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A STUDY OF SOME HEAVY METAL CONTENT IN SELECTED VEGETABLE TYPES IRRIGATED WITH WASTE IN TAKORADI METROPOLIS OF GHANA

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ABSTRACT

One of the easiest ways of ameliorating the effect of fresh water scarcity created by climate change among resource poor farmers in the developing countries world-wide is the use of waste water for vegetable production in irrigated fields. Unfortunately, it often results in heavy metal contamination of the vegetables produced. This development is a major concern among food producers and health professionals all over the world due to the systemic health problems which can develop as a result of excessive accumulation of dietary heavy metals such as iron (Fe), copper (Cu) and zinc (Zn) in human body. The aim of this study was to establish the effect of waste water source location within Takoradi metropolis of the Western Region of Ghana on their heavy metal content and the vegetables produced with them under full irrigation systems. The objectives were to: i) determine the iron, copper and zinc content of the waste water used for irrigating the vegetable crops. ii) determine the iron, copper and zinc content of the vegetables produced with the waste water used during irrigation of the crops. iii) Compare the heavy metal content of the vegetables produced with the maximum recommended level by the FAO/WHO. The concentration of heavy metals (iron, copper and zinc) in samples consisting of six types of the vegetables (cabbage, lettuce, spring onion, onion, garden eggs and tomatoes) collected from ten (10) different sites in Takoradi metropolis were determined in micrograms with the use of the Atomic Adsorption Spectrophotometer (AAS) in a 50 ml solution volume and later converted into concentration in milligrams per kilograms (mg/kg). With the use of Microsoft EXCEL Statistical package, the mean values of the heavy metal concentrations were determined for each of the vegetable studied at each site (Takoradi New Site 1, 2, 3 and 4, Takoradi Pioneer Tobacco Company (PTC), Takoradi Anaji 1,2, 3 and Tanokrom 1 and Tanokrom 2) . The study showed that the iron concentrations of the sampled vegetables ranged between 26.32 – 91.28 mg/kg with copper concentration levels ranging between 0 - 50.43 mg/kg, zinc concentration levels between 11.56 - 38.69 mg/kg. Iron concentration levels of sampled wastewater were between 6.95 – 28.20 mg/kg with copper concentrations levels in the sampled wastewater ranging between 1.72 – 2.28 mg/kg, zinc concentrations levels between 3.64 – 25.50 mg/kg. The Iron, copper and zinc concentration levels in the sampled vegetables far exceeded the FAO/WHO recommended maximum levels of 5.0 for Fe, 0.4 for Cu and 1.0mg/kg for Zn. The Iron, copper and zinc concentration levels in the sampled wastewater used for irrigation were also not within the FAO/WHO recommended maximum values of 50 mg/kg for Fe, 1 mg/kg for Cu and 20 mg/kg for Zn. The water samples collected from the New Site 3 recorded the highest level of Fe content, followed by those from New Site 1 and Tanokrom 1 respectively. The water samples collected from Takoradi Anaji 1 had the highest level of Cu content followed by those collected from Takoradi Anaji 2. The water samples collected from Takoradi Anaji 1 had the highest Zn content. It was concluded in the study that vegetable consumers in New Site 3, Tanokrom 1 and Takoradi Anaji 1 and 2 are more prone to the health hazards posed by heavy metals than any other vegetable consumers in the study areas.

INTRODUCTION

As a consequence of the high global food demand, it is not surprising that, worldwide, the biggest user of wastewater (treated or not) is agriculture (Jiménez and Asano, 2008). An important factor which makes wastewater valuable is that it is a reliable source of water, as it is available all year round, unlike pluvial precipitation or seasonal streams. Consequently, it permits higher crop yields, year-round production, and increases the range of crops that can be irrigated, particularly in (but not limited to) arid and semi-arid areas (Keraita et. al., 2008). Where vegetables are the main commodity produced with wastewater, there can be a significant aggregate benefit for the society in terms of a more balanced diet. In the case of Accra, Ghana, for example, more than 200,000 people eat vegetables produced with wastewater every day (Amoah et. al, 2007). On the other hand, this is also the group potentially at risk as the possible adverse health effects to farmers and consumers are well established (WHO, 2006).

