

Heavy metal levels in leafy vegetables and some selected fruits

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Received: 29 March 2010 / Accepted: 7 April 2010 / Published online: 6 May 2010
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Abstract The aim of this study was to determine the levels of Cu, Zn, Fe, Pb and Cd in various fruits (tomato, cherry, grape, strawberry) and vegetables (parsley, onion, lettuce, garlic, nettle, peppermint, rocket, spinach, dill, broad bean, chard, purslane, grapevine leaves) grown in Manisa region. Flame and Graphite Furnace Atomic absorption spectrometry was used to estimate and evaluate the levels of these metals. Detected levels ranged from 0.56 to 329.7, 0.01 to 5.67, 0.26 to 30.68, 0.001 to 0.97 and 0 to 0.06 µg/g for Fe, Cu, Zn, Pb and Cd, respectively. While the highest mean levels of Cu and Zn were detected in grapevine leaves, the lowest mean levels of Fe and Pb were detected in nettle. Cd was not detected in most of the fruits and vegetables studied. The estimated daily intakes of Cu, Zn, Fe, Pb and Cd through fruits and vegetables were found to be below the maximum tolerable levels recommended by FAO/WHO. The element concentrations of fruits and vegetables analyzed in this study were within safety baseline levels for human consumption.

Keywords Atomic absorption spectrometer · Heavy metals · Leafy vegetables · Fruits

Abbreviations

EPA	The Environmental Protection Agency
JECFA	Joint Expert Committee of Food Additives and Contaminants
PMTDI	Provisional maximum tolerable daily intakes
PTWI	Provisional maximum tolerable weekly intakes
RfDs	Reference doses

1 Introduction

Vegetables are vital to the human diet, and in particular provide the well-known trace elements and heavy metals. Minor or trace elements are essential for good health if they come from an organic or plant source. In contrast, if they come from an inorganic or metallic source, they become toxic. The processes of plant growth depend on the cycle of nutrients including trace elements, from soil to plant (Mohamed et al. 2003). Vegetables, especially leafy vegetables, accumulate higher amounts of heavy metals because they absorb these metals in their leaves.

The consumption of leafy vegetables and fruits in Turkey, especially in Aegean and Mediterranean regions, is common. The people living in these areas consume significant amounts of leafy vegetables and fruits. Manisa is both an industrial and agricultural city and is placed in the Aegean Region of Turkey. Leafy vegetables are both cultivated and consumed in Manisa.

Heavy metals are among the major contaminants of food supply and may be considered the most

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important problem to our environment (Zaidi et al. 2005) that can reduce both the productivity of plants and endanger the safety of plant products as foods and feeds (Zheljazkov et al. 2006). This problem is even getting more serious all over the world especially in developing countries. Heavy metals, in general, are not biodegradable, have long biological half-lives and have the potential for accumulation in the different body organs leading to undesirable side effects (Sathawara et al. 2004; Radwan and Salama 2006). Heavy metal contamination may occur due to factors including irrigation with contaminated water, the addition of fertilizers and metal-based pesticides, industrial emissions, transportation, harvesting process, storage and/or sale (Radwan and Salama 2006; Tuzen and Soylak 2007; Duran et al. 2007).

Lead and cadmium are among the most abundant heavy metals and are particularly toxic. The excessive amount of these metals in food is associated with etiology of a number of diseases, especially with cardiovascular, kidney, nervous as well as bone diseases (Sanchez-Castillo et al. 1998; Steenland and Boffetta 2000). Lead is well known for its toxicity and adverse effects on human health. Absorption of ingested lead may constitute a serious risk to public health. Some chronic effects of lead poisoning are colic, constipation and anemia (Bolger et al. 2000).

Other metals such as copper and zinc are essential for important biochemical and physiological functions and necessary for maintaining good health throughout life (Radwan and Salama 2006). Copper is necessary for body pigmentation in addition to iron, for the maintenance of a healthy central nervous system, for prevention of anemia, and is interrelated with the function of zinc and iron in the body (Goldhaber 2003; Duran et al. 2007).

