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Deposition of Heavy Metals on Green Leafy Vegetables Sold on Roadsides of Riyadh City, Saudi Arabia

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The risk of contaminants accumulating in soil, environment and crops due to sewage water, fertilizer and pollutants is of a serious concern. Heavy metals have been reported to produce mutagenic, teratogenic, neurotoxic and carcinogenic effects even at very low concentrations (Das 1990; Al-Saleh et al 1996; Waalkes et al 1999). Human beings have also been reported to develop several diseases like cardiovascular, tubular dysfunction in kidneys and nervous disorders due to metal toxicity (Friberg et al 1986, WHO 1996).

The rapid urbanization and industrialization of Riyadh City has resulted in an increase in the levels of environmental pollutants from factory emissions, industrial and domestic waste water, refuse incineration as well as exhaust from the increasing number of automobiles that circulate in the city. Winds are, sometimes, dusty due to the desert surrounding the city. Earlier, presence of cadmium, lead, and other metals has been studied in the street dust in the City of Riyadh (Ahmed et al 1993). Studies have shown that lead concentration in the air depends on traffic load and industrial activities (Al-Saleh and Taylor 1994; El-Shobokshy 1983; 1984). The fine dust associated with toxic metals remains in urban air for longer duration and also transport to pristine areas, causing deterioration of environment. Principal routes of these metals into humans are through food, water and air. Cereals followed by green leafy vegetables contain higher concentrations of toxic metals. It is well known that vegetables absorb these metals from soil and atmosphere. Vegetables and fruits are mostly sold on pavements of busy roads in many areas of Riyadh City. The deposition from dust onto the foliage will add to their concentration since heavy metals from the surface can not be washed completely as they are firmly attached. So far very few studies have been done on the levels of toxic metals in foods and vegetables of Saudi Arabia. Considering the significance of heavy metals, the present study was aimed to determine the concentrations of cadmium, lead, copper and zinc in green leafy vegetables procured from roadsides, before and after thoroughly washing.

MATERIALS AND METHODS

All the chemicals and reagents were of the highest purity analytical reagent grade procured from BDH Laboratory Suppliers (Poole, England) or Merck (Darmstadt, Germany).

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Six kinds of locally grown and commonly consumed green leafy vegetables viz., garden rocket, coriander, watercress, parsley, purslane and lettuce were selected. Two kg of each vegetable was purchased ostensibly for consumption from five different pavement selling points in Riyadh City i.e. east (*Rabwa*), west (*Atiqua*), south (*Hilla*), north (*Dabbab*) and central (*Khazzan*). Edible portions of each vegetable were randomly divided into two fractions. The first fraction was soaked in tap water for 15 min to remove the earthly impurities, and then washed twice with distilled water, decant the water present on it, and the sample was labeled as 'Washed Sample'. The second fraction was subjected to digestion without washing and hence labeled as 'Unwashed Sample'.

Both the washed and unwashed samples were weighed and dried in an oven at 65°C for 24 -- 30 hrs, and then re-weighed to determine the water content. The dried and homogenized sample was wet digested with a mixture of concentrated HNO_3, H_2SO_4 and $HClO_4$ (10:1:4) on a hot plate maintained at 70 ± 2 °C. After digestion solution was made up to 50 ml with distilled de-ionized water, cooled and filtered through Whatmann filter paper (Ash less No # 42), and then stored in polyethylene bottles at 5 °C until analysis.

Lead, cadmium, copper and zinc analyses were performed using a Shimadzu AA-6800 atomic absorption spectrophotometer equipped with hollow cathode lamp, a deuterium lamp for background correction and a programmable sample dispenser (Shimadzu ASC-6100). Conditions of instrument were shown in Table 1.

Table 1. Standard working conditions for Shimdzu AA-6800 atomic absorption spectrophotometer.

Element	Wavelength (nm)	Slit width (nm)	Lamp current (mA)	Atomizer	Lamp mode
Cd	228.8	1.0	8	Electro thermal/ graphite furnace	BGC-D_2
Pb	283.3	1.0	10	Electro thermal/ graphite furnace	BGC-D_2
Cu	324.8	0.5	6	Flame (air-C_2H_2; 1.8 L/min)	BGC-D_2
Zn	213.9	0.5	8	Flame (air-C_2H_2; 2.0 L/min)	BGC-D_2

The optimized furnace-heating program followed for the analysis of cadmium and lead was as described by the instrument manufacturer. Recovery studies were performed for five vegetable samples and the results showed recoveries exceeded 98 ± 2 percent for heavy metals. The precision of the metal analysis was controlled by including triplicate samples in analytical batches, blanks and the method of standard addition. Relative standard deviation of means of triplicate measurements was less than 4%, which was regarded as a satisfactory precision. The results were expressed as mg metal in per kg dry weight of sample. The metal deposition on leafy vegetables due to pollution was calculated as a difference between the concentrations of unwashed sample and washed sample.

