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Heavy metals in edible green vegetables grown along the sites of the Sinza and Msimbazi rivers in Dar es Salaam, Tanzania

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Abstract

Four heavy metals (cadmium, copper, lead and zinc) were determined in some green vegetables cultivated along the sites of the Sinza and Msimbazi rivers. Atomic absorption spectrophotometry was used to estimate and evaluate the levels of these metals in the vegetables. The contributions of the vegetables to the daily intake of the heavy metals from the vegetables were determined. The results showed the following ranges (mg/100 g): 0.01–0.06, 0.25–1.60, 0.19–0.66, and 1.48–4.93 for cadmium, copper, lead and zinc, respectively. Some vegetables contained high levels beyond the permissible levels given by FAO and WHO for human consumption. When the mean levels of cadmium, copper, lead and zinc (0.20, 7.95, 3.95 and 33.75 mg per kg, respectively) were taken into account, the daily intake contribution of these metals was found to be 21.60 µg, 858.60 µg, 426.60 µg and 3.65 mg for cadmium, copper, lead and zinc, respectively.

1. Introduction

Vegetables constitute essential components of the diet, by contributing protein, vitamins, iron, calcium and other nutrients which are usually in short supply (Thompson & Kelly, 1990). They also act as buffering agents for acid substances obtained during the digestion process. However, these plants contain both essential and toxic elements over a wide range of concentrations. African spinach (*Amaranth* sp.), Chinese cabbage (*Brassica chinensis*), Cowpea leaves (*Vigna unguiculata*), Leafy cabbage (*Brassica rapa*), Lettuce (*Lactuca sativa*) and Pumpkin leaves (*Moschata cucurbita*) are the most common green vegetables consumed by people living in Dar es Salaam, Tanzania.

Chronic low level intakes of heavy metals have damaging effects on human beings and other animals, since there is no good mechanism for their elimination. Metals such as lead, mercury, cadmium and copper are cumulative poisons. These metals cause environmental hazards and are reported to be exceptionally toxic (Ellen, Loon, & Tolsma, 1990). Vegetables take up metals by absorbing them from contaminated soils, as well as from deposits on parts of the vegetables exposed to the air from polluted environments (Zurera, Moreno, Salmeron, & Pozo, 1989).

In Tanzania, Dar es Salaam in particular, it has been a common practice to cultivate vegetables along the banks of the rivers passing through the city. Waters of these rivers are reported to be polluted by heavy metals (Mashauri & Mayo, 1990). The heavy metals reported include Pb, Cu, Zn, Fe, Cr, Cd and Hg. The major sources of these heavy metals are industrial effluents, and indiscriminate disposal of domestic or sewage drainage directed to the rivers untreated or partially treated. It is therefore anticipated that plants grown along the banks of the rivers Sinza and Msimbazi are not free from heavy metal pollution.

The purpose of the present study was thus to determine the concentrations of heavy metals in selected green vegetables grown along the banks of the Sinza and Msimbazi rivers, and to estimate their contribution to the daily intake of the metals.

2. Materials and methods

2.1. Sample collection

Vegetable samples of African spinach (*Amaranth* sp.), Chinese cabbage (*Brassica chinensis*), Cowpea leaves (*Vigna unguiculata*), Leafy cabbage (*Brassica rapa*), Lettuce (*Lactuca sativa*) and Pumpkin leaves (*Moschata*

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cucurbita) were collected along the cultivated banks of the rivers Sinza and Msimbazi. The samples were collected from these growing areas over a period of six months during the dry season (July–December) of the year 1994. All samples were collected and stored in polythene bags according to their type and brought to the laboratory for preparation and treatment.

2.2. Sample preparation and treatment

The samples were washed with distilled water to eliminate air-borne pollutants. The leafy stalks were removed from all samples and these were sliced and dried on a sheet of paper to eliminate excess moisture. Once dried, each sample was weighed and oven-dried at 60°C to constant weight. Each oven-dried sample was ground in a mortar until it could pass through a 60 mesh sieve. The samples were then stored in a clean, dry, stoppered glass container before analysis.

2.3. Determination of heavy metals

2.3.1. Reagents

All reagents used were analytical grade obtained from Aldrich Chemical company limited, BDH. Ltd. and May and Baker Ltd. Dagenham, all from England.

