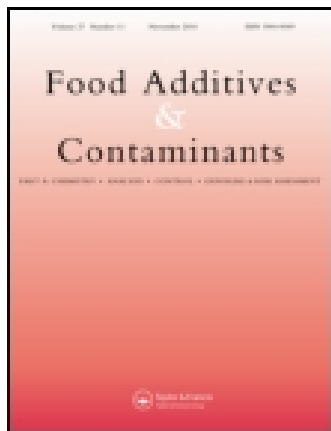


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F. Mor<sup>a</sup> & S. Ceylan<sup>b</sup>

<sup>a</sup> Department of Pharmacology and Toxicology, Faculty of Veterinary Medicine, University of Mehmet Akif Ersoy, 15100 Burdur, Turkey

<sup>b</sup> Department of Pharmacology and Toxicology, Faculty of Veterinary Medicine, University of Uludag, Bursa, Turkey

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## Cadmium and lead contamination in vegetables collected from industrial, traffic and rural areas in Bursa Province, Turkey

F. MOR<sup>1</sup> & S. CEYLAN<sup>2</sup>

<sup>1</sup>Department of Pharmacology and Toxicology, Faculty of Veterinary Medicine, University of Mehmet Akif Ersoy, 15100 Burdur, Turkey and <sup>2</sup>Department of Pharmacology and Toxicology, Faculty of Veterinary Medicine, University of Uludag, Bursa, Turkey

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### Abstract

Cadmium and lead contamination of vegetables produced in rural areas of Bursa Province, Turkey, was found to be less contaminated than vegetables grown close to heavy traffic and industrial activities. The highest levels of cadmium and lead were found in lettuce; the lowest levels in vegetables were found in leeks. The lead levels in spinach grown in traffic areas were at least twofold higher than those found in industrial areas. For other vegetables, the results from industrial and traffic areas were almost identical. Lettuce grown in traffic areas had the highest amount of cadmium ( $0.81 \pm 0.25 \text{ mg kg}^{-1}$ ) and lead ( $1.59 \pm 0.45 \text{ mg kg}^{-1}$ ), whilst leeks grown in rural areas had the lowest levels of lead ( $0.10 \pm 0.03 \text{ mg kg}^{-1}$ ) and cadmium ( $0.05 \pm 0.01 \text{ mg kg}^{-1}$ ) compared with other vegetables. This study shows that people and animals living in the same area in Bursa are always exposed to metallic pollution and in turn the consumption of contaminated vegetables could lead to increased dietary intake.

**Keywords:** Cadmium and lead, vegetables, Bursa, Turkey

### Introduction

Contamination of the biosphere by cadmium and lead due to industrial, traffic, farming and domestic activities has now created serious problems for safe agricultural utilization of soils. It is of public interest to know whether vegetables, fruit and other food crops cultivated in contaminated soils are safe for human consumption especially now the environmental quality of food production is of major concern (Chaney et al. 1998). Vegetables grown in soils contaminated with cadmium and lead metal can be an important exposure pathway for those consuming food from this source. The principal long-term effects of low-level exposure to cadmium are chronic obstructive pulmonary disease, emphysema and chronic renal tubular disease. There might also be effects on the cardiovascular and skeletal systems (Goyer and Clarkson 2001).

Studies of vegetables grown in locations close to industry have indicated elevated levels of

heavy metals. Voutsas et al. (1996) studied the impact of atmospheric pollution from industry on heavy metal contamination in vegetables grown in Greece. The results of the study indicated significantly higher levels of metal accumulation in leafy vegetables as compared with root vegetables. This partitioning of cadmium is well known, with accumulation of greater concentrations in the edible leafy portions of crops than in the storage organs or fruit (Jinadasa et al. 1997; Lehoczy et al. 1998).

Most lead compounds, particularly alkyl lead used as an antiknock additive in petrol, are important toxic contaminants and impose significant health hazards in urban environments (Nriagu 1990; Nriagu et al. 1996a, b). The largest source of anthropogenic lead is derived from the combustion of leaded petrol, which accounts for approximately 90% of the atmospheric lead input in urban environments (Nageotte and Day 1998). Public concern over the effects of lead and cadmium on

people and the environment has led to many countries adopting legislation restricting or banning their use. However, most developing countries are not at the forefront of controlling the release of lead and cadmium into the environment.