Metal deposited = (Conc. of metal in unwashed sample – Conc. of metal in washed sample).

Concentration of metals in unwashed samples were compared with the concentration of metals in respective washed samples and statistically analyzed using 'Students t – test' and the value of $P<0.05$ was considered significant.

RESULTS AND DISCUSSION

In the present study, levels of lead, cadmium, copper and zinc were determined in six selected, and washed and unwashed green leafy vegetable samples. Mean concentration with standard deviation and range of Pb and Cd in leafy vegetables are illustrated in table 2. The highest and the lowest concentration of Pb in washed samples were found in coriander 0.101 mg/kg and garden rocket 0.059 mg/kg respectively. The levels of Pb in washed samples were in the order of coriander > lettuce > purslane > watercress > parsley > garden rocket.

Soil may be a source of lead in plants, either through uptake or through deposition of leaded dust on plant surfaces. Lead in the soil comes from deposition of atmospheric lead, lead containing pesticides (e.g. lead arsenate), sewage sludge, lead containing phosphate fertilizers and soil pH. Crop variety also affects the uptake of lead from soil (Reilly 1991; Sterrett et al., 1996). The variation in levels of Pb as observed in our study might be due to the method of cultivation and also due to aerosol resulting from automobiles' emission and industrial exhaust (Mielke and Reagan 1998). The average deposition of Pb and Cd in unwashed vegetable samples is shown in figure1. Amongst the unwashed samples, maximum deposition of Pb was found in purslane while a minimum was observed in lettuce. The amount of Pb metal depositing on leafy vegetables depends upon numerous factors. The difference in deposition of metal in the samples studied may be due to the dissimilarity in air pollution, dust in the air, nature of roads, and traffic loads and the period of exposure or duration to which these vegetables are put on the roadsides for selling. Increase in the duration of exposure may increase the concentration of dust leading to more deposition of metal on vegetable surface. The higher levels of deposition on purslane and coriander may be due to the reasons mentioned earlier.

Cadmium is another toxic heavy metal and its adverse effects on kidneys, skeleton and lungs have been well documented (WHO 1992, 1996). In washed samples cadmium concentration was maximum in garden rocket 0.384 mg/kg and minimum in parsley 0.046 mg/kg. In unwashed samples, maximum deposition was found on garden rocket and minimum on parsley. Leafy vegetables were found to accumulate Cd from soil much more efficiently than any other heavy metal; hence leafy vegetables show higher levels of Cd. Potential sources of incremental cadmium in agricultural soil include the type of soil, the setting of airborne dust, polluted water used for irrigation, phosphate fertilizers and compost from household waste (Alloway 1995). Cadmium contamination observed in the present study is probably due to the cultivation in sandy soils, construction works, metal plating activities, abrasion from automobile tyres, paints and emissions from gypsum and cement factories of Riyadh City. Similar effects in the levels of cadmium and lead from

Table 2. Mean concentration, standard deviation and range of Lead and Cadmium metals in leafy vegetables.

Leafy Vegeta-ble	LEAD (mg/kg)		CADMIUM (mg/kg)	
	Washed	Unwashed	Washed	Unwashed
Garden rocket	0.059 ± 0.006 (0.053 – 0.069)	0.092 ± 0.015* (0.075 – 0.11)	0.384 ± 0.202 (0.135 – 0.601)	0.492 ± 0.288 (0.187 – 0.803)
Corian-der	0.101 ± 0.033 (0.054 – 0.143)	0.171 ± 0.076* (0.088 – 0.289)	0.278 ± 0.289 (0.023 – 0.495)	0.353 ± 0.289 (0.109 – 0.856)
Water-cress	0.066 ± 0.028 (0.039 – 0.106)	0.084 ± 0.036 (0.041 – 0.133)	0.207 ± 0.205 (0.033 – 0.495)	0.259 ± 0.214 (0.056 – 0.526
Parsley	0.060 ± 0.023 (0.039 – 0.099)	0.117 ± 0.075 (0.047 – 0.235)	0.046 ± 0.016 (0.024 – 0.062)	0.078 ± 0.031* (0.045 – 0.118)
Purslane	0.087 ± 0.012 (0.072 – 0.103)	0.226 ± 0.156* (0.11 – 0.495)	0.222 ± 0.158 (0.072 – 0.427)	0.310 ± 0.191 (0.123 – 0.527)
Lettuce	0.096 ± 0.040 (0.051 – 0.155)	0.111 ± 0.046 (0.062 – 0.183)	0.176 ± 0.062* (0.127 – 0.280)	0.272 ± 0.095* (0.171 – 0.410)
All	0.078 ± 0.019	0.134 ± 0.055*	0.219 ± 0.112	0.294 ± 0.135

Values are mean concentration ± standard deviation.
Results in parenthesis ( ) indicate range.
* (P<0.05), when compared to respective washed sample by 'Student's t test'.

roadside vegetables have also been reported in the literature (Ndiokwere 1984; Tumbo-Oeri 1988).

