: Trace metals, maximum permissible level, atomic absorption spectrophotometry, mean concentration, edible parts.

INTRODUCTION

Globally vegetables are treasured in many cultures because of their nutritional and ethno-medicinal properties. Vegetables such as *Cucumis sativus, Brassica oleraceae, Solanum melongena and Allium sativum* serve as ingredients in most meals. *Lycopersicum esculentum* consumption might be beneficial for reducing cardiovascular risk associated with type 2 diabetes (Shidfar *et al.*, 2011). *Lycopersicum esculentum* and *Brassica oleracea* are good sources of ascorbic acid which is important in tyrosine metabolism as reducing agent. Vegetables serve as sources of neutralizing agents for acidic substances during digestion. They boost neural development in babies and protect the hearts and minds of adults. Vegetables are composed of different types of vitamins such as A, B_6, E, C, K, and several others. For example *Daucus carota* contains vitamins B_1, B_2, B_6, nicotinic acid, pantothenic acid and vitamin C. Vitamin E increases the body's absorption of calcium, an essential mineral for strong teeth and bones whilst vitamin A keeps eyes healthy and increases body's resistance to diseases. Vegetables also possess phytoconstituents with antioxidant, antibacterial, antifungal, antiviral, anticarcinogenic and hypoglycaemic properties (Gruda, 2005).

Trace metals are environmental pollutants which originate from both natural sources (e.g. volcanoes, etc.) and human activities such as mining, preservation of wood and application of fertilizers on farm lands. Vegetables may be contaminated with hazardous metals such as lead (Pb), arsenic (As), cadmium (Cd), copper (Cu) and several others. These contaminants are absorbed from the atmosphere and soil through the leaves and roots. On absorption they are stored in the leaves, stems and roots. Bioaccumulation of hazardous metals in the food chain is perilous to living organisms even at minute concentrations. Trivalent methylated arsenic is very toxic and is more efficient at causing DNA breakdown (Vaclavikova *et al.*, 2008). Lead is toxic to living organisms such as man, microorganisms and animals and mercury is also known to affect photosynthesis and oxidative metabolism by interfering with the electron transport in chloroplasts and mitochondria (Tangahu *et al.,* 2011).

Trace metals may enter humans' through direct inges-

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tion of soil, inhalation of dust and consumption of plants grown in metal-contaminated soil (Cambra *et al.*, 1999; Dudka and Miller, 1999; Hawley, 1985). Hazardous metal intake via food chain by humans has been reported in many countries (Suruchi and Khanna, 2011). Trace metal contamination of vegetables must be of great concern to scientist because of the health threat hazardous metals pose to humans and other living organisms. The concentrations of trace metals in most of these vegetables sold in the markets are unknown as much research had not been carried out. Contents above and critically below the WHO/FAO maximum permissible limits (MPL) of hazardous metals may adversely affect the health of humans. The current study sought to determine the concentrations of trace metals in vegetables sold in selected markets in Ghana.

MATERIALS AND METHODS

Sampling Sites

Vegetable samples were randomly obtained from 7 different markets within 3 regions of Ghana. Five markets were sampled in Ashanti region and 1 market each in Western and Brong-Ahafo regions. Sampled markets from Ashanti region were in Kumasi, Asante-Mampong, Obuasi, Nkenkesu and Akomadan. The remaining 2 markets were in Daboase and Nobekwaw from Western and Brong-Ahafo regions respectively. Brief descriptions of the locations of the towns in which the markets are situated are as below:

Kumasi (6^o35′N – 40′N, 1^o30′W) is the capital town of Ashanti Region of Ghana and is located 250-300 m above sea level. It is the second most populous city after the nation's capital, Accra. The Ghana Districts (2012) reported that the population of Kumasi is two million, twenty-two thousand nine hundred and nineteen (2,022,919) and covers an area of two hundred and fifty-four square kilometers (254 km^2). Kumasi is relatively at the central location of Ghana and serves as the trading center for all people from the ten regions of the country. The products traded include vegetables, medicinal plants, foodstuffs and many others.

