HEAVY METALS IN GREEN VEGETABLES AND SOILS FROM VEGETABLE GARDENS IN DAR ES SALAAM, TANZANIA

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ABSTRACT

Edible portions of five varieties of green vegetables, namely amaranth, chinese cabbage, cowpea leaves, leafy cabbage and pumpkin leaves, collected from several areas in Dar es Salaam, were analyzed for lead, cadmium, chromium, zinc, nickel and copper. Except for zinc, the levels of heavy metals in the vegetables grown at Tabata area were much higher than in the vegetables from Ukonga and Kiwalani. Amaranth and pumpkin leaves had more than 60% higher content of heavy metals, especially copper, chromium and lead, than the other vegetables. All vegetables from Tabata, Buguruni and Sinza had lead-levels higher then the FAO/WHO recommended permissible levels in foods. Amaranth, leafy and chinese cabbages had high zinc content. Zinc levels in chinese cabbage and leafy cabbage from Kiwalani, Sinza and Ukonga areas were higher than the permissible FAO levels in foods. The soils from Tabata and Sinza areas had high levels of lead, chromium, zinc and copper while the soils from Kiwalani, Makongo and Ukonga areas had high levels of zinc and copper. There was a direct positive correlation between the zinc and lead levels in soils with the levels in vegetables. Such relation was absent for the other heavy metals. Considering an average daily intake of only 202g of fresh vegetables per person per day, all the vegetables grown at Tabata and Buguruni had lead concentration which would be a health hazard for human consumption.

INTRODUCTION

Both raw and cooked green vegetables form a substantial portion of the daily human diet of the population in Dar es Salaam. These plants are now grown on all types of available land such as abandoned waste dumping sites, banks of polluted rivers, alongside roads and areas enclosing waste water ponds. Normally the waters close to the growing areas are used for watering these plants.

Vegetables contain both essential and toxic elements and other constituents over a wide range of concentrations. While some elements are essential for normal human health, others such as lead, cadmium and mercury are exceptionally toxic and are recognized as dangerous environmental pollutants. The toxic effects of lead and cadmium to humans through food consumption are well-documented (Bonner & Bridges 1983, Reilly 1991). Human exposures to such toxic metals are usually through the consumption of polluted food material (Shrikanth & Reddy 1991).

Rivers are being polluted with heavy metals coming from untreated or partially treated industrial effluents and by indiscriminate disposal of untreated domestic wastes and sewage directed to these rivers (Paulsson 1990). When such polluted water is used for agricultural purposes the plants being watered will acquire a significant increase in the content of the elements. Studies carried out on heavy metal pollution in Tanzania have revealed the presence of heavy metals in the rivers flowing through Dar es Salaam (Qamara 1995), in fishes (Mashauri & Mayo 1990), in some species of algae (Wekwe 1990) and in vegetables (Raja *et al.* 1997).

The rapid increase in the human population of Dar es Salaam and the resurgence of industrial activities mean that there will be a progressive increase in the levels of the heavy metals in the city's environment. The present study quantified the heavy metals Pb, Cd, Cr, Zn, Ni, and Cu in both vegetables and soils from different areas in Dar es Salaam. Amounts of fresh vegetables consumed that would result in health hazards were also calculated.

METHODS

Sample collection

Soils samples and samples of cowpea leaves, *Vigna unguiculata,* amaranth, *Amanathus* sp , leafy cabbage, *Brassica oleracea*, pumpkin leaves, *Curcubita moschata* and Chinese cabbage, *Brassica chinensis,* were obtained from cultivation plots at Kiwalani, Makongo, Ukonga, Buguruni, Tabata and Sinza over a period of six months. About two kilograms of each vegetable were collected as samples between January and June 1997, stored in polythene bags and transported to the laboratory for preparation and analysis. Simultaneously, soil samples were collected from a depth of between 10 to 15 cm from the surface (Allen 1974). Four such soil samples were collected from different locations within one cultivating location and then thoroughly mixed. They were placed in clean dried plastic bottles and transported to the laboratory for investigation.

Sample preparation

Vegetable stems and leaf stalks were removed and the leaves were then washed with distilled water to remove dust and dirt. They were subsequently placed on sheets of paper and left to drain-dry at room temperature to remove excess moisture. The samples were then weighed and dried at 60°C to a constant weight in a 'Memmert' oven equipped with fresh air facilities. Each dried sample was ground in a mortar sufficiently to pass through a 60-mesh sieve. The powder was packed and stored in clean, dry, stoppered glass containers for further analysis.