Although copper and zinc are essential elements yet they may be toxic to both animals and humans when their concentration crosses the safe limits (Merian 1991). The mean concentration, standard deviation and range of Cu and Zn in leafy vegetables have been represented in table 3. The maximum and minimum concentration of copper in washed samples was found in purslane (20.18 mg/kg) and in garden rocket (8.63 mg/kg) respectively. Average deposition of Cu and Zn metals on roadside leafy vegetables has been illustrated in figure 2. The deposition of this metal from dust and air borne pollution as observed in unwashed samples was maximum in purslane and minimum in coriander. Copper concentration in crops and forages depends on its concentration in the soil, soil pH, plant species, crop management, yield and climate (Mc Dowell 1992). Elevated levels of copper have been found to produce anemia, intestinal disorders, and circulatory disturbances and kidney and liver failure (Turnlund 1994). The results obtained here may be attributed to application of micronutrient fertilizers and copper sulphate as a fungicide, which may increase the levels of Cu to alarming level.

Table 3. Mean concentration, standard deviation and range of Copper and Zinc metals in leafy vegetables.

Leafy Veget-able	COPPER (mg/kg)		ZINC (mg/kg)	
	Washed	Unwashed	Washed	Unwashed
Garden rocket	8.63 ± 2.73 (5.98 – 13.19)	19.87 ± 8.70* (9.43 – 30.52)	19.24 ± 4.79 (14.21 – 25.40)	26.88 ± 7.56* (17.16 – 36.78)
Corian-der	15.29 ± 6.65 (8.79 – 25.42)	20.99 ± 6.29 (12.09 – 27.65)	31.42 ± 11.43 (12.78 – 41.05)	38.07 ± 16.40 (14.14 – 44.91)
Water-cress	13.79 ± 4.13 (8.79 – 17.19)	27.02 ± 11.81* (14.52 – 40.58)	34.29 ± 11.65 (20.18 – 46.45)	41.13 ± 18.33 (16.69 – 61.41)
Parsley	13.99 ± 7.11 (8.17 – 24.89)	20.52 ± 11.21 (11.21 – 35.29)	30.57 ± 7.98 (24.5 – 43.54)	41.73 ± 10.29* (31.34 - 58.77)
Purslane	20.18 ± 9.95 (9.24 – 32.49)	32.96 ± 13.47* (20.15 – 50.48)	41.93 ± 11.67 (27.78 – 57.27)	60.68 ± 13.90* (46.88 – 76.28)
Lettuce	12.51 ± 8.39 (3.83 – 25.07)	21.93 ± 14.97 (6.34 – 46.52)	27.95 ± 11.74 (18.99 – 42.10)	36.81 ± 17.71 (15.16 – 61.96)
All	14.06 ± 3.77	24.22 ± 5.86*	30.90 ± 7.46	40.88 ± 11.08*

Values are mean concentration ± standard deviation.
Results in parenthesis ( ) indicate range.
* ($P<0.05$), when compared to respective washed sample by 'Student's t test'.

Maximum zinc level was found in purslane 41.93 mg/kg and garden rocket showed a minimum level 19.24 mg/kg in washed samples. Among the unwashed samples deposition was maximum on purslane and minimum on coriander. Zinc is a bio essential element; hence plants absorb zinc in adequate concentrations from soil and water. Zinc absorption and accumulation by plants varies considerably between species and cultivars. Long-term excessive exposure of zinc may interact with the metabolism of other trace elements (Yadrick et al., 1989) and may impair immuno response (Chandra 1984). Excess zinc might be arising from pollution especially sewage sludge, fertilizers, pesticides and galvanizing factories nearer to the City. In this study, the observed lesser concentration of lead compared to cadmium was probably due to the strict prohibition of lead use in gasoline in Saudi Arabia. Heavy metal concentration for the examined leafy vegetables showed large variations probably due to difference in cultivation and fertilizers used and uptake of metal by plants. Among the leafy vegetables purslane showed elevated levels of almost all the metals examined, probably due to high water contents in its leaves.

