Influence of Human Activities and Land Use on Heavy Metal Concentrations in Irrigated Vegetables in Ghana and Their Health Implications

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Abstract Anthropogenic activities are major sources of heavy metal pollution which serve as major pathways for plant uptake of heavy metals like cadmium (Cd) and lead (Pb) to enter the human food chain from the soil and irrigation water. This study was conducted to investigate the levels of Cd, Pb, Zn, Fe, Ni and Cu concentrations in sampled vegetables (cabbage and carrots) from two major markets in Kumasi, a metropolis and two producing rural towns along the Accra – Kumasi road. Apart from Ni all other heavy metals in cabbage were far higher than the FAO/WHO permissible values of samples from both urban/peri-urban and rural communities. Cadmium content of the vegetables from the peri-urban communities were extremes (0.5–4.2 mg/kg) and were generally higher than produce from the rural communities with values between 1.6 and 1.9 mg/kg. However, cabbage from Asikam, a rural and mining community contained 2.9 mg/kg of Cd. Lead concentration levels in the sampled vegetables from the peri-urban communities ranged between 6–45 mg/kg whilst values from the rural communities were between 12 and 13 mg/kg. Cadmium and lead concentration levels in the sampled vegetables far exceeded FAO/WHO recommended maximum values of 0.3 and 0.2 mg/kg respectively with samples from urban/peri-urban communities registering higher values than those from the rural towns.

1 Introduction

Anthropogenic activities are major sources of heavy metal pollution which serve as major pathways for plant uptake of heavy metals like cadmium (Cd) and lead (Pb) to enter the human food chain from the soil and irrigation water. Lead leaf contents,

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for example, are very high in plants growing in urban and industrial areas (Maisto et al. 2004). Heavy metals found in agricultural soils originates from many sources including paints, gasoline additives, smelting and refining of Pb, pesticide production and Pb acid battery disposal (Eick et al. 1999; Paff and Bosilovich 1995), phosphate fertilizers, sewage sludge, wastewater for irrigation, waste from smelting sites and others (Ingwersen and Streck 2005). Cadmium is one of the most mobile and bioavailable heavy metals in soil and may cause human and ecotoxicological impacts even at low concentrations. There is considerable published information about the action of Cd^{2+} on plant growth and on physiological and biochemical processes. Harmful effects produced by Cd might be explained by its ability to inactivate enzymes possibly through reaction with the SH-groups of proteins (Fuhrer 1982). Detrimental effects are manifested in inhibition of photosynthesis and in oxidative stress leading to membrane damage (Prasad 1995).

Application of sewage sludge to agricultural land is a feasible alternative for reutilization residual resource of high nutrient and organic matter contents which represent a good fertilizer and/or soil conditioner for plant and soil (Logan et al. 1997; Wong 1996). Besides, sludge amendment could improve soil physical properties such as soil aeration, water holding capacity and aggregation (Logan and Harrison 1995) while the slightly alkaline property of the sludge buffers against the acidity of acidic soils.

Wastewater and sludge for irrigation or amendment of the agricultural land may lead to build higher concentrations in soils as a result of accumulation. The higher metal levels in soil may cause negative impact on crops, inhibiting the growth in one or other way. One of the most important factors is the pH of the soils. Alkaline pH of the soil would restrict the mobilization of the metal in soil matrix and consequently the metal uptake by crop plant would be controlled, reducing the risk of metal toxicity.

Heavy metals may enter the human body through inhalation of dust, direct ingestion of soil, and consumption of food plants grown in metal-contaminated soil (Sterrett et al. 1996) and/or irrigated with wastewater (Ingwersen and Streck 2005). Prolonged exposure to heavy metals (e.g. Cd, Cu, Pb, Ni and Zn) can cause deleterious health effects in humans (Reilly 1991). In children, Pb has been known to cause decreases in IQ scores, retardation of physical growth, hearing problems, impaired learning, as well as decreased attention and classroom performance. In individuals of all ages, Pb may cause anemia, kidney disease, brain damage, impaired function of the peripheral nervous system, high blood pressure, reproductive abnormalities, developmental defects, abnormal vitamin D metabolism, and in some situations death (Hrudey et al. 1995).