Asante-Mampong is the capital of Sekyere - West Municipal Assembly. Mampong is 50 km north of Kumasi. The municipality is located within longitudes $0^0$05''W and $1^0$30''W and latitudes $6^0$55''N and $7^0$30''N, covering a total land area of about 449 km^2 (Mampong Municipal Assembly, 2010).The projected population for 2011 is about 43,469.

Obuasi is located in the Obuasi Municipality situated at the Southern part of Ashanti region between latitude 5.35 N and 5.65 N and longitude 6.35 N and 6.90 N. It covers a land area of 162.4 km^2. According to the 2000 Housing and Population Census the population of the town is 205,000 (Ghana Statistical Services, 2000). The district has an undulating topography and semi-equatorial type of climate with a double rainfall regime. The Municipality is situated 64 km from Kumasi.

Daboase which is the capital of Mpohor Wassa East District has a population of 36,409. The district is located at the southern-eastern end of Western region and has a land area of 1,880 km^2. The coordinates of Daboase are $5^0$8″ N and $1^0$39 ″ E.

Akomadan and Nkenkesu are urban localities found in the Offinso municipal which lies between longitude 1' 65 W and 1' 45 E and latitudes 6' 45 N and 7' 25 S. Akomadan is the capital of Offinso North district with a population of 14,018 whilst Nkenkesu has a population of 10,014. The main economic activity in both towns is farming.

Nobekwaw is one of the towns found in the Asunafo South District located at the southern part of the Brong - Ahafo region on latitude 60 10^0 and 60 45^0 N and longitude 20 45^0 W and 00 45^0 E. About 61.7% of the residents are farmers (Ghana districts, 2012).

Samples Collection, Identification and Preparation

Samples were randomly purchased directly from 7 selected local markets of the studied areas. These markets were popularly known for the sale of vegetables and other farm products. A total of 91 samples were identified and collected between March and June 2012 and specimen vouchers kept at the College of Agriculture Education, University of Education, Winneba, Asante - Mampong, Ghana. The samples purchased were as indicated in Table 1. The edible portions of the samples were washed thoroughly with distilled water to remove any soil contaminants and later solar dried for forty-eight hours (48 hrs). Dried samples were weighed and mechanically ground using stainless steel grinder. The pulverized samples were sent to CSIR-SRI, Kwadaso-Kumasi, Ghana for digestion and trace metal content analysis.

Digestion and Analysis of Vegetable Samples

The content of metals was determined according to the method employed by Sarpong *et al*. (2012). The vegetables plants samples were sent to Council for Scientific and Industrial Research –Soil Research Institute (CSIR-SRI) at Kwadaso, Kumasi for digestion and analysis. Dry Ashing Method of digestion was adopted from the protocol of Perkin –Elmer manual for atomic absorption spectrophotometry. Samples were weighed (8 g) each into a crucible made of porcelain, contents dried at 110 ^{0}C and moistened with magnesium nitrate (50% w/v). The contents were ashed in a controlled muffle carbolated furnace at a temperature of 450 ^{0}C and left overnight to ensure complete oxidation of

Table 1. Names of vegetable samples and areas of study.

Name of Plant	Common Name	Family Name	Part of Plant Used	Areas of Study
Piper nigrum	Pepper	Solanaceae	Fruit	Kumasi, Asante-Mampong, Obuasi, Nkenkesu, Akomadan, Nobekwaw and Daboase.
Lycopersicum esculentum	Tomato	Solanaceae	Fruit	
Daucus carota	Carrot	Apiaceae	Root	
Albermoschus esculentus	Okro	Melvaceae	Fruit	
Solanum melongena	Garden eggs	Solanaceae	Fruit	
Cucumis sativus	Cucumber	Cucurbitaceae	Fruit	
Capsium annuum	Green pepper	Solanaceae	Fruit	
Ipomoea batatas	Sweet potatoes	Convolvulaceae	Tuberous root	
Allium ascalonicum	Spring onion	Liliaceae	Bulb	
Phaseolus vulgaris	French beans	Leguminaeceae	Seeds	
Lactuca sativa	Lettuce	Asteraceae	Leaves	
Allium cepa	Onion	Liliaceae	Bulb	
Brassica oleraceae	Cabbage	Brassicaceae	Leaves	