World Health Organization has recommended a safe limit of Provisional Tolerable Daily Intake (PTDI) as 214 µg for lead, 60 µg for cadmium, 30 mg for copper and

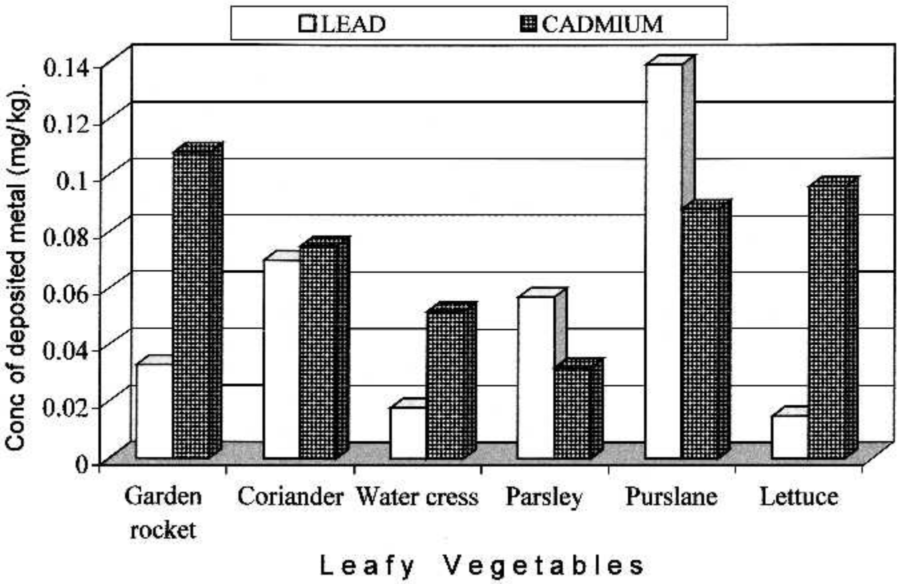

Figure 1. Average deposition of Pb and Cd on leafy vegetables of roadside area.

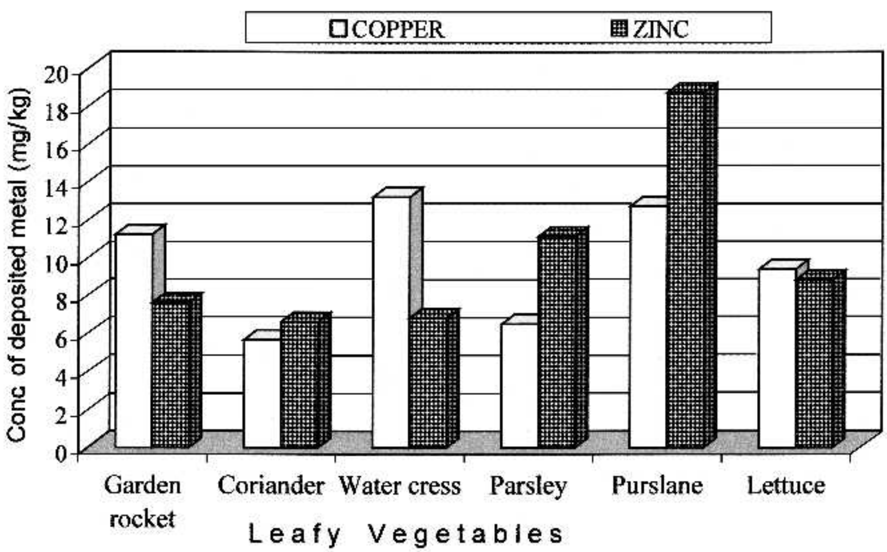

Figure 2. Average deposition of Cu and Zn on leafy vegetables of roadside area.

60 mg for zinc (for a reference adult = 60 kg) (WHO 1982a, 1982b, 1993). In the present study, the mean concentrations of the metals found in washed fresh leafy vegetables were used to calculate their daily intakes and compared with PTDI set by WHO. Some countries adopted the daily consumption of fresh vegetables per person as nearly 200 g (Ursinyova et al 1997), but Saudis consume vegetables in

lesser quantities compared to Europeans. If it is assumed that Saudis may consume 150 g fresh vegetables per day (which corresponds to 9% of total food consumed), the calculated daily mean lead, cadmium, copper and zinc intakes were 1.23 µg, 3.46 µg, 0.22 mg and 0.49 mg respectively. Though this may vary certainly with the dietary pattern of an individual. Further the above calculations are based on metal contents found in locally grown vegetables. It is evident that values might be slightly affected by the consumption of imported vegetables where contents of respective metals may be slightly different. The results of this study in comparison with PTDI values indicate that intakes of metals through leafy vegetables from Saudi Arabia would not mean a health hazard for consumers, but gets significance in light of the reported daily intakes for Pb and Cd through rice in Saudi diet as 67.41µg Pb and 10.31µg Cd (Al-Saleh and Shinwari 2001).

However, follow up studies need to be conducted on a broader scale to monitor any bioaccumulation of metals in order to evaluate any health risks from heavy metal exposure in Saudi Arabia.

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