2.3.2. Dry ashing of the vegetable samples

The dry ashing method was used followed by atomic absorption spectrophotometric analysis as stipulated in the Perkin–Elmer manual for atomic absorption spectrophotometry (Perkin–Elmer, 1982). Each determination was carried out by accurately measuring a sample of 1 g of a ground sample in a crucible. The crucible with its content was placed in a muffle furnace and ashed at 450°C for 12 h. The ash was digested with 5 ml of 20% (v/v) AnalaR HCl solution. The residue was filtered into a 50 ml volumetric flask using Whatman filter paper No. 41, and the solution was made to the mark with deionised water. Atomic absorption spectrophotometry (AAS) was used for the determination of the heavy metals. Each sample solution was run in duplicate to ensure the repeatability of the obtained results. The same procedure was followed for each sample and the appropriate dilution factors were used in the calculation.

2.3.3. The atomic absorption spectrophotometer (AAS) determination

The ash solution was aspirated into the instrument after all necessary set-up and standardisation procedures. All metals were determined with a Perkin–Elmer Model 2380 atomic absorption spectrophotometer at the Department of Chemistry, University of Dar es Salaam. For analytical quality assurance, the result of each metal was corrected by subtracting the value from the blank. Also, after every five sample readings, standards were run to make sure that the obtained results were within range. A 10 cm long slot-burner head, a lamp and a standard air-acetylene flame were used. Other AAS conditions employed in these determinations are as summarised in Table 1.

3. Results and discussion

3.1. Levels of heavy metals

The concentrations of heavy metals found in vegetables sampled from cultivated sites along the Sinza and Msimbazi rivers are summarised in Table 2(a) and (b), respectively. The heavy metal concentrations determined were based on vegetables dry weight. Sixteen samples per vegetable category per heavy metal were analysed to ensure good and reliable data. In this study, we collected and analysed 192 vegetable samples from along the two rivers. The results showed a high level of zinc in all vegetables from the two areas. It ranged from 1.48 mg/100 g in lettuce [Table 2(b)] to 4.93 mg/100 g in Chinese cabbage [Table 2(a)]. There was no significant variation in the levels of these metals among the vegetables examined. The levels of copper were between 0.25 mg/100 g in lettuce and 1.6 mg/100 g in pumpkin leaves from cultivated sites along the Msimbazi river. Cadmium contents varied from 0.01 mg/100 g in leafy cabbage [Table 2(a) and (b)] to 0.06 mg/100 g in both African spinach and cowpea leaves [Table 2(b)]. The content of lead varied from 0.19 mg/100 g in leafy cabbage [Table 2(b)] to 0.66 mg/100 g in cowpea leaves [Table 2(a)].

The variations of the metal contents observed in these vegetables depend on the physical and chemical nature of the soil and absorption capacity of each metal by the plant, which is altered by innumerable environmental and human factors and nature of the plant (Zurera et al., 1989).

The amounts of lead in African spinach, Chinese cabbage and cowpea leaves [Table 2(a)] and that of cadmium in African spinach, cowpea leaves [Table 2(b)] and lettuce [Table 2(a)], were above the permissible

Table 1
Wavelength, slit width and lamp current used in the AAS determination of different elements with their detection limits in ppm

Element	Wavelength (nm)	Slit width (nm)	Lamp current (mA)	Detection limit (ppm)
Cd	228.8	0.7	4	0.001
Cu	324.7	0.7	15	0.002
Pb	283.3	0.7	10	0.03
Zn	213.9	0.7	15	0.002

Table 2
(a) Levels of heavy metals in vegetables cultivated along the sites of Sinza river

Vegetable	Heavy metal (mg/100 g)			
	Cd	Cu	Pb	Zn
African spinach	0.03	0.72	0.59	4.81
Chinese cabbage	0.02	0.49	0.61	4.93
Cowpea leaves	0.02	0.85	0.66	3.46
Leafy cabbage	0.01	0.5	0.31	3.76
Lettuce	0.04	0.58	0.36	1.59
Pumpkin leaves	0.02	0.94	0.39	3.67
Mean	0.02	0.68	0.49	3.54
Standard deviation	±0.001	±0.03	±0.02	±0.07
Permissible levels in food as per WHO & FAO	0.03	4.0	0.5	6.0

(b) Levels of heavy metals in vegetables cultivated along the sites of Msimbazi river