In Turkey, many old vehicles are still actively in use despite the toxicity of leaded gasoline. There have been no controls over exhaust emissions. However, Turkey steadily reduced lead in gasoline between 1998 and 2005. The lead content in high-octane leaded gasoline that contained  $0.84 \text{ g l}^{-1}$  in the pre-1988 period was reduced to  $0.40 \text{ g l}^{-1}$  in 1988 and to  $0.1 \text{ g l}^{-1}$  in 2002. Due to the high growth rate in the population with migration and speed development of industry, Bursa has become a city facing a serious level of environmental pollution caused by the use of high amounts of fertilizers, agricultural insecticides, and the generation of industrial wastes and residues of cadmium and lead from automobile exhausts.

The present study was conducted to investigate cadmium and lead contamination levels in vegetables, to find out the contributions of these pollution sources to overall contamination, and to investigate if any effects of this pollution harm human and animal health in Bursa where industrial and agricultural activity exist side by side and there is intense traffic. The study was designated to investigate cadmium and lead contamination levels in vegetables particularly growing close to industrial activities, heavy traffic and rural areas.

### Materials and methods

Vegetables samples — spinach ( $n=16$ ), cauliflower ( $n=14$ ), cabbage ( $n=16$ ), leek ( $n=13$ ), lettuce ( $n=14$ ), eggplant ( $n=23$ ), pepper ( $n=19$ ) and tomato ( $n=18$ ) — were collected from three sampling sites between August 2001 and September 2002 according to the types of activities applied. Vegetable samples were collected from areas with heavy traffic (Bursa–Ankara Highway, Bursa–Istanbul Highway, Urunlu, Ozluce), industrial areas (Yeniceabat, Minarelicavus, Demirtas, Cali) and rural sites (Gursu, Adakoy–Hasankoy, Yolcatı, Research and Training Farm in Uludag University, Faculty of Veterinary Medicine and Agricultural). Traffic density at the study sites ranged from 8000 to 16 000 vehicles per day at Bursa–Ankara Highway, Bursa–Istanbul Highway, Urunlu, and Ozluce. Samples were taken according to the type of harvest. Vegetables were washed and non-edible parts were removed according to common household practices. They were then cut into small pieces and oven-dried at  $60^\circ\text{C}$  for 72 h

until they reached a constant weight. The dried products were homogenized by grinding in a stainless steel blender to pass through a 2-mm sieve and stored in pre-cleaned polyethylene bottles in the refrigerator until they were analysed.

For digestion, a microwave closed system (Milestone Mega MLS-1200, Bergamo, Italy) was used (Sitonen 1998). A sample (1 g) was digested with 6 ml of nitric acid (65%  $\text{HNO}_3$ ) and 1 ml hydrogen peroxide (30%  $\text{H}_2\text{O}_2$ ) in a microwave digestion system for 30 min and diluted with deionized water to 25 ml. A blank digest was carried out in the same way.

### Analytical procedure

The cadmium and lead concentrations were analysed by a graphic furnace atomic absorption spectrophotometer (Ati-Unicam 90 Graphite Furnace, Ati Unicam 929 AAS, Cambridge, UK) by the methods of Jorhem (1993), AOAC (2002), and Zhang et al. (1997). All analysis involved standard addition after optimization of the temperature–time programs by way of ashing atomization. Palladium nitrate was used for cadmium and ammonium sulfate for lead as matrix modifiers. The precision of the metal analysis was controlled by including triplicate samples in analytical batches, blanks and the method of standard additions.

For cadmium and lead analysis an Ati-Unicam 929 atomic absorption spectrometer with deuterium background corrector was used. The cadmium and lead levels were determined with an Ati-Unicam graphite furnace using argon as the inert gas. The instrumental conditions were 228.8 and 283.3 nm for cadmium and lead, respectively, with a  $20 \mu\text{l}$  injected volume and a 7-s reading time. Measuring was performed in peak height mode. Uncoated graphite tubes were used throughout. Argon of 99.9998% purity was used as the purging gas through the graphite tube.