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Another well-established advantage of wastewater and sludge reuse is their nutrient content. Even when treated, wastewater recycles organic matter and a larger diversity of nutrients than any commercial fertilizer can provide. Bio solids, sludge and excreta in particular, provide numerous micronutrients such as cobalt, copper, iron, manganese, molybdenum and zinc, which are essential for optimal plant growth. It is estimated that 1000 cubic metres of municipal wastewater used to irrigate one hectare can contribute 16–62 kg total nitrogen, 4–24 kg phosphorus, 2–69 kg potassium, 18–208 kg calcium, 9–110 kg magnesium, and 27–182 kg sodium (Qadir et. al, 2007). It, therefore, can reduce the demand for chemical fertilizers especially where the wastewater is not diluted, i.e. make crop nutrients more accessible to poor farmers. In the light of the global phosphorus crisis, excreta and wastewater can be critical sources of phosphorus (Rosemarin, 2004). On the other hand, excessive concentrations of nitrogen in wastewater can lead to over-fertilization and cause excessive vegetative growth, delayed or uneven crop maturity and reduced quality (Jiménez, 2006; Qadir et. al, 2007). Excessive concentrations of some trace elements may also result in plant toxicity and sometimes become a health risk for crop consumers.

While farmers and their families are direct beneficiaries, there are also indirect beneficiaries along the supply chain including farm labourers, transporters, vendors, processors, input suppliers and consumers (Buechler et. al, 2002). With low investments and quick returns, this practice is lucrative and enables many farmers to leap over the poverty line (Danso et. al, 2002). In many West African countries, it is especially attractive to poor migrants looking for jobs in the cities (Faruqui et. al, 2004).

Sensitivity to the toxic effects of excess dietary copper is influenced by its chemical form, species, and interaction with other dietary minerals. High levels can cause symptoms of acute toxicity, including nausea, abdominal discomfort (diarrhea), emesis, haemoglobinuria and/or haematuria, jaundice, oliguria/anuria, hypotension, coma and even death. As a result of Histopathological effects observed in the gastrointestinal tracts, livers and kidneys of some victims, it was concluded by the World Health Organization that the fatal oral human dose is about 200 mg/kg (WHO, 2006). Although there is dearth of information on chronic copper toxicity, copper does not seem to constitute a cumulative toxic hazard for man, except for individuals suffering from Wilson's disease. Despite the fact that Tera-togenicity/embryo-toxicity was observed in some animal studies, Copper is not considered to be mutagenic, carcinogenic or affect reproduction(FAO/WHO, 2011).

In human, high levels of zinc cause acute effects such as vomiting and gastrointestinal irritation (nausea, cramps, diarrhea), however when bound to food components (i.e. meat, oysters) these