Zinc is a component of a variety of enzymes, including the ribonucleic polymerases, alcohol dehydrogenase, carbonic anhydrase, and alkaline phosphatase in humans (Goldhaber 2003). Deficiency of zinc can result from inadequate dietary intake, impaired absorption, excessive excretion or inherited defects in zinc metabolism (Colak et al. 2005) whereas copper deficiency is characterized by anemia, neutropenia and skeletal abnormalities (Radwan and Salama 2006).

Iron is an essential element for humans. It is a constituent of hemoglobin, myoglobin and a number of enzymes, and as much as 30 % of the body iron is found in storage forms such as ferritin and hemosiderin, in the spleen, liver, and bone marrow, and a small amount is associated with the blood transport protein transferrin. Iron deficiency results in anemia,

which ranges from a fall in plasma ferritin with no functional impairment to severe iron deficiency characterized by small red blood cells with low hemoglobin concentrations (Goldhaber 2003).

Essential trace elements are the compounds needed in the human diet to maintain normal physiological functions. Risk assessment of trace elements has shown two levels of toxicity: (1) that associated with high intakes resulting toxicity (Tuzen 2003) and (2) that associated with low intakes result in nutritional problems (Goldhaber 2003).

Apart from their rich contents of vitamin C and beta-carotene, leafy vegetables are an excellent source of mineral constituents whose importance in the human diet is undisputable. Some of them, such as potassium, sodium, phosphorus, calcium, magnesium, or iron, are indispensable in the sustaining human health (Lozak et al. 2002). However, it is important to monitor the levels of toxic metals in leafy vegetables and fruits due to environmental concerns.

The purpose of the present study was to determine the levels of some trace elements in 13 different leafy vegetables and four different fruits samples sold in Manisa (Turkey) marketplaces. Fruits and vegetables were selected on the basis of their consumption rates.

2 Materials and methods

2.1 Sampling

Leafy vegetables (parsley, onion, lettuce, garlic, nettle, peppermint, rocket, spinach, dill, broad bean, chard, purslane, grapevine leaves) and fruits (tomato, strawberry, cherry, grape) samples were purchased (10 samples of each species) from local retailers in Manisa, Turkey (during the year of 2005–2006). Local and botanical names of fruit and vegetable samples are given in Table 1. Parts of the samples that were obviously dust contaminated, damaged by insects or mechanically injured were removed. Then, the selected samples were washed in distilled water. Only edible parts of the samples were blended using a kitchen blender (Arcelik, Eskisehir) and stored in polyethylene bags at -18°C until analysis.

2.2 Reagents

All reagents used were of analytical grade. All the plastic and glassware were cleaned by soaking them in a 10 % nitric acid solution and rinsing them with distilled water prior to use. The element stock

Table 1 Fruits and vegetables samples, with their local and botanical names

	Local name (Turkish)	Botanical name	Used part
Strawberry	Cilek	<i>Fragaria ananassa</i>	Fruit
Cherry	Kiraz	<i>Prunus avium</i>	Fruit
Tomato	Domates	<i>Lycopersicum esculantum</i>	Fruit
Grape	Uzum	<i>Vitis vinifera</i>	Fruit
Parsley	Maydanoz	<i>Petroselinum sativum</i>	Leaf
Onion (fresh)	Sogan	<i>Allium cepa</i>	Leaf
Lettuce	Marul	<i>Lactuca sativa</i>	Leaf
Garlic (fresh)	Sarmisak	<i>Allium sativum</i>	Leaf
Nettle	Isirgan otu	<i>Folium urtiace</i>	Leaf
Peppermint	Nane	<i>Menthae piperitae</i>	Leaf
Rocket	Roka	<i>Erucae sativae</i>	Leaf
Spinach	Ispanak	<i>Spinaciae oleracea</i>	Leaf
Dill	Dere otu	<i>Anethum graveolens</i>	Leaf
Broadbean	Bakla	<i>Vicia faba</i>	Fruit
Chard	Pazi	<i>Betavulgaris cicla</i>	Leaf
Purslane	Semiz otu	<i>Portulaca oleracea</i>	Leaf
Grapevine leaves	Asma yapragi	<i>Vitis vinifera</i>	Leaves

solutions (1,000 mg/L) and HNO₃ used for digestion were provided by Merck (Darmstadt, Germany).