Each soil sample was spread on a clean polythene sheet. Stones and other debris were removed and the bulk of the soil was thoroughly mixed by hand. Samples were then air dried to constant weight for about seven days. The air-dried soils were then ground in a motor sufficiently to pass through an 80-mesh sieve (Shrikanth & Reddy 1991). The fraction that passed through the sieve was placed in a large crucible and dried in a muffle furnace at 450°C for 24 hours. After cooling the samples were stored and analyzed for heavy metal content.

Determination of metals

Destruction of organic matter of each vegetable sample was done by a dry ashing method (Perkin-Elmer 1982, Anon. 1975). A preliminary comparison between wet and dry-ashing procedures on the samples showed no difference in the results obtained. One gram of dried vegetable, weighed in a crucible with lid, was ashed in the muffle furnace by programmed gradual heating. The ashed sample was digested with 5 cm^3 of 20% (v/v) analytical grade hydrochloric acid. Any residue was dissolved using stronger heating. The solution was filtered into a 50 cm^3 volumetric flask and made to the mark with de-ionized water. Concentrations of metals in the ash solution were measured using a Perkin Elmer Model 2380 atomic absorption spectrophotometer (AAS). The set up, standardization and determination procedures were done as stipulated in the AAS manual for analytical methods (Perkin-Elmer 1982).

Soil samples were analyzed according to the method described by Zurera *et al.* (1989). Two grams of dried soil were placed in a tall, lip-less beaker and 10 cm^3 of hot concentrated nitric acid added. The beaker was covered with a watch glass and its contents left to react for 30 minutes. The beaker and its content were then placed on a hot water bath and the solution allowed to evaporate to about 5 cm^3. The solution was then filtered into a 25-cm^3 volumetric flask and diluted to the mark with de-ionized water prior to analysis using the AAS. The AAS analytical methods used for trace metal determination were verified on reference samples MA-A-2/TM and SD-M-2/TM supplied by the International Atomic Energy Agency (IAEA), Monaco.

RESULTS AND DISCUSSION

Levels of heavy metals in soils

Higher levels of lead, cadmium and chromium were obtained at Tabata than at the other locations (Table 1). The concentrations at Tabata, even though high, were lower than those reported for other polluted sites (De Konic 1974 (for polluted soils surrounding a lead smelter), Davies & Roberts 1978 (for contaminated soils in northern Clwyd, Wales).

Table 1: Heavy metal concentration in soils (mg/100-g dry soil) from vegetable gardens in Dar es Salaam, Tanzania. January - June 1997

Metal element /Place	Kiwalani	Tabata	Buguruni	Makongo	Sinza	Ukonga
cadmium	0.05 ± 0.01	0.53 ± 0.03	0.08 ± 0.01	0.03 ± 0.01	0.24 ± 0.01	0.08 ± 0.01
chromium	0.38 ± 0.04	5.34 ± 0.44	3.28 ± 0.10	3.12 ± 0.10	3.19 ± 0.09	0.43 ± 0.05
copper	2.71 ± 0.10	2.59 ± 0.23	1.61 ± 0.04	2.97 ± 0.21	3.92 ± 0.14	2.82 ± 0.16
lead	1.22 ± 0.11	8.23 ± 0.26	6.29 ± 0.08	4.84 ± 0.05	7.77 ± 0.15	1.18 ± 0.13
nickel	0.46 ± 0.05	0.72 ± 0.03	1.16 ± 0.03	1.44 ± 0.11	1.39 ± 0.06	0.57 ± 0.04
zinc	10.9 ± 0.3	6.01 ± 0.43	9.82 ± 0.21	25.7 ± 0.93	34.4 ± 0.9	10.1 ± 0.4
Place characteristic	open land	Old municipal dumping site	close to a polluted river	close to a river and main road	close to a river	open land

Values represent mean of ten independent soil determinations per location.

The main sources of metals at Tabata included both industrial and municipal wastes dumped there up until 1990. This place was the main waste-dumping site of the city of Dar es Salaam for many years. The soils of Kiwalani and Ukonga were the least polluted. The soils of Makongo and Sinza had the highest levels of zinc, nickel and copper whereas the highest content of soil lead, chromium and cadmium were found at Tabata.