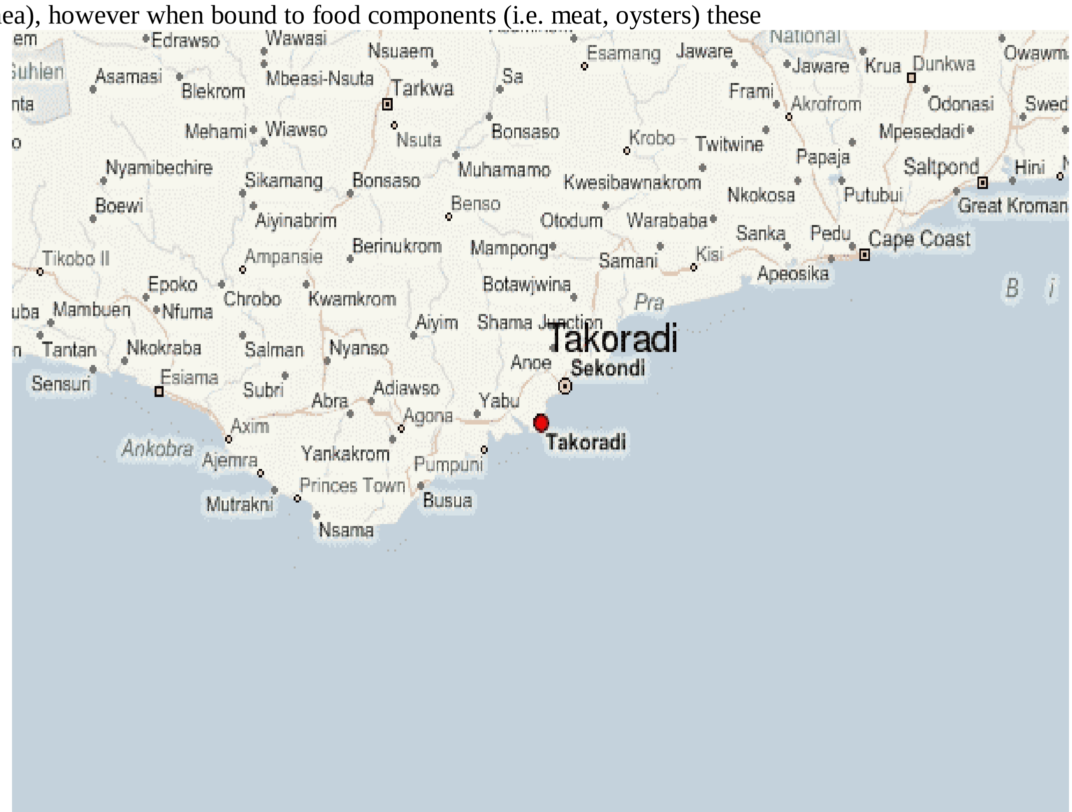

Figure 1: Location Map of Takoradi

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SOURCE: TAKORADI LOCATION GUIDE.

Effects are expected to be less. No information is available on toxic effects in man due to chronic excessive intake of zinc; however impaired copper uptake in humans has been noted following the chronic elevated intake of zinc. Some effects of zinc therefore may be secondary to impaired copper utilization (i.e. anemia) (FAO/ WHO, 2011). In human, acute toxicity of iron ingested from normal dietary sources has not been reported; the amount of iron absorbed in normal subjects is subject to mucosal regulation so that excessive iron is not stored in the body. However, subjects with impaired ability to regulate iron absorption (i.e. suffering from idiopathic hemochromatosis), will be at risk from excessive exposure to iron. Excess iron intake may result in siderosis (deposition of iron in tissue) in liver, pancreas, adrenals, thyroid, pituitary and heart depending on the chemical form (FAO/WHO, 2011).
The general objective of this study is to investigate the effect of waste water source on the heavy metal content of some vegetables irrigated with waste water in Takoradi metropolis of the Western Region of Ghana.
The specific objectives of the study were to: i) determine the amount of iron, copper and zinc present in some selected vegetable species irrigated with waste water; ii) determine the amount iron, copper and zinc present in the waste water used for irrigating the vegetables; iii) Compare the amount of the heavy metals present in the vegetables and waste water used for irrigation with the maximum recommended amounts by the FAO and WHO; iv) determine whether or not the location of the source of wastewater used for irrigating the vegetables has significant effect on the concentration of their heavy metal content; v) determine whether or not the specie of the vegetables has effect on the concentration of their heavy metal content.

MATERIALS AND METHODS

Samples of leaf and fruit vegetables comprising tomato, cabbage, lettuce, spring onion onion and garden eggs irrigated with waste water were collected together with the samples of water used for irrigating and tested for their iron, copper and zinc content. Thereafter, the amounts found in them were compared with the maximum recommended amount by the FAO/WHO.

STUDY AREA AND DURATION

The samples were collected from Takoradi Metropolis, Western Region of Ghana and tested at the School Farm Laboratory Teaching and Research Farm of the University of Cape Coast, Ghana between February and March 2012. The collected samples were of two types viz: samples of vegetables that were irrigated with waste water and samples of the waste water used for irrigating them. Both samples were tested for their heavy metal content comprising iron (Fe^{2+}), copper (Cu^{2+}) and zinc (Zn).