2.3 Sample preparation

Wet digestion method was used for sample preparation (Hseu 2004). Ten grams of samples were weighed into digestion tubes and 10 ml of concentrated HNO₃ were added. The samples were digested for 45 min at 90 °C and for 3 h at 130 °C, respectively. After digestion, the residue was filtered through blue band filter paper. Then, the samples were diluted to 50 ml with distilled water. Duplicated analysis was performed on the samples. Blank digestion was also carried out.

2.4 Standard solutions

The standard solutions were prepared by diluting the stock solutions of 1,000 mg/L of lead, cadmium, iron, zinc and copper.

2.5 AAS apparatus and analysis conditions

All the analysis was performed by Perkin-Elmer Analyst 800 model atomic absorption spectrometer (Perkin-Elmer Instruments, Shelton, CT, USA) equipped with THGA (Transversely Heated Graphite Atomization) and longitudinal Zeeman affect background corrector was used. Iron, zinc and copper were determined using air/acetylene flame,

cadmium and lead by graphite furnace as atomization systems. Lumina and EDL (Electrodeless Discharge Lamp) hollow cathode lamps were employed as a radiation source. Argon was used as an inert gas for graphite furnace measurements. The operating parameters for elements were recommended by the manufacturer. The temperature program of graphite furnace is given in Table 2. Samples were injected into the graphite tubes using a Perkin-Elmer AS-800 Autosampler. Matrix modifiers at the concentration of 0.005 mg (5 µL, 1 % w/v) NH₄H₂PO₄ and 0.003 mg (5 µL, 0.06 % w/v) Mg(NO₃)₂ were added to 20 µL sample. The atomic absorption signal was determined in peak height mode against a calibration curve.

A recovery study was carried out by spiking and homogenizing several analyzed samples with varied amounts of standard metal solutions. The average recoveries obtained were 91.15 ± 8.12, 96 ± 5.23, 97 ± 3.00, 85.25 ± 10.50, and 90.00 ± 5.00 % for Fe, Cu, Zn, Pb and Cd, respectively.

3 Results and discussion

Trace element analysis in the collected 170 samples of 13 different leafy vegetables and 4 different fruits was run in duplicate. Data obtained from the analyzed samples are given in Table 3. Mineral elements were found to vary widely among studied fruits and vegetables. The concentrations of metals in samples were

Table 2 The temperature program for graphite furnace method

Steps	Operation	Temperature (°C)	Ramp time (s)	Hold time (s)	Internal flow (ml/min)
1	First drying	110	10	20	250
2	Second drying	130	10	20	250
3	Pyrolysis	450	10	20	250
4	Atomization	2,400	0	5	0
5	Clean-out	2,500	1	3	250

as follows: Fe (0.56–329.7 µg/g), Cu (0.01–5.67 µg/g), Zn (0.26–30.68 µg/g), Pb (0.001–0.97 µg/g) and Cd (nd–0.06 µg/g). Vegetables absorb heavy metals from the soil and polluted air and water. Especially leafy vegetables accumulate higher amounts of heavy metals in their leaves (Demirezen and Aksoy 2006).

3.1 Minerals and toxic elements in fruits

The levels of Fe were in the range of 2.20–8.95 µg/g in strawberry, 0.56–3.27 µg/g in tomatoes, 1.73–5.92 µg/g in cherry and 2.35–4.48 µg/g in grapes. The copper and zinc levels were among 0.28–1.13 and 0.80–1.67 µg/g in strawberry, 0.59–0.84 and 0.81–1.30 µg/g in tomatoes, 0.84–0.87 and 0.97–1.66 µg/g in cherry and 0.40–0.71 and 0.26–0.58 µg/g in grapes, respectively. The standard deviation of the mean values of Cu and Zn are quite low implying that the fruits analyzed in this study were not highly contaminated with copper and zinc based contaminants. Within the selected fruits studied, lead levels ranged from 0.001 to 0.022 µg/g. Lead content of all fruit samples were below EC limits. The maximum lead level permitted for fruits and small fruits are 0.10 and 0.20 mg/kg, respectively (EC 2006). Cadmium contents of all fruit samples were found under detectable limits (Table 3).