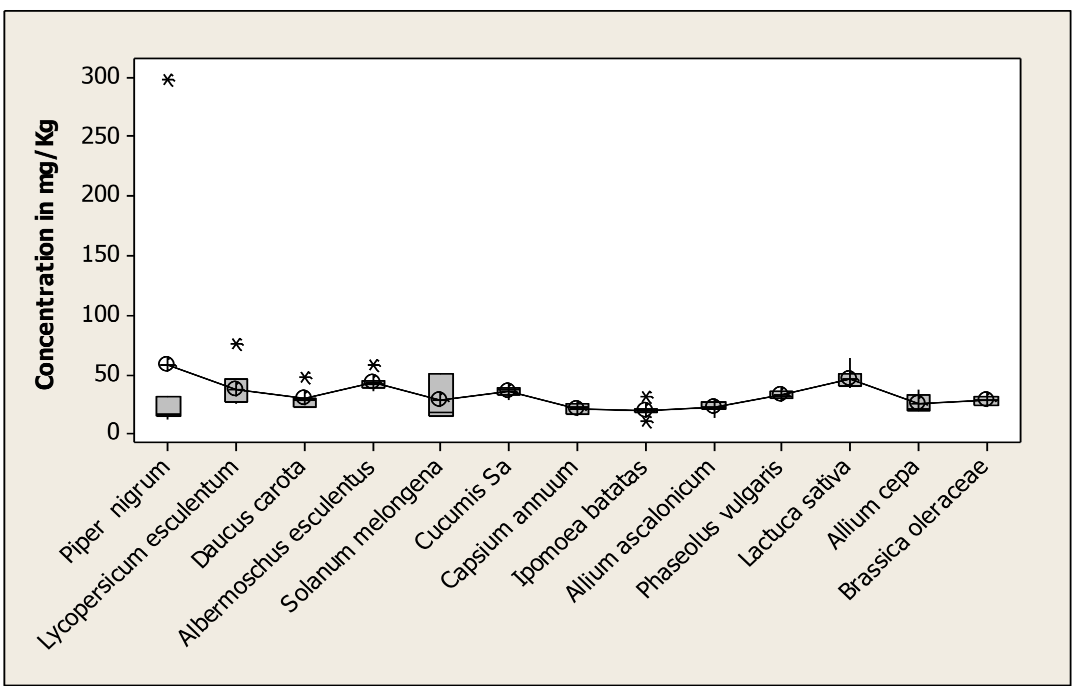

Figure 1. Mean concentration of Zn in selected vegetables samples.

organic components of the sample. The ash of each sample was dissolved in 20 ml of concentrated nitric (HNO_3) and perchloric ($HClO_4$) acids in a ratio of 9:4 in a 200 ml digestion tube. It was then heated in a block digester to allow thorough dissolution of ash in acid. Heating continued until the brown fume of nitric acid cea-