### Analytical quality assurance

Appropriate quality assurance procedures and precautions were carried out to ensure the reliability of the results. Samples were generally carefully handled to avoid contamination. Glassware was properly cleaned, and the reagents were of analytical grade. Double-distilled deionized water was used throughout the study. Reagent blank determinations were used to correct instrument readings. For validation of the analytical procedure, a recovery study was carried out by spiking and homogenizing several already analysed samples with varied amounts of standard solutions of the metals. The average recoveries obtained were  $91.35\% \pm 8.73\%$  and  $87.44\% \pm 9.60\%$  for lead and

cadmium, respectively. The results obtained for five replicate injections were in agreement with certified values for lead and cadmium (Table I).

The methods produced results which differ, with a few exceptions, less than 10% from the certified contents, with relative standard deviations of around 5%. The detection limits were  $0.66 \text{ ng g}^{-1}$  for lead and  $0.30 \text{ ng g}^{-1}$  for cadmium.

## Results and discussion

Heavy metals not only affect the nutritive values of vegetables, but also have a deleterious effect on human health. National and international regulations on food quality have lowered the maximum permissible levels of toxic metals in human food; hence, an increasingly important aspect of food quality should be to control the concentrations of trace metals in food.

Cadmium and lead concentrations of 133 vegetables (cabbage, cauliflower, eggplant, leek, lettuce, pepper, spinach, and tomato) were determined on the basis of their dry weight. Table I shows the mean cadmium and lead levels in vegetable samples. The results showed that the levels of lead in all commodities were between  $0.14\text{--}0.30 \text{ mg kg}^{-1}$  in leek and  $1.01\text{--}1.59 \text{ mg kg}^{-1}$  in lettuce. Cadmium contents varied from the amount of  $0.05\text{--}0.13 \text{ mg kg}^{-1}$  in leek to  $0.44\text{--}0.81 \text{ mg kg}^{-1}$  in lettuce.

When regarded to the average contamination, the highest levels of cadmium and lead were found in lettuce, collected from heavy traffic areas. The lowest levels of lead were in leek followed by cauliflower, eggplant, cabbage, tomato, pepper and spinach. Cadmium contamination was the highest in lettuce and pollution levels decreased in the order of spinach, eggplant, tomato, pepper, cabbage,

cauliflower and leek. As seen in Table I, cadmium and lead levels in the samples of vegetables were the highest close to intense traffic areas than the vegetables raised in areas close to settlement areas and industrial activities with intense agricultural activities.

The levels of the lead and cadmium in vegetables in some other parts of the worlds are given in Table II. The results are on the basis of dry weight. Comparison with levels in vegetables in the present study revealed that the levels are generally comparable. Leafy vegetables (lettuce and spinach) appear to contain high levels of lead and cadmium. This trend is similar to those reported in Egypt (Dogheim et al. 2004) and other countries: Germany (Engst et al. 1983), British Columbia in Canada (De Pieri et al. 1996), and Greece (Fytianos et al. 2001). However, cadmium levels are higher in Greece (Fytianos et al. 2001) and lead levels are higher in Pakistan (Parveen et al. 2003) than those found in the present paper's similar food samples. On the other hand, the cadmium and lead concentrations in cabbage were higher than those detected in Germany (Engst et al. 1983) and British Columbia (De Pieri et al. 1996). The present values for cadmium and lead in lettuce were similar to those recorded in Germany (Engst et al. 1983), while these values were above the amount found in British Columbia (De Pieri et al. 1996).

Table II compares the levels of cadmium and lead in vegetables from the present study with those obtained from studies in Germany, Pakistan, Greece, British Columbia, the USA and Ethiopia, and these countries phased out leaded petrol for general use by road vehicles in 2000; 1 October 2001–1 July 2002; 1 January 2002; 1 December 1990; 1995; and not controlled, respectively

Table I. Cadmium and lead levels in vegetables raised in the planting sites grouped according to their distance from industry sites and intense vehicle traffic areas, agricultural activities in Bursa.