Ozcan and Haciseferogullari (2007) found Fe, Cu, Zn, Pb and Cd contents of strawberry fruit of 12.15, 1.65, 8.09, 0.51 and 0.19 mg/kg, respectively. In an other study, Radwan and Salama (2006) found Cu, Zn, Pb and Cd of 2.17, 7.49, 0.87 and 0.02 mg/kg in strawberry and 1.83, 7.69, 0.26 and 0.01 mg/kg in tomatoes, respectively.

3.2 Minerals and toxic elements in vegetables

Trace element concentrations on wet basis are given in Table 3. According to the results, iron had the highest concentration, followed by zinc and copper.

The rocket (149.56 µg/g), nettle (95.75 µg/g), parsley (94.02 µg/g) and peppermint (82.25 µg/g) exhibited higher levels of Fe than the other vegetables. All

vegetable species except garlic showed a wide range of Fe concentration. Mohamed et al. (2003) reported Fe contents of 323.0 µg/g for lettuce, 182.8 µg/g for parsley, 166.4 µg/g for spinach and 93.6 µg/g for onion. In previous studies, iron levels in vegetables have been reported in the range of 9.3–76.6 µg/g in bean and tomato (Gebeloglu et al. 2004), 4.5–9.7 µg/g in tomato, pepper and corn (Tuzen 2003), and 40.1–261.6 µg/g in lettuce, cabbage, spinach (Divrikli et al. 2003).

Plants grown in the Zn and Cu-contaminated soils accumulate a great portion of metals in their roots (Stalikas et al. 1997). Copper is known to be vital and toxic for many biological systems. In the present study, Cu levels were determined in the range of 0.51–0.85 µg/g for fruits, and 0.01–22.03 µg/g for vegetables. Mean values of copper content of samples generally shows low standard deviation value (Table 3). This means that samples are not contaminated with copper compounds except grapevine leaves. Although eight of grapevine leaves samples contain below 1 µg/g copper, only two of them are highly contaminated (22.03 and 41.98 µg/g). High copper content may be caused by some copper-based fungicides used in vineyards. Fresh grapevine leaves are often used in *sarma meal* which is lovely consumed in Turkey. Cu levels in vegetables are between 0.11 and 4.12 µg/g in Greece (Stalikas et al. 1997), 0.43 and 5.71 µg/g in Egypt (Mohamed et al. 2003), 0.83 and 16.5 µg/g in Egypt (Radwan and Salama 2006), 22.19 and 76.5 µg/g in Turkey (Demirezen and Aksoy 2006), 0.10–5.04 mg/kg in Pakistan (Parveen et al. 2003), and 0.25–12.50 mg/kg in Nigeria (Onianwa et al. 2001).

In this study, maximum level of zinc was detected in grapevine leaves (10.81 µg/g) while garlic had the lowest level (2.41 µg/g). Zinc values in samples do not vary widely, except for parsley, spinach and grapevine leaves samples. Two of parsley, four of spinach and three of grapevine leaf samples contain over 10 µg/g zinc, thus these samples may be contaminated. Zinc levels in vegetables have been reported in the range of 4.50–105.2 µg/g (Mohamed et al. 2003), 7.16–20.9 µg/g (Radwan and Salama 2006),

Table 3 Concentration of trace elements in different leafy vegetables and fruit samples ($\mu\text{g/g}$) ($n = 10$)