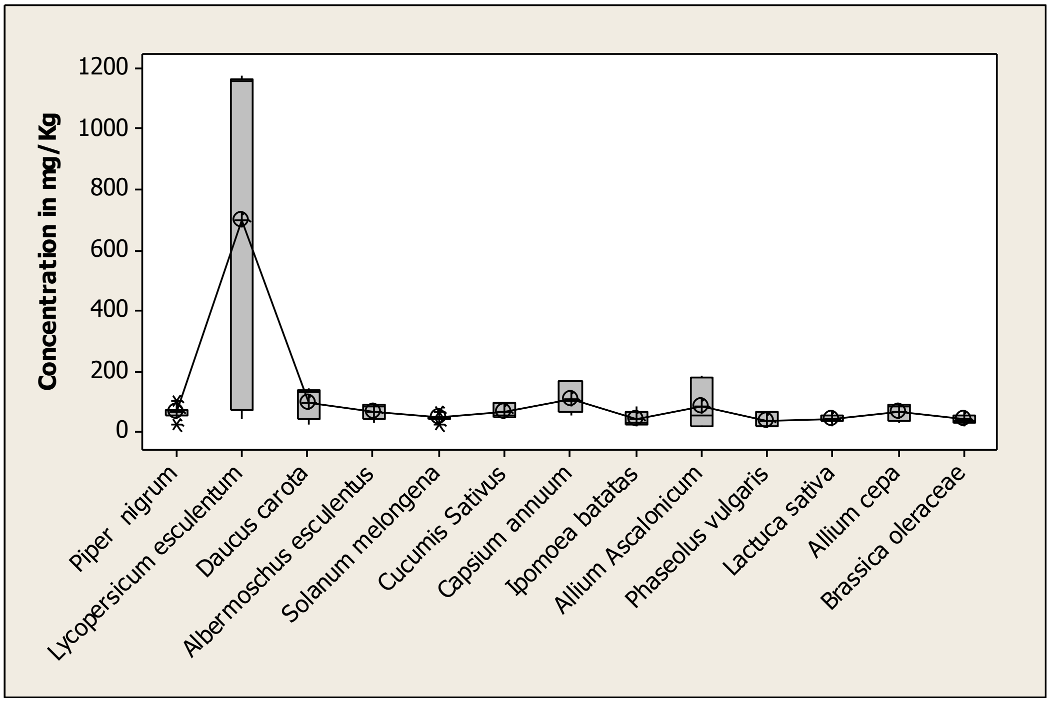

Figure 2. Mean concentration of Fe in selected vegetables samples.

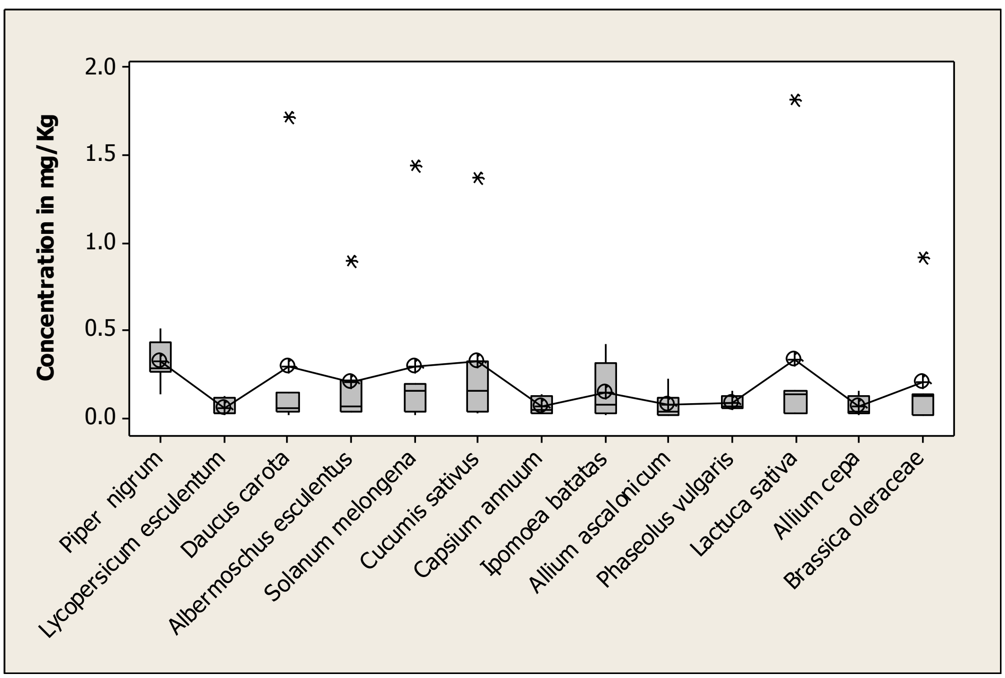

Figure 3. Mean concentration of Pb in selected vegetable samples.