Heavy metal contamination can affect plant health and nutritional value of crops. High Cd concentrations can lead to toxicity symptoms like chlorosis and reduced growth of the leaves of crops. The severity of Cd phytotoxicity is found most evident from dry matter yield in both leaves and roots of crops (Michalska and Asp 2001). The extent of contamination to food crops is likely to increase with intensification of production systems, urbanisation and industrialisation but levels of food contamination are not regularly monitored or controlled. In Ghana vegetable consumption has been on the increase as a result of changes in the eating habits of urban dwellers due to socio-economic changes with time. However, high percentages of vegetables consumed by urban dwellers are produced under wastewater irrigation. These exotic vegetables (cabbage, carrots, lettuce, spring onions, etc.) are produced mainly in the urban/peri-urban communities of Ghana. However, cabbage and carrots may be produced in some locations in a few rural communities. Location influences the type of inputs for vegetable production. Urban/peri-urban produced vegetables are irrigated with wastewater or urban streams that are receptacle of urban effluent, hand-dug wells and in very few situations treated water from the mains while the soils are conditioned and the nutrient levels are improved with sewage sludge. For vegetables produced in the rural communities source of irrigation water is mainly a stream or river and soil nutrient improvement and conditioning is by the application of inorganic fertiliser. The objective of this study was to determine the extent of human activities through the type of input used and land use on heavy metal concentration in irrigated vegetables in Ghana and probable health implications.

2 Materials and Methods

Vegetable samples were collected from two main vegetable markets in Kumasi (Asafo and "European") and two rural towns (Nsutam and Kibi) along the Accra–Kumasi highway between August and September, 2005, for the study. The collected samples were washed and rinsed with distilled water and chopped on a distilled water rinsed kitchen chop board using a washed and rinsed kitchen knife into pieces (of about 25 × 25 mm size for cabbage and 1 mm thickness for carrots). The chopped samples were sun-dried for about 8 h before subjecting them to oven drying for about 24 h at 70 °C. The oven dried samples were milled to pass a 2 mm sieve and were packaged in transparent plastic bags and sealed to prevent moisture ingression. 0.2 g of each plant sample was placed into a teflon beaker and 6 ml of concentrated nitric acid (HNO_3) was added and weighed. The beaker was assembled, placed in a rotor and tightened with torque wrench before placing the rotor in the chamber of an already programmed microwave digester for digestion. A 1-ml aliquot of digested sample was placed in a 15-ml centrifuge tube, diluted with 5 ml of deionized water, and analysed for Cd, Pb, Ni, Zn, Fe and Cu and lead with Agillent 7500 c ICP- MS.

3 Results

Figure 1 shows the concentrations of Cd, Pb, Ni, Zn, Fe, and Cu in vegetables from the various sites. Apart from Ni all the other heavy metals concentrations in cabbage were far higher than the FAO/WHO permissible values of samples from both urban/peri-urban and rural communities.