	Fe		Cu		Zn		Pb		Cd	
	Ranges	Mean \pm SD	Ranges	Mean \pm SD	Ranges	Mean \pm SD	Ranges	Mean \pm SD	Ranges	Mean \pm SD
Fruits										
Strawberry	2.20–8.95	5.55 \pm 2.57	0.28–1.13	0.54 \pm 0.22	0.80–1.67	1.10 \pm 0.26	0.003–0.010	0.006 \pm 0.002	nd	nd
Cherry	1.73–5.92	3.28 \pm 1.79	0.84–0.90	0.85 \pm 0.03	0.97–1.66	1.35 \pm 0.27	0.005–0.010	0.007 \pm 0.003	nd	nd
Tomato	0.56–3.27	1.76 \pm 0.80	0.59–0.84	0.71 \pm 0.07	0.81–1.30	1.09 \pm 0.17	0.001–0.022	0.004 \pm 0.009	nd	nd
Grape	2.35–4.38	3.58 \pm 0.78	0.40–0.71	0.51 \pm 0.11	0.26–0.58	0.41 \pm 0.09	0.001–0.015	0.006 \pm 0.005	nd	nd
Vegetables										
Parsley	22.59–181.7	94.02 \pm 53.03	1.19–2.83	1.83 \pm 0.49	2.12–16.82	7.57 \pm 4.25	0.005–0.077	0.044 \pm 0.026	nd	nd
Fresh onion	3.36–63.11	24.21 \pm 20.80	3.15–4.32	3.78 \pm 0.39	1.11–3.78	2.57 \pm 0.73	0.009–0.045	0.022 \pm 0.012	nd	nd
Lettuce	4.04–66.13	24.46 \pm 22.26	0.32–0.71	0.48 \pm 0.13	1.86–3.63	2.41 \pm 0.54	0.075–0.249	0.163 \pm 0.070	nd–0.031	0.005 \pm 0.001
Fresh garlic	2.63–8.51	4.99 \pm 1.89	0.30–1.21	0.71 \pm 0.31	1.71–6.52	2.95 \pm 1.47	0.003–0.019	0.011 \pm 0.007	nd	nd
Nettle	37.23–329.7	95.75 \pm 84.59	1.53–5.67	2.74 \pm 1.27	4.83–8.40	6.53 \pm 1.32	0.079–0.970	0.249 \pm 0.230	nd–0.001	0.001 \pm 0.001
Peppermint	31.99–132.6	82.25 \pm 38.6	0.51–1.81	1.10 \pm 0.49	3.13–9.14	5.40 \pm 1.64	0.040–0.268	0.192 \pm 0.067	nd–0.034	0.004 \pm 0.001
Rocket	31.02–283.1	149.56 \pm 85.14	4.92–5.27	5.11 \pm 0.09	3.37–5.12	3.83 \pm 0.57	0.004–0.008	0.006 \pm 0.002	nd–0.060	0.024 \pm 0.001
Spinach	13.02–127.6	55.84 \pm 31.50	0.99–1.69	1.30 \pm 0.20	3.99–14.00	8.34 \pm 4.07	1.008–0.207	0.139 \pm 0.033	nd–0.055	0.024 \pm 0.001
Dill	20.91–80.04	44.98 \pm 19.00	0.70–1.16	0.87 \pm 0.15	1.77–5.70	3.65 \pm 1.38	0.004–0.409	0.159 \pm 0.120	nd–0.008	0.001 \pm 0.001
Broadbean	10.04–14.20	12.13 \pm 1.50	1.06–2.38	1.71 \pm 0.38	3.28–6.45	4.31 \pm 1.00	0.024–0.103	0.053 \pm 0.022	nd	nd
Chard	15.41–218.1	53.21 \pm 58.49	0.10–1.59	0.71 \pm 0.61	1.71–4.24	2.91 \pm 0.81	0.026–0.232	0.106 \pm 0.067	nd–0.047	0.007 \pm 0.001
Purslane	28.87–122.2	57.02 \pm 29.58	0.40–0.93	0.64 \pm 0.16	4.11–6.56	5.18 \pm 1.08	0.017–0.350	0.184 \pm 0.114	nd–0.030	0.013 \pm 0.001
Grapevine leaves	10.04–14.20	12.10 \pm 1.54	0.01–41.98	6.62 \pm 4.19	6.21–30.68	10.81 \pm 7.29	0.042–0.105	0.071 \pm 0.025	nd	nd
Mean values										
Fruits		3.54		0.65		0.99		0.006		nd
Vegetables		50.59		2.12		5.11		0.108		0.007

nd not determined

0.88–6.77 $\mu\text{g/g}$ (Stalikas et al. 1997) and our data are lower than in these reports.

The toxic elements, Cd and Pb, are natural constituents of the earth's crust: they are taken up from the soil by plants and transferred further through the food chain. In Table 3, the results showed that cadmium levels present were below the detection limits especially in fruits and certain vegetables. Cd level of rocket samples (0.06 $\mu\text{g/g}$) was the highest among the vegetables. Cadmium contents of vegetable samples changed between 0 and 0.060 mg/kg. According to EC Regulations, permissible maximum limit of Cd is 0.20 mg/kg for vegetables (EC 2006). Cd is found predominantly in phosphoric fertilizers and many agricultural soils have heavy doses of phosphate fertilizers (Demirezen and Aksoy 2006). Cadmium contents have been reported in the ranges of 0.0002–0.527 mg/kg in foodstuffs from the Greek market (Karavoltzos et al. 2002). Stupski et al. (2005) reported that the leaves of dill contained 0.023–0.028 mg cadmium.