Levels of heavy metals in vegetables

The results of the determinations of heavy metals are summarized in Table 2 along side similar determinations in vegetables from Sinza and Kariakoo markets by Raja *et al.* (1997). The ranges in the content of heavy metals in 100 g of dried-vegetables were 0.25 - 2.36 mg-Cu, 2.66 – 11.24 mg-Zn, 0.01 – 0.85 mg–Pb, 0.01 – 0.05 mg-Cd, 0.22 – 1.35 mg-Cr and 0.01 - 0.69 mg-Ni. These levels were lower than those reported for similar vegetables from Nigeria by Faboya (1983) but higher than those reported for raw leafy vegetables from Libya (Voegborlo 1993).

Table 2: Heavy metals content in vegetables from vegetable gardens at different areas in Dar es Salaam, Tanzania. January - June 1997

		Heavy Metal content in mg/100 g dry weight							
		Location							
Metal	Vegetable	Tabata	Kiwalani	Makongo	Ukonga	Buguruni	Sinza	*Sinza	*Kariakoo
Lead									
	Amaranth	0.65	0.00	0.34	0.00	0.37	0.30	0.59	0.30
(maximum	Chinese cabbage	0.61	0.18	0.37	0.14	0.85	0.50	0.61	0.32
tolerable daily	Cowpea leaves	0.59	0.03	0.35	0.02	0.33	0.42	0.66	0.25
intake: 3.5-4.0	Leafy cabbage	0.60	0.00	0.22	0.00	0.76	0.56	0.31	0.19
µg/kg body mass)	Pumpkin leaves	0.59	0.00	0.77	0.00	0.75	0.55	0.39	0.34
Maximum level	Green pepper	nd	nd	nd	nd	nd	nd	0.42	0.25
of contaminant:	Lettuce	nd	nd	nd	nd	nd	nd	0.36	0.38
0.3 mg/kg food	Okra	nd	nd	nd	nd	nd	nd	0.16	0.22
produce (FAO/WHO)	Average error	±0.03	±0.01	±0.03	±0.02	±0.03	±0.03	±0.02	±0.02
Cadmium									
	Amaranth	0.03	0.00	0.01	0.00	0.03	0.05	0.03	0.06
	Chinese cabbage	0.03	0.01	0.01	0.01	0.04	0.03	0.02	0.02
(maximum	Cowpea leaves	0.02	0.01	0.01	0.01	0.03	0.02	0.03	0.06
tolerable daily	Leafy cabbage	0.04	0.01	0.02	0.01	0.05	0.02	0.01	0.01
intake: 1.0 -1.2	Pumpkin leaves	0.02	0.01	0.02	0.00	0.04	0.04	0.02	0.03
µg/kg body mass)	Green pepper	nd	nd	nd	nd	nd	nd	0.04	0.02
(WHO)	Lettuce	nd	nd	nd	nd	nd	nd	0.04	0.03
	Okra	nd	nd	nd	nd	nd	nd	0.01	0.01
	Average error	±0.005	±0.001	±0.002	±0.002	±0.005	±0.005	±0.005	±0.005

Table 2: continued

Chromium	Amaranth	0.69	0.42	0.24	0.44	0.24	0.43	0.07	0.13
(maximum	Chinese cabbage	0.49	0.40	0.36	0.41	0.35	1.35	0.08	0.24
tolerable adult	Cowpea leaves	0.44	0.31	0.30	0.34	0.36	1.15	0.12	0.17
daily amount -	Leafy cabbage	0.68	0.22	0.28	0.27	0.38	0.26	0.24	0.26
10 mg)	Pumpkin leaves	0.39	0.30	0.39	0.29	0.30	0.74	0.48	0.42
	Green pepper	nd	nd	nd	nd	nd	nd	0.74	0.49
	Lettuce	nd	nd	nd	nd	nd	nd	0.34	0.61
	Okra	nd	nd	nd	nd	nd	nd	0.13	0.11
	Average error	±0.03	±0.02	±0.02	±0.03	±0.04	±0.03	±0.02	±0.01
Nickel	Amaranth	0.35	0.03	0.23	0.03	0.19	0.18	0.19	nd
	Chinese cabbage	0.28	0.15	0.27	0.16	0.69	0.24	0.23	nd
(maximum	Cowpea leaves	0.27	0.07	0.32	0.08	0.33	0.12	0.16	nd
tolerable daily	Leafy cabbage	0.28	0.00	0.23	0.00	0.29	0.29	0.36	nd
intake : 12 mg/	Pumpkin leaves	0.48	0.13	0.28	0.15	0.32	0.21	0.22	nd
person/day,	Green pepper	nd	nd	nd	nd	nd	nd	0.42	nd
US-EPA)	Lettuce	nd	nd	nd	nd	nd	nd	0.36	nd
	Okra	nd	nd	nd	nd	nd	nd	0.16	nd
	Average error	±0.01	±0.01	±0.02	±0.01	±0.02	±0.02	±0.01	-
Zinc	Amaranth	4.99	3.87	11.2	4.07	7.97	5.84	4.81	4.08
(maximum	Chinese cabbage	5.54	9.63	4.47	9.54	5.65	6.24	4.93	2.38
tolerable daily	Cowpea leaves	3.57	2.76	5.65	2.66	5.24	3.80	3.46	4.36
intake: 6.0 mg.	Leafy cabbage	3.75	7.69	5.75	7.88	4.90	7.97	3.76	4.18
Maximum level	Pumpkin leaves	4.75	4.50	5.27	4.57	5.67	4.43	3.67	2.77
of contaminant:	Green pepper	nd	nd	nd	nd	nd	nd	1.94	1.90
5.0 mg/kg-food	Lettuce	nd	nd	nd	nd	nd	nd	1.56	1.49
produce)	Okra	nd	nd	nd	nd	nd	nd	3.02	2.43
(FAO/WHO)	Average error	±0.11	±0.15	±0.09	±0.15	±0.07	±0.11	±0.07	±0.15