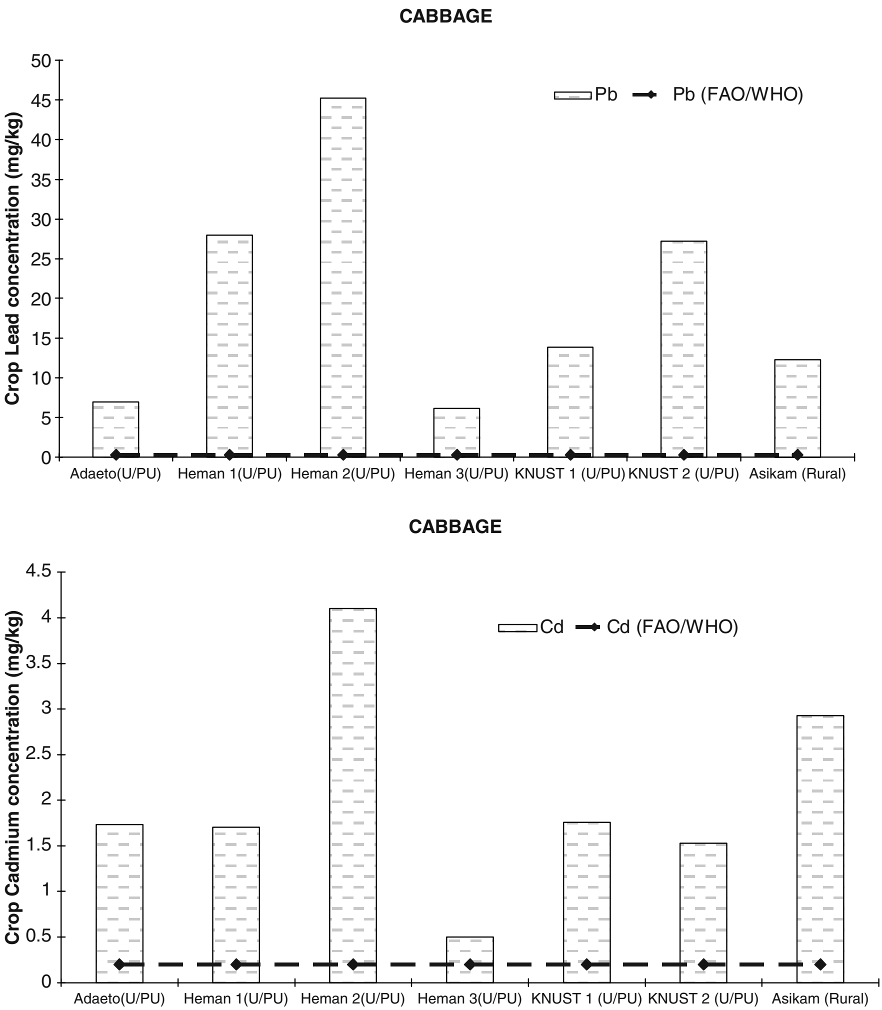

Fig. 1 Relationship between analysed heavy metals concentrations in cabbage samples from both rural and urban/peri-urban communities and permissible FAO/WHO permissible values/ guidelines

4 Discussion

The recommended concentration levels of the analysed heavy metals by FAO/WHO in vegetables is shown in Table 1.

Plant samples differed in levels of concentrations of heavy metals based on location. Most of the cabbage sampled had high levels of heavy metal concentration at Heman site 2, a rural community north of Kumasi. The high values of heavy metals concentrations of lettuce and cabbage may be due to the sources of irrigation water (streams) that receive

Table 1 FAO/WHO maximum permissible values of heavy metals in vegetables

Element	FAO/WHO maximum permissible values (mg/kg)
Cd	0.2
Pb	0.3
Ni	67.9
Fe	425.5
Cu	73.3
Zn	99.4

effluents and storm water from Kumasi “Magazine”, the largest public sector garage in Africa. The values of Cd and Pb were similar to concentrations of cabbage grown and irrigated with water from streams close to a smelting factory in Addis Ababa, Ethiopia from a study carried out there (Itanna 2002). For the least plant heavy metal concentrations, there were variations for both plants and locations. Cabbage showed the highest concentrations of Cd and Pb which confirms results from a similar study by Petterson (1977). Most of the heavy metals concentration levels recorded were above maximum permitted concentrations by FAO/WHO. Human health implications of heavy metals are determined by accumulated concentration levels from ingestion through food. Food intake is 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 the people live. In a developing country, it has been recommended that an average intake of carrots and cabbage per person in a day by a vegetarian is 113 g each and 21 g of lettuce (USEPA 2002). The WHO (1989) recommended daily intake of Cd per unit (kg) body weight of an adult is 1 μg. The maximum daily Cd intake, therefore, by a vegetarian of 50 kg weight will be 50 μg. A composite meal of carrots, cabbage and lettuce, for example, weighing 247 g for a 50 kg vegetarian in Ghana will be ingesting between 123.5 and 1,037 μg Cd which is about 2 to 21 fold of the recommended value. Sources of the heavy metals in the vegetables may vary and the sources may be fertilisers, poultry manure and water bodies used for production. The farmers use these inputs based on their availability and affordability. Because the Kumasi metropolis is choked with poultry farms majority of the farmers apply poultry manure to improve the soil. However, due to lack of extension services, the farmers tend to use knowledge from their counterparts in solving problems relating to soil fertility and plant diseases. This has been a major factor in the vegetable production sector in terms of environmental pollution.

5 Conclusion

The study showed that metal concentrations of the vegetables sampled were higher for those produced in the urban/peri-urban communities than those from the rural areas. It could be concluded that the vegetables on the Ghanaian market have high heavy metals concentration levels above the maximum recommended by health authorities and this calls for a thorough investigation to track the source(s) of the metals and measures put in place to ameliorate or eliminate the menace. Soils being used for vegetable production locally are mainly sandy with low pH and organic matter content, favouring high uptake of heavy metals.

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