Lead levels of parsley (0.044 $\mu\text{g/g}$), rocket (0.006 $\mu\text{g/g}$), garlic (0.011 $\mu\text{g/g}$), onion (0.022 $\mu\text{g/g}$) and broad bean (0.053 $\mu\text{g/g}$) samples were found to be low (Table 3). Among the vegetables especially spinach, nettle, peppermint, purslane, lettuce, chard and dill samples showed much higher lead levels (over 0.10 $\mu\text{g/g}$) than the others. But only two dill, three purslane and one nettle samples have contained lead over permissible limits. In Turkish Food Codex (2008) and EC Regulations (EC 2006), the limit value is 0.30 mg/kg for leafy vegetables. The high contamination found in vegetables might be closely related to the pollutants in irrigation water, farm soil or due to pollution from the highway traffic (Qui et al. 2000; Radwan and Salama 2006).

Similar results were reported by some researchers. In Turkey, Erdogrul and Erbilir (2006) found Fe, Cu and Cd in spinach in concentrations of 13.02, 0.043, 0.021 mg/kg, respectively. Our results were lower than those obtained by Demirezen and Aksoy (2006), who found Cd, Pb, Cu and Zn in vegetable samples from Kayseri region in the range of 0.24–0.97, 3.00–10.70, 22.19–76.5, and 3.56–259.2 $\mu\text{g/g}$, respectively. The multielement levels in various common vegetables from two growing areas of Greece were reported as 0.001–0.009 $\mu\text{g/g}$ for Cd, 0.002–0.090 $\mu\text{g/g}$ for Pb, 2.18–14.3 $\mu\text{g/g}$ for Fe, 0.11–4.12 $\mu\text{g/g}$ for Cu, and 0.21–2.24 $\mu\text{g/g}$ for Zn (Stalikas et al. 1997).

3.3 Estimation of heavy metal intakes

Human beings are encouraged to consume more vegetables and fruits since they are a good source of

vitamins, minerals, fibers and also beneficial to human health. It is necessary to test and analyze food items to ensure that the levels of metal contaminants met international requirements. An increasingly important aspect of food quality should be the control of the concentrations of trace metals in food.

To protect humans from harmful effects of heavy metals, Joint Expert Committee of Food Additives and Contaminants, FAO/WHO (JECFA) has set similar values for toxicity, termed Provisional Maximum Tolerable Weekly Intakes (PTWI) and Provisional Maximum Tolerable Daily Intakes (PMTDI). PMTDI is the end point for contaminants with no cumulative properties and also, PTWI is the end point for food contaminants such as heavy metals with cumulative properties, used by JECFA (FAO/WHO 1999).

Daily metal intakes of some toxic elements for an adult are given in Table 4. Daily metal intakes (mg/day) are calculated by multiplying mean levels of elements in foodstuffs with mean fruit or vegetable consumption amount in Turkey. The mean daily fruit and vegetable consumptions are 315 and 398 g, respectively, in Aegean region in Turkey (TUIK 2007). As a result, the daily intake of an element from food consumption is dependent on the element concentration in vegetables and the amount of vegetables consumed.

FAO/WHO has set a PMTDI of 56 mg/day for a 70 kg adult (0.8 mg/kg-bw-day) for iron (Goldhaber 2003; IPCS 1983). According to our data, the average daily intake of Fe in the fruits and vegetables was

Table 4 Estimation of heavy metal intakes (for 70 kg adult) through consumption of fruits and vegetables in Turkey

	Daily or weekly intakes ^a		Maximum limits	References
	Fruits	Vegetables		
Fe	1.12 mg/day	20.13 mg/day	56 mg/day	PMTDI, WHO ^b
Cu	0.21 mg/day	0.85 mg/day	35 mg/day	PMTDI, WHO
Zn	0.31 mg/day	2.04 mg/day	21 mg/day	RfD, EPA ^c
Pb	13.2 $\mu\text{g/week}$	301 $\mu\text{g/week}$	1,750 $\mu\text{g/week}$	PTWI ^d , WHO
Cd	0 $\mu\text{g/week}$	19.5 $\mu\text{g/week}$	490 $\mu\text{g/week}$	PTWI, WHO