sed and the sample turned clear. The digestion was stopped and distilled water added to obtain a total volume of 20 ml. The final solution was filtered through a 0.45 µm pore size membrane filter paper (Whatman filter paper No. 41). The solution was then analysed for trace metals using VARIAN SPECTRA AA220 Zeeman Atomic Absorption Spectrometer (AAS) (Varian Canada Inc). Determinations of the various metal levels (triplicates) in each sample were performed and the mean values of samples recorded.

RESULTS AND DISCUSSION

The concentration of the trace metals (Zinc, Iron, Copper and Lead) in selected vegetable samples collected from

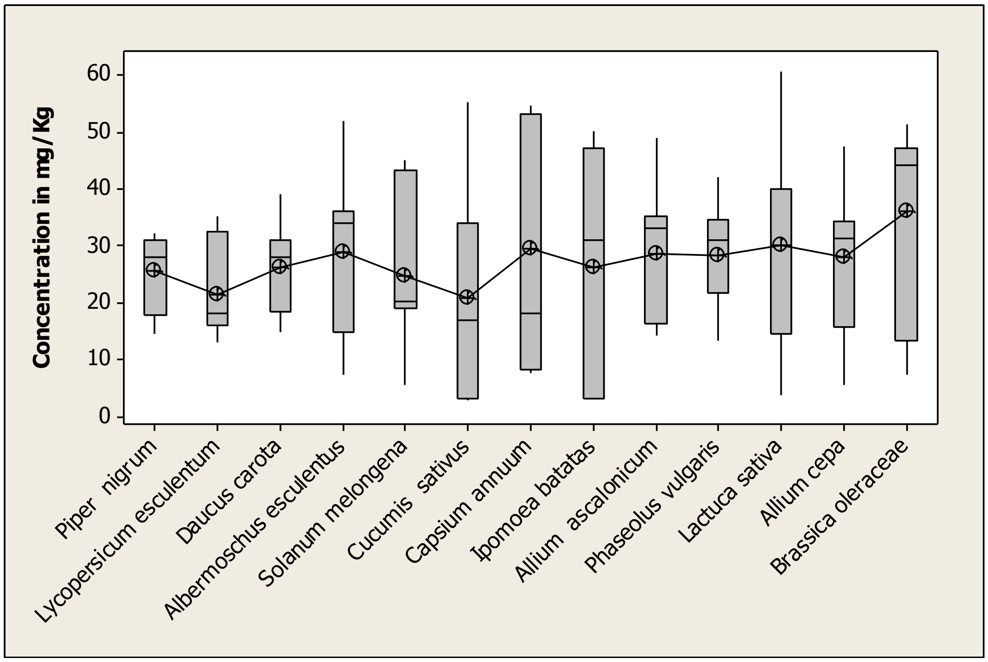

Figure 4. Mean concentration of Cu in selected vegetable samples.

the seven studied areas are indicated in Figure 1-4. These figures showed variation in the contents of the trace metals.

Zinc

Zinc is essential for boosting up immunity, proper growth of foetus, DNA, RNA synthesis and protein synthesis. It is used in reducing diarrhoea in malnourished children or in children who have low Zn levels. Information concerning the harmful effects of Zn is scanty. However, Barone *et al.*, 1998; Gyorffy and Chan, 1992 reported that Zn interferes with Cu metabolism. Also Zn concentration above the permissible amounts may cause intestinal cancer, fever, coughing, fatigue and others. Salgueiro *et al.* (2000) stated that symptoms of acute oral Zn dose may cause dyspeptic nausea, vomiting and diarrhoea.