MATERIALS

- Atomic Absorption Spectrophotometer (AAS), Chopping board, Oven, Selenium powder, Lithium Sulphate, Hydrogen peroxide 30%, Concentrated sulphuric acid, Transparent plastic bag, Sieve, Miller, Spatula, Stirrer, Beaker, Knife, Teflon beaker and Kjeldahl flask.
- Weighing scales comprising of beam balance (Camry with capacity of 20 kg by 50 g) and electronic balance (ADP 2100).

METHODS

Preparation of Digestion Mixture

About 0.42 gm of selenium powder was measured out with the use of the weighing balance and added to a previously measured out 14.0 gm of lithium sulphate added to 350 ml 30% hydrogen peroxide to form a solution after mixing thoroughly. A 420 ml measured quantity of concentrated sulphuric acid (H_2SO_4) was slowly and carefully added to the mixture while it was being cooled in an ice bath. The mixture was then stored at a temperature of 2 ˚C for about 4 weeks.

Determination of heavy metal content in the collected waste water and vegetable samples

The collected vegetable samples, kitchen chop board and knife were washed and rinsed with distilled water. The washed and rinsed leaf vegetable samples comprising of cabbage and lettuce were cut into average size of about 25 mm x 25 mm while the washed and rinsed fruit vegetable samples comprising of onion bulbs, tomatoes, garden eggs and spring onions were chopped on the washed and rinsed kitchen chop board into average thickness of about 1 mm with the use of the washed and rinsed kitchen knife on the chop board. All the chopped vegetable samples

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were oven dried for about 24 hours at 70˚C. The oven dried samples were milled to a fineness that will pass through a 2mm sieve size and packaged into transparent plastic bags which were sealed to prevent moisture ingression from the ambient air. A 0.2 g of each of the prepared samples was weighed into numbered Kjeldahl flask to which 4.5 ml of digestion mixture was added and allowed to digest at a temperature of 360˚C for 2 hours ; by this time the solution had turned colourless and was, therefore allowed to cool. After cooling, about 50 ml of distilled water was added to the solution and agitated in order to ensure proper mixing and dissolution of all the solid particles. With the use of the Atomic Absorption Spectrophotometer (AAS), the solution was analyzed for iron, copper and zinc content.

Fifty ml of each of the 10 water samples were carefully measured out and digested at 360˚C for 2 hours after which they were evaporated. About 100ml of distilled water was added to the solid matter left behind and mixed properly to form a solution which was analyzed for iron, copper and zinc content with the use of the Atomic Absorption Spectrophotometer (AAS). The entire process was replicated three times for both the waste water and vegetable samples.

The concentration of heavy metals in micrograms per gram of the dried vegetable samples earlier determined by the Atomic Adsorption Spectrophotometer (AAS) in a 50 ml solution volume were converted directly into concentration in milligrams per kilograms (mg/kg) because the conversion factor is one because 1.0µg/g = 1.0 mg/kg.

With the use of Microsoft EXCEL package and equation (1), the average concentration of heavy metals in the wastewater and vegetable samples were computed and arranged in tabular form. These were compared with the maximum recommended concentration levels by FAO/WHO and arranged as shown in Tables 1 and 2.

Statistical Analysis of the Data

In order to reduce the estimate of chance variation (the experimental error), that is freed of variability due to extraneous causes, a randomized block design with two-way classification was used. With this design, the analysis-of-variance table in Table 3 was obtained by looking on the location of the irrigation plots from where the wastewater samples were collected as treatments and the heavy metals as block and testing at 0.05 level of significance whether there are differences in the plot locations or in the heavy metal content. Table 4 was obtained by looking at the vegetable types as treatments and the heavy metals as blocks and testing at 0.05 level of significance whether there differences in the vegetable types or in the heavy metal content.