African spinach	0.06	1.37	0.30	4.08
Chinese cabbage	0.02	0.75	0.32	2.38
Cowpea leaves	0.06	0.91	0.28	4.36
Leafy cabbage	0.01	0.56	0.19	4.18
Lettuce	0.03	0.25	0.38	1.48
Pumpkin leaves	0.02	1.60	0.34	2.77
Mean	0.03	0.91	0.30	3.21
Standard deviation	±0.001	±0.02	±0.02	±0.02
Permissible levels in food as per WHO & FAO	0.03	4.0	0.5	6.0

levels set by FAO and WHO for human consumption. However, other amounts were within the acceptable levels. Good agreement of these data was observed when the levels of lead and cadmium were compared with previously reported data by Fergusson (1991). For instance, our values for lead were within the range of 0.05 to 6.7 mg/100 g, and 0.13 to 2.27 mg/100 g, reported for similar vegetables from Ireland and New York, respectively. For cadmium, vegetables from Ireland showed a range of 0.005 to 0.06 mg/100 g, and those from New York had a range of 0.004 to 0.061 mg/100 g within which some of our values fell. However, the concentrations of both cadmium and lead in this study were below the range (0.09 to 0.26 mg/100 g of cadmium, and 1.1 to 1.7 mg/100 g of lead) reported for vegetables grown in Metropolitan Boston and Washington DC (Hibber, Hagar, & Mazza, 1984). Furthermore, the cadmium and lead levels reported in this study were lower than those reported for vegetables in Nigeria (Ndiokwere, 1984).

The average levels of zinc in green vegetables from the Msimbazi and Sinza rivers were 3.21 and 3.54 mg/100 g, respectively. These values were close to the value 3.48 mg/100 g reported by Ndiokwere (1984), and appreciably higher than 1.46 mg/100 g reported by Voegborlo (1993) in similar green vegetables. However, the data were extremely lower than that given by Aremu and Undoessien (1990) (18.8 mg/100 g). All vegetables had lower levels of zinc than the permissible value (6 mg/100 g) in food provided by FAO/WHO (Codex Alimentarius, 1984).

The average values of copper were 0.91 and 0.68 mg/100 g for Msimbazi and Sinza green vegetables, respectively. Apart from its function as a biocatalyst, copper is necessary for body pigmentation in addition to iron, the maintenance of a healthy central nervous system, prevention of anaemia, and is interrelated with the function of zinc and iron in the body (Akinyele & Osibanjo, 1982). From the results, it can be noted that the levels of copper obtained in this study are comparatively lower than those reported by Ndiokwere (1984), Aremu and Undoessien (1990) and Ifon and Bassir (1979) for similar green vegetables.

The average contents of the heavy metals obtained in this study show that the Msimbazi area exceeds Sinza by 33.3% and 14.2% of cadmium and copper levels, respectively. Likewise, Sinza exceeds that of Msimbazi in the contents of lead by 38.5% and in zinc by 9.3%.

3.2. Daily intake estimate of cadmium, copper, lead and zinc

Estimates made in the coastal region of Tanzania, showed that the average consumption of leafy vegetables per person per day is 108 g of the average food ration of 1587 g (Lukwanjo & Tanner, 1985). If the mean levels [calculated from the average values in Table 2(a) & (b)] of cadmium, copper, lead and zinc (0.20, 7.95, 3.95 and 33.75 mg per kg) obtained are consumed daily, then the contribution of the green vegetables to dietary intake of an individual for these metals is 21.6 μg, 859 μg, 427 μg and 3.65 mg per day, respectively. Other estimates made from various countries have shown that the dietary intake for lead in adults is between 54 μg per day (Dabeca, McKenzie, & Lacroix, 1987) and 412 μg per day (Dick, Hughes, Mitchell, & David, 1978), and that of cadmium is between 10 and 30 mg per day (Reilly, 1991). For zinc and copper, the estimated daily intake is from 1 to 3 mg, and 10 to 20 mg, respectively (Fox, 1982). It can be concluded that our estimation for lead and zinc are above those reported from other countries whereas the estimation for cadmium is within the range. The levels of copper are observed to be below the estimation. The authors have the opinion that a large daily intake of these vegetables is likely to cause a detrimental health hazard to the consumer.

4. Conclusion

A comparison of the levels of heavy metals in the vegetables studied, with the permissible levels required for safe food was done. The results showed a divergence from the permissible levels by FAO and WHO. High lead contents were found in African spinach, Chinese cabbage and cowpea leaves [Fig. 2(a)]. High levels of cadmium were found in African spinach, cowpea leaves [Table 2(b)] and lettuce [Table 2(a)], and these amounts could be toxic and hazardous if taken in large quantities. The authors strongly recommend that people living in Dar es Salaam should not take large quantities of these vegetables so as to avoid large accumulation of the heavy metals in the body.

Since the dietary intake of food may constitute a major source of a long term low level body accumulation of heavy metals, the detrimental impact becomes apparent only after several years of exposure. Regular monitoring of these metals from effluents, sewage, in vegetables and in other food materials is essential to prevent excessive build up of the metals in the food chain.

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