Values are means of ten independent determinations

Table 2: continued

Copper	Amaranth	0.72	0.32	0.72	0.45	0.25	1.16	0.70	1.37
	Chinese cabbage	2.36	0.53	0.61	0.57	1.11	0.52	0.49	0.75
(maximum level	Cowpea leaves	1.47	0.63	0.22	0.61	0.68	0.51	0.85	0.91
of contaminant:	Leafy cabbage	1.36	0.72	0.37	0.77	0.15	0.14	0.50	0.56
5 mg/kg-food	Pumpkin leaves	0.92	0.65	0.25	0.69	1.42	1.15	0.94	1.60
produce)	Green pepper	nd	nd	nd	nd	nd	nd	0.84	0.58
(FAO/WHO)	Lettuce	nd	nd	nd	nd	nd	nd	0.58	0.25
	Okra	nd	nd	nd	nd	nd	nd	1.39	0.94
	Average error	±0.09	±0.07	±0.10	±0.05	±0.03	±0.05	±0.03	±0.12

nd - not determined
Values are means of ten independent determinations
*determinations at the Sinza and Kariakoo markets (Raja *et al.* 1997)

All the vegetables from Tabata, Makongo, Buguruni and Sinza had lead concentration levels which were higher than the recommended maximum (0.3 mg/kg food; FAO/WHO (Anon 1954, 1972, 1991)) and were likely to be a health hazard to human consumers. The vegetables from Kiwalani and Ukonga appeared to be safe for human consumption. These lead levels were lower than the levels reported elsewhere (Preer *et al.* 1980, Furr *et al.* 1976 (New York city) and Page *et al.* (1971) (southern California)).

The cadmium concentration levels of 0.01 to 0.05 mg/100-g dried vegetable, were lower than the maximum tolerable daily intake of 0.06 mg per a 60-kg average person (WHO). These levels were lower than some of the levels reported elsewhere (Preer *et al.* 1980, Page *et al.* 1971).

The level of chromium concentration (0.22 to 1.35 mg/100-g dried vegetable) were less than the tolerable daily adult intake amount of 10 mg per day and were above the minimum requirement of 0.2-mg chromium per day for adults (Schroeder 1976).

Zinc concentration levels ranged from 2.66 mg to 11.24 mg per 100 g of dried vegetables and were higher than the maximum level recommended by FAO/WHO.

The copper concentration levels in the vegetables (0.25–2.36 mg/100-g-dried vegetable) were mostly higher than the maximum level of copper as food contaminant (0.5 mg/100-g food produce) as recommended by FAO/WHO. All the vegetables from Tabata had high levels of copper and were a possible health hazard.

The concentration levels of nickel found in the vegetables ranged from 0.01 mg to 0.69 mg/100-g dried vegetable. These levels were similar to the levels of lead found in the vegetables. Nickel is an essential element at low concentration and a toxic element when intake is at concentration higher than 12 mg per person per day (Anon 1985). Therefore nickel was present at very safe levels in the Dar es Salaam green vegetables.

The average levels of each heavy metal in the vegetables from the six cultivating locations are presented in Table 3. When the average heavy metal contents are compared to the maximum levels permitted in foods (FAO/WHO) we observe that people eating vegetables grown at Tabata, Makongo, Buguruni and Sinza were consuming lead at concentration levels potentially hazardous to their health. Those eating vegetables of Makongo and Buguruni were consuming potentially hazardous levels of zinc also, while those eating vegetables grown at Kiwalani and Ukonga were consuming unsafe levels of zinc only.