The mean concentration of Zn in the vegetable samples were all below the FAO/WHO MPL of 100 mg/kg with the exception of *Piper nigrum* from Kumasi where a mean Zn value of 298.78 mg/kg was recorded. *Piper nigrum* is widely used locally for medicinal purposes and also to spice food. The value (298.78 mg/kg) is disturbing since continuous use of the specie would be detrimental to the health of consumers. The lowest mean Zn level of 19.13 mg/kg was registered in *Ipomoea batatas*. The observed mean Zn levels in vegetable samples in the current investigation showed elevated levels in relation to the previous study where Zn contents ranged between 2.76 mg/kg and 13.85 mg/kg (Krejpcio *et al*., 2007). The mean Zn concentration of 21.1 mg/kg in *Capsicum annuum* in the present study was lower than 68 mg/kg in the study carried out by Nkansah and Opoku (2010). It was observed that mean Zn contents in *Lactuca sativa*, 45.88 mg/kg was higher than the other edible parts of vegetable samples studied. This observation agreed with an earlier finding made that leafy vegetables could accumulate elevated amounts of trace metals (Vousta *et al*.,1996). *Albermoschus esculentus* is a specie locally used to prepare soup or stew, eaten with kenkey and banku. With a mean Zn concentration of 42.37 mg/kg and the fact that trace metals bioaccumulate as a result of continuous consumption, *Albermoschus esculentus* could adversely affect the health of consumers.

Statistically no significant difference ($P>0.05$) was observed in mean Zn levels among the selected vegetables.

Iron

The human body requires Fe for proper growth and development. Iron plays an important part in the production of haemaglobin and red blood cells. Insufficient amounts of iron leads to anaemia and cough. It plays a vital part in strengthening the immune system of humans.

Analysis of variance (ANOVA) indicated a significantly higher ($p<0.05$) concentration of Fe in *Lycopersicum esculentus* compared with the other selected vegetable samples, figure 2.

Results from the studies revealed mean Fe concentration to be less than WHO/FAO MPL for Fe of 425 mg/kg except *Lycopersicum esculentus* which recorded mean Fe concentration of 698.79 mg/kg. Four out of the seven markets studied namely: Nobekwaw, Daboase, Obuasi and Asante Mampong recorded mean Fe concentrations of *Lycopersicum esculentus* in excess of 1100 mg/kg. The lowest concentration of Fe was recorded in *Phaseolus vulgaris*, 35.63 mg/kg. Small amounts of Fe are required by the body. Dietary Fe intake for men and pregnant women are 0.5 - 1.0 mg/day and 2.0 - 4.8 mg/day respectively. Menstruating women and adolescents need 1.0 and 2.0 mg/day of Fe respectively. Children require 0.4 - 1.0 mg/day while infants require 0.5 - 1.5 mg/day (Shabib, 1996).

Human bodies absorb minute amounts of Fe in the foods we consume. To meet the Fe requirements of the body large quantities of Fe rich vegetables had to be consumed. This notwithstanding, it appears that large intake of samples of *Lycopersicum esculentus* containing higher concentrations of Fe would be harmful to the health of consumers since beyond FAO/WHO MPL the concentrations tends to be toxic. Symptoms of toxicity include vomiting, hemorrhage and cardiac depression.

Daucus carota has numerous health benefits and its usage is very popular among Ghanaians. The presence of beta carotene makes it a natural anti-oxidant. It also serves as an excellent source of vitamins A, B, C and metals such as calcium, iron, magnesium, sodium and potassium. Although *Daucus carota* registered a mean Fe concentration of 96.56 mg/kg, which is below the FAO/WHO MPL amounts, continuous usage of these species can be dangerous to the health of consumers.

Lead

It has unknown biological importance to humans. It gets into the body via inhalation of Pb dust, ingestion of Pb contaminated soil and consumption of Pb contaminated food. Levels above MPL are perilous to humans. It can adversely affect body organs and may lead to death. Lead also interferes with the metabolism of calcium and vitamin D.