Vegetable	Cadmium						Lead					
	Industrial		Traffic		Rural		Industrial		Traffic		Rural	
	Mean	<i>n</i>	Mean	<i>n</i>	Mean	<i>n</i>	Mean	<i>n</i>	Mean	<i>n</i>	Mean	<i>n</i>
Cabbage	$0.20 \pm 0.04$	5	$0.22 \pm 0.02$	6	$0.08 \pm 0.02$	5	$0.68 \pm 0.18$	5	$0.70 \pm 0.13$	6	$0.15 \pm 0.04$	5
Cauliflower	$0.23 \pm 0.02$	4	$0.17 \pm 0.03$	5	$0.05 \pm 0.01$	5	$0.40 \pm 0.01$	4	$0.31 \pm 0.03$	5	$0.10 \pm 0.03$	5
Eggplant	$0.31 \pm 0.03$	9	$0.44 \pm 0.08$	6	$0.13 \pm 0.02$	8	$0.55 \pm 0.08$	9	$0.62 \pm 0.07$	6	$0.17 \pm 0.05$	8
Leek	$0.13 \pm 0.04$	3	$0.11 \pm 0.10$	6	$0.05 \pm 0.01$	4	$0.30 \pm 0.04$	3	$0.30 \pm 0.04$	6	$0.14 \pm 0.01$	4
Lettuce	$0.60 \pm 0.08$	4	$0.81 \pm 0.25$	6	$0.44 \pm 0.07$	4	$1.51 \pm 0.32$	4	$1.59 \pm 0.45$	6	$1.01 \pm 0.10$	4
Pepper	$0.23 \pm 0.04$	7	$0.26 \pm 0.03$	6	$0.06 \pm 0.04$	6	$0.66 \pm 0.16$	7	$0.75 \pm 0.17$	6	$0.28 \pm 0.08$	6
Spinach	$0.32 \pm 0.06$	5	$0.52 \pm 0.04$	6	$0.28 \pm 0.04$	5	$0.78 \pm 0.26$	5	$1.36 \pm 0.30$	6	$0.36 \pm 0.05$	5
Tomato	$0.23 \pm 0.03$	6	$0.26 \pm 0.03$	6	$0.11 \pm 0.01$	6	$0.62 \pm 0.07$	6	$0.67 \pm 0.10$	6	$0.34 \pm 0.08$	6
Certified reference materials in vegetables	n:5		22 ppb to 1.6 ppm				n:5		85 ppb to 4.8 ppm.			

Values are the mean  $\pm$  standard deviation (SD), dry weight; ppm.

Table II. Levels of lead (Pb) and cadmium (Cd) in vegetables from Turkey compared with previously published results from other parts of the world.

Vegetable	Heavy metal concentrations (ppm)													
	Present study		Germany <sup>a</sup>		Pakistan <sup>b</sup>		Greece <sup>c</sup>		British Columbia <sup>d</sup>		USA <sup>e</sup>		Ethiopia <sup>f</sup>	
	Pb	Cd	Pb	Cd	Pb	Cd	Pb	Cd	Pb	Cd	Pb	Cd	Pb	Cd
Cabbage	0.15–0.70	0.08–0.22	0.48	0.05	–	–	–	–	0.03–0.07	0.06–0.12	–	–	–	–
Cauliflower	0.10–0.40	0.05–0.23	0.46	0.06	–	–	0.26	0.44	0.36–0.38	0.09–0.10	0.013	0.26	1.02	2.57
Eggplant	0.17–0.62	0.13–0.44	–	–	1.30	0.31	–	–	–	–	–	–	–	–
Leek	0.14–0.30	0.05–0.13	–	–	–	–	0.19	1.22	–	–	–	–	–	–
Lettuce	1.01–1.59	0.44–0.81	1.49	0.68	–	–	0.32	1.75	0.09–0.21	0.28–0.39	–	–	–	–
Pepper	0.28–0.75	0.06–0.26	–	–	1.62	0.32	–	–	–	–	–	–	–	–
Spinach	0.36–1.36	0.28–0.52	2.20	0.74	–	–	0.46	1.67	–	–	–	–	–	–
Tomato	0.34–0.67	0.11–0.26	–	–	1.56	0.33	–	–	–	–	0.009	0.031	–	–

<sup>a</sup>Engst et al. (1983).<sup>b</sup>Parveen et al. (2003).<sup>c</sup>Fytianos et al. (2001).<sup>d</sup>De Pieri et al. (1996).<sup>e</sup>Pennington et al. (1995a, b).<sup>f</sup>Rahlenbeck et al. (1999).

Values are dry weight