Table 3: Mean heavy metal content (mg/g dried vegetable) in vegetables from different locations

Location	lead	cadmium	chromium	nickel	zinc	copper
Tabata	0.0061	0.0003	0.0054	0.0033	0.0452	0.0137
Kiwalani	0.0004	0.0001	0.0033	0.0008	0.0569	0.0057
Makongo	0.0041	0.0001	0.0031	0.0027	0.0647	0.0043
Ukonga	0.0003	0.0001	0.0035	0.0008	0.0574	0.0062
Buguruni	0.0061	0.0004	0.0033	0.0036	0.0589	0.0052
Sinza	0.0047	0.0003	0.0079	0.0021	0.0566	0.0070
*Sinza	0.0044	0.0004	0.0044	0.0023	0.0339	0.0079
*Kariakoo	0.0028	0.0003	0.0030	nd	0.0295	0.0139
Max. level of contaminant (mg/kg-food) (FAO/WHO)	0.3	0.06	-	-	5.0	5.0

*Raja TK *et al.* (1997) nd - not determined

The percent moisture content and mean heavy metal contents in fresh vegetables are presented in Table 4. From the results we note that all fresh vegetables contained lead and zinc at levels higher than the maximum levels permitted in food (FAO/WHO).

Table 4: Moisture content and mean heavy metal content (mg/kg-fresh vegetable) in different vegetables

Vegetable	% moisture content	lead	cadmium	chromium	nickel	zinc	copper
Amaranth	83.0 ± 2.1	0.54	0.04	0.56	0.46	9.96	1.16
Chinese cabbage	91.3 ± 4.6	0.39	0.02	0.40	0.25	5.26	0.76
Cowpea leaves	87.8 ± 2.5	0.40	0.03	0.49	0.23	4.81	0.90
Leafy cabbage	88.8 ± 1.8	0.37	0.03	0.36	0.24	6.43	0.64
Pumpkin leaves	85.1 ± 1.5	0.63	0.03	0.60	0.39	6.65	1.42
Average	87.2 ± 2.5	0.47	0.03	0.48	0.32	6.62	0.98
Max. level of I contaminant in food (mg/kg-food) I (FAO/WHO)		0.30	0.06	-	-	5.0	5.0
Maximum tolerable daily intake in mg/60-kg person /day		0.24	0.07	10	12	6.0	-

The average consumption of leafy vegetables per person per day in Tanzania for 1985 was about 108 g of fresh vegetable (Lukwanjo & Tanner 1985). The daily average intake of heavy metal from any vegetable source by a person at a location was calculated using the formula:

Daily intake of metal by a person at a location (µg) = Average consumption of vegetable per person per day (= 108 g) **x** Percent dry weight of vegetable i.e. (=100 - % moisture) / 100 (Table 4) **x** Mean heavy metal content per gram of dry vegetable at a location (mg/g) (Table 3) **x** 1000 (µg/mg)

Using the results in tables 3 and 4 we calculate the average daily intake of lead from eating vegetables grown at the different locations. This is presented as Table 5. The average daily intake of lead from eating Amaranth grown at Tabata or Buguruni is 112 µg per person. For a 60-kg person the maximum tolerable daily intake of lead is 210 µg (FAO/WHO). This is equivalent to a person eating only 202 g of fresh Buguruni/Tabata-Amaranth per day. Thus, considering intake of lead only, amaranth from Tabata and Buguruni are potentially hazardous to human health. The amaranth from Makongo and Sinza are potentially hazardous too, considering the daily intake of lead, if a person's daily consumption of this vegetable is more than 301 and 264 g respectively.

Table 5: Average daily intake of lead (μg/person/day) from eating (108 g) vegetables

Location / Vegetable	Tabata	Kiwalani	Makongo	Ukonga	Buguruni	Sinza
Amaranth	112.0	7.34	75.3	5.5	112.0	86.3
Chinese cabbage	57.3	3.75	38.5	2.8	57.3	44.2
Cowpea leaves	80.4	5.27	54.0	3.9	80.4	61.9
Leafy cabbage	73.8	4.84	49.6	3.6	73.8	56.8
Pumpkin leaves	98.2	6.4	66.0	4.8	98.2	75.6

(Maximum tolerable daily intake of lead per person = 210 μg/person/day, FAO/WHO)

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