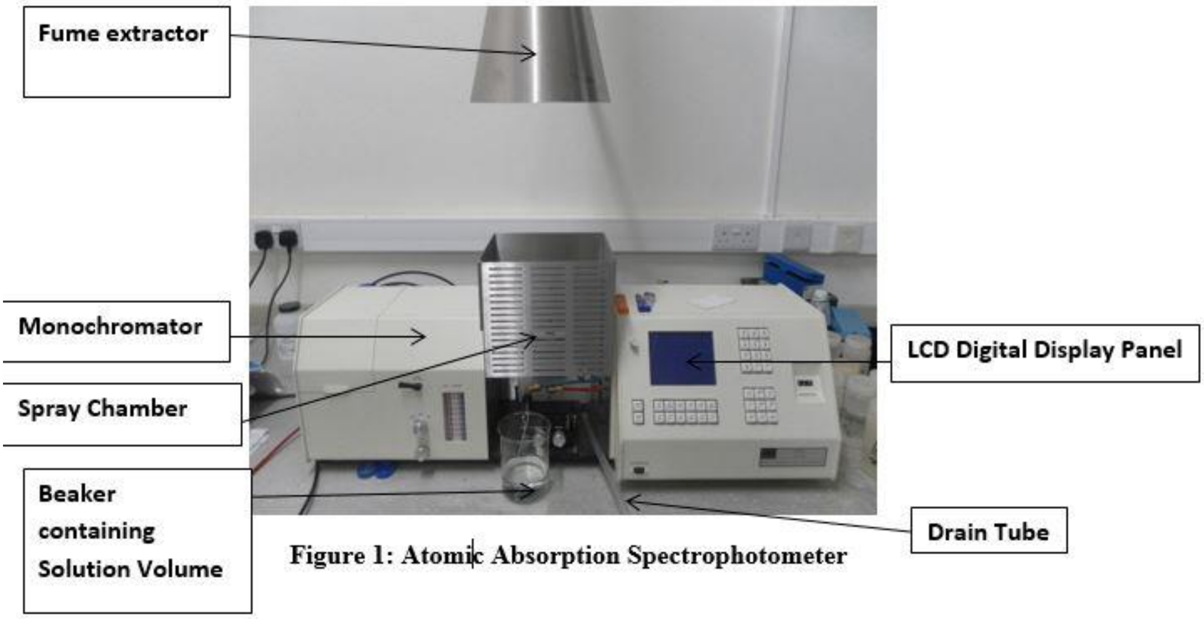

Figure 1: Atomic Absorption Spectrophotometer

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RESULTS AND DISCUSSION

Table 1: Comparison of Quantities of Heavy Metals in Wastewater Samples with WHO/FAO Maximum Recommended Quantities

Location	Heavy Metals in Wastewater Samples			WHO Max. Recom. Level in Water used for Irrigation		
	Fe2+ (mg/L)	Cu2+ (mg/L)	Zn (mg/L)	Fe2+ (mg/L)	Cu2+ (mg/L)	Zn (mg/L)
New Site 1(Ganny's Day Care)	21.72	1.67	7.63	50	1.0	20
New Site 2(Estate Housing)	17.53	2.28	8.88	50	1.0	20
New Site 3(Heaven on Earth)	24.76	1.41	9.30	50	1.0	20
New Site 4 (RCompound)	15.87	1.17	5.85	50	1.0	20
Takoradi PTC (Pioneer Tobacco Company)	6.95	1.97	3.64	50	1.0	20
Takoradi Anaji1(Asekɛe)	20.60	1.42	10.57	50	1.0	20
TakoradiAnaji2 (Ahenkofikro)	28.20	1.46	4.90	50	1.0	20
TakoradiAnaji3 (Kanasawiredo)	19.48	1.66	13.10	50	1.0	20
Tanokrom 1 (Tamsco)	26.01	1.40	21.44	50	1.0	20
Tanokrom 2 (Tadisco)	20.54	1.55	25.50	50	1.0	20

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Table 2: Comparison of Average Quantities of Heavy Metals in Dried Vegetable Samples with WHO/FAO Maximum Recommended Quantities

Vegetable Type	Average Quantities of Heavy Metals in Dried Vegetable Samples			Max. FAO/WHO Recommended Levels in Dried Vegetables		
	Fe2+ (mg/kg)	Cu2+ (mg/kg)	Zn (mg/kg)	Fe2+ (mg/kg)	Cu2+ (mg/kg)	Zn (mg/kg)
Cabbage	82.81	20.74	22.70	5.0	0.4	1.0
Lettuce	72.69	8.86	26.90	5.0	0.4	1.0
Spring Onion	90.32	5.29	25.47	5.0	0.4	1.0
Onion	67.74	25.40	22.68	5.0	0.4	1.0
Garden eggs	26.32	4.16	11.56	5.0	0.4	1.0
Tomato	80.31	50.43	38.69	5.0	0.4	1.0