^a Intake (mg/day) = mean level ($\mu\text{g/g}$) \times mean fruit or vegetable consumption (g/person/day); mean level ($\mu\text{g/g}$) = mean level of each element in analyzed vegetable (or fruit) samples; mean fruit consumption (g/person/day) in Turkey = 315 g (TUIK 2007); mean vegetable consumption (g/person/day) in Turkey = 398 g (TUIK 2007)

^b PMTDI (mg/day): provisional maximum tolerable daily intakes (Goldhaber 2003)

^c RfD (mg/day): reference doses (EPA, Environmental Protection Agency) (EPA 2002)

^d PTWI ($\mu\text{g/week}$): provisional tolerable weekly intakes (FAO/WHO 1999)

estimated to be 1.12 and 20.13 mg, respectively, for people who live in Manisa, Turkey. Therefore, these estimated values are lower than the maximum limits.

The WHO has calculated a PMTDI of 35 mg/day for a 70 kg adult (0.5 mg/kg-bw-day), based on the fact that copper does not appear to be a cumulative toxic hazard in humans, except for those individuals with Wilson's disease (Goldhaber 2003; IPCS 1982). The daily intake level of Cu in fruits and vegetables was estimated to be 0.21 and 0.85 µg/day, respectively, in the area studied.

The WHO has not set a PMTDI for zinc. The Environmental Protection Agency (EPA) has carried out risk assessments dealing with the toxicity, developing Reference doses (RfDs) for a large number of chemicals, including some essential trace elements (Goldhaber 2003). The RfD is calculated in units of milligram per kilogram body weight per day (Goldhaber 2003). The EPA (2002) has set an RfD of 21 mg zinc/day (0.30 mg/kg-bw-day) for a 70 kg adult. Based on the results, average intake of Zn in fruits and vegetables collected from the study area was considered 0.31 and 2.04 µg/day, respectively. The toxicity of daily zinc and copper intakes is very low at the determined concentration levels.

Lead is well known for its toxicity and adverse effects on human health. JECFA has set a PTWI (provisional tolerable weekly intake) of 25 µg/kg-bw (equal to 1,750 µg/week for a 70 kg adult) for lead (FAO/WHO 1999). Estimated lead intakes in the sampling area were 13.2 and 301 µg/kg for fruits and vegetables, respectively.

The estimated average weekly intakes of Cd were 0 and 19.5 µg/week for fruits and vegetables, respectively. These values are lower than the PTWI of 490 µg/week for a 70 kg-adult (7 µg/kg-bw-week) (FAO/WHO 2003). The average intake of cadmium by adults in the European Union Member States is estimated by JECFA at its sixty-first meeting ranging from 2.8 to 4.2 µg/kg-bw per week, which is equivalent to approximately 40–60 % of the current PTWI of 7 µg/kg-bw per week (FAO/WHO 2003).

In other studies, daily intakes of Pb, Cd, Cu and Zn were calculated as 30 µg, 4.67 µg, 0.45 mg and 1.58 mg in Egypt (Radwan and Salama 2006), 228 µg, 63.7 µg, 0.64 mg, 14.9 mg in Turkey (Demirezen and Aksoy 2006), and 60 µg, 6 µg, 0.52 mg, 1.44 mg in Greece (Stalikas et al. 1997), respectively. The results of the present study indicate that mean intakes of heavy metals due to mean consumption of fruits and vegetables, pose no health risk as the values are lower than the respective permissible intakes. Exposures to Fe, Cu, Zn, Pb and Cd, by consumption of

vegetables were 36, 2.4, 9.7, 17.2, and 4 % of the maximum limit values, respectively.

This survey provides additional data on heavy element pollution in fruits and vegetables sold in Manisa markets in Turkey. For public health, high quality of fruits and vegetables contribute to the essential metal intake in Aegean region in Turkey. It is suggested that further studies should be performed to assume food safety and to protect the consumer.

Acknowledgments The authors are grateful for the financial support of the Unit of the Scientific Research Projects of Celal Bayar University (Project number MUH 2004/058).

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