The mean Pb concentration recorded in *Piper nigrum* (0.31 mg/kg), *Cucumis sativus* (0.32 mg/kg) and *Lactuca sativa* (0.33 mg/kg) were slightly above the FAO/WHO MPL of 0.3 mg/kg. The highest concentration of Pb was registered in *Lactuca sativa* (1.82 mg/kg) followed by *Daucus carota* (1.72 mg/kg), *Solanum melongena* (1.44 mg/kg) and *Cucumis sativus* (1.37 mg/kg) all from Obuasi. The lowest mean Pb concentration was recorded in *Lycopersicum esculentus* (0.054 mg/kg), *Allium cepa* (0.061 mg/kg), *Capsium annuum* (0.061 mg/kg), *Allium ascalonicum* (0.067 mg/kg).

Obuasi is a mining town. During mining operations trace metals are released into the environment (Sen *et al.*, 2011). Trace metals released may include Pb which may be taken up by the vegetables. The use of metal-based pesticides and application of fertilizers to the soil might lead to contamination and elevated levels of Pb in vegetable samples (Maleki and Zarasvand, 2008).

Current results obtained for mean Pb concentrations in *Capsicum annuum* (0.02 mg/kg - 0.13 mg/kg), *Piper nigrum* (0.13 mg/kg - 0.51 mg/kg) and *Allium cepa* (0.01 mg/kg - 0.15 mg/kg) were lower than that of Krejpcio (2007) who reported *Capsicum annuum* (0.21 mg/kg - 0.65mg/kg), *Piper nigrum* (0.17 mg/kg - 0.82 mg/kg) and *Allium cepa* (0.34 mg/kg - 0.61 mg/kg). However, the mean Pb concentration recorded in the current study from *Cucumis sativus* (0.32 mg/kg), *Solanum melongena* (0.29 mg/kg), *Daucus carota* (0.29 mg/kg) and *Piper nigrum* (0.31 mg/kg) was in agreement with the mean Pb levels of 0.28 mg/kg reported by Odoh and Adebayo (2011).

Copper

Copper is prevalent in our vicinities and released through natural and anthropogenic sources. Naturally Cu is released through decaying of vegetation and forest fires. Human activities such as mining, production and application of phosphate fertilizers and several others contribute to increasing levels of Cu in the surrounding. Like other trace metals humans are exposed to Cu through the food chain by consuming food contaminated with Cu. Humans require trace amounts of Cu for good health, for example it aids Fe in the formation of red blood cells. Deficiency in Cu results in anaemia and osteoporosis. FAO/WHO MPL for Cu is 73 mg/kg. Above this concentration Cu becomes toxic to the body and may cause vomiting, stomach cramps and nausea.

The highest mean concentration of Cu, 36.13 mg/kg was recorded for *Brassica oleraceae* while the lowest mean concentration of 20.88 mg/kg was registered in *Cucumis sativus.* Though mean concentration of Cu was below FAO/WHO MPL, long term use of these vegetables can be perilous to consumers. No significant difference ($p > 0.05$) was observed in mean concentration of Cu among the selected vegetables.

The mean Cu level, 0.31 mg/kg recorded for *Piper nigrum* in the current study was a little lower than the 0.38 mg/kg (*Piper nigrum*) reported by Krejpcio *et al.* (2007).

CONCLUSION

Vegetables can take up high amount of metals from contaminated soils, as well as from contaminated water and polluted air. Besides the natural levels present in soils, water and air, a matter of concern is the addition of chemical products such as fertilizers, fungicides, insecticides and herbicides to crops. These products may contain several metals and their additions can increase the metal amounts in soil and water. Furthermore, the physical and chemical forms in which they are dispersed can increase the metal availability for plants and so increase the metal concentrations in vegetables.

Majority of the vegetable samples analyzed demonstrated presence of hazardous metals, though concentrations were below the FAO/WHO MPL amounts. Due to mankind's actions especially in modern industrialization there is increase in release of hazardous metals to the ecosystem. Hazardous metals' presence even in minute quantities should be a cause of worry because hazardous metals bio-accumulate in vegetables and ingestion can be harmful to consumers.

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