Table 3: ANOVA for Heavy Metal Concentration in Waste Water Samples

Source of variation	Degree of freedom	Sum of squares	Mean square	F	Tabulated F α=0.05
Plot Location	9	338.86	37.65	1.52	2.46
Heavy Metal Content	2	1723.93	861.97	34.83	3.55
Error	18	445.56	24.75		
Total	29	2508.35			

Table 4: ANOVA for Heavy Metal Content in Dried Vegetable Samples

Source of variation	Degree of freedom	Sum of squares	Mean square	F	Tabulated F α =0.05
Vegetable Type	5	2828.29	565.66	3.18	3.33
Heavy Metals	2	9355.47	4677.74	26.27	4.10
Error	10	1780.45	178.05		
Total	17	13964.21			

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The data set in Tables 1 and 2 show the concentration of iron, copper and zinc in the wastewater samples from the ten sites and dried vegetable samples with which they were irrigated compared with the maximum recommended level by the FAO/WHO. Tables 3 and 4 show the Two-way ANOVA for the heavy metal Concentration in the waste water samples and the vegetables with which they were irrigated respectively in a Randomized-Block experimental design. The data set in Table 1 shows the average concentrations of iron, copper and zinc in Wastewater Samples in Milligrams per Liter (mg/L) from the various locations while Table 2 shows the data set for the concentration of iron, copper and zinc in the Dried Vegetable Samples in Milligrams per Kilograms (mg/kg). Iron concentration levels in spring onion ,cabbage and tomato obtained from New Site 3, New Site 1 and Takoradi Anaji 1 were the highest while it was the zinc concentration levels in tomato, spring onion and lettuce irrigated with waste water from Takoradi Anaji 2, Tanokrom 1, New Site 3, New Site 1, Takoradi Anaji 1and Tanokrom 2 that were highest. In other words, Spring onion contained the highest level of iron, followed by Cabbage; Tomato contained the highest level of copper and zinc followed by cabbage for copper and onion for zinc.

The vegetable samples obtained from Takoradi Pioneer Tobacco Company (PTC) contained the lowest level of iron and zinc; the samples obtained from New Site 4 contained no zinc at all.
Although the recommended maximum level of iron for vegetables by FAO/ WHO was 5.0 mg/kg, the 91.28mg/kg iron concentration in Spring onion was 18 times as high as the maximum recommended level for vegetables. The 50.43 mg/kg copper concentration level found in Tomato was 126 times as high as the maximum recommended level of 0.4 mg/kg for vegetables by FAO/ WHO.

Generally all Plants have different levels of heavy metal concentrations depending on such factors as soil type, mode of water supply(completely rain fed ,supplemented with irrigation or dependent solely on irrigation). Most of the vegetables sampled (Spring onion, cabbage, tomato, onion and lettuce) had high levels of heavy metal concentration at New Site 3, New Site 1, Takoradi Anaji 1, Tanokrom 2 and New Site 2 perhaps because of continuous irrigation with wastewater as well as the soil type. These are all suburb areas of Takoradi which also had high levels of heavy metal concentrations in their wastewaters. The high levels of iron, copper and zinc concentrations in spring onion and cabbage may be due to the sources of irrigation water (streams) used continuously which receive effluents from sewage and storm drains originating from various residential, commercial and industrial buildings. This is similar to iron, copper, zinc, lead and cadmium concentrations found in lettuce and cabbage grown and irrigated with water from streams close to a smelting factory in Addis Ababa, Ethiopia as reported from a study carried out in Ethiopia (Itanna, 2002).

The data set in the ANOVA table in Table 3 shows that there is no significant differences among the level of heavy metal concentrations obtained from the 10 irrigated plot locations for each of the 3 heavy metals considered in the study. In other words, the variations in the heavy metal concentrations among the 10 locations were not significant at 5% level of significance. This is not the case for the three heavy metals considered in the study because the differences among them were significant implying that the metal type had significant effect on their level of concentration in the water used for irrigation.

The data set in the ANOVA table in Table 4 shows that although the concentration of heavy metals in each of the six vegetable types were high, there are no significant differences in the concentration of heavy metals in the six vegetable of them whereas the concentration of each of the three heavy metals were high in the vegetables, there were significant differences in the level of concentration among the three of them.

In this study, there were no significant variations in heavy metals concentrations for both plants and locations although spring onion and cabbage showed the highest concentrations of iron, zinc and copper which confirm results from a similar study by Petterson (1977). Most of the iron, copper and zinc concentration levels recorded were above maximum permitted concentrations recommended for health reasons by FAO/ WHO. Human health implications of iron, copper and zinc are determined by accumulated concentration levels from ingestion through food as food intake is also related to body weight and age (Oliver et. al, 1995). Also the quantity of vegetable intake is influenced by the level of development of a community in which people live. In a developing country, it has been recommended that an average intake of Spring onion and cabbage per person in a day by a vegetarian is 113g each and 21g for lettuce (USEPA, 2002). WHO, (2006) recommended daily intake of iron per unit (kg) body weight of an adult is 5mg/kg. The maximum daily intake of iron, therefore, by a vegetarian of 50kg weight

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will be 250mg/kg. A composite meal of spring onion, cabbage, tomatoes and lettuce, for example, with vegetable weighing 0.5g for a 50kg vegetarian in Ghana will be ingesting between 26.32 to 91.28mg/kg of iron for each vegetable which is about 5 to 18 fold of the recommended value. Sources of iron, copper and zinc in the vegetables may vary due to the continuous irrigation with wastewater and the soil type. For instance the wastewater used for irrigating onion contained 1.17mg/L of zinc but the soil made zinc unavailable to onion. The farmers use these input based on their availability and affordability. Because Takoradi Metropolis is choked with waste water majority of the farmers apply waste water instead of treated water which is more expensive.

CONCLUSION

This work determined the concentration of iron, copper and zinc present in six vegetable species(spring onion, cabbage, tomato ,lettuce, onion and garden eggs) irrigated with waste water in ten peri-urban areas of Takoradi in the Western Region of Ghana. The amount of iron present in spring onion, cabbage, tomato, lettuce, onion and garden eggs were 90.32,82.81,80.31, 72.69, 67.74 and 26.32 mg/kg respectively ; the concentration of copper were 5.29,20.74,50.43,8.86, 25.40 and 4.16 mg/kg respectively while the concentration of zinc were 25.47,,22.70, 38.69, 26.90,22.68 and 11.56 mg/kg respectively. The concentration of iron in the waste water used for irrigating them in each of the ten studied sites were 21.72, 17.53, 24.76, 15.87, 6.95, 20.60, 28.20, 19.48, 26.01 and 20.54 mg/L ; the concentration of copper were 1.67, 2.28, 1.41, 1.17, 1.97, 1.42, 1.46, 1.66, 1.40 and 1.55 mg/L respectively ; the concentration of zinc were 7.63, 8.88, 9.30, 5.85, 3.64, 10.57, 4.90, 13.10, 21.44 and 25.50 mg/L respectively . With the exception of copper, the concentration of heavy metals in the waste water was less than the maximum recommended level by the FAO/WHO in all the ten sites from which water samples were taken to the laboratory for tests. The concentration of the three heavy metals tested in all the six species of vegetable samples were higher than the maximum recommended levels by the FAO/WHO despite the fact that not all of them exceeded the maximum recommended levels in the waste water used for irrigating them. The location of the sites from which the waste water samples used for irrigating the vegetables were obtained did not significantly affect the level of concentration of heavy metals in them. Similarly, the specie of the irrigated vegetables did not significantly affect the level of concentration of the heavy metals in them. However, there were significant differences in the level of concentration of each type of heavy metal in both the waste water and vegetables irrigated with them. It could therefore be concluded that the rate at which each vegetable specie absorb a particular type of heavy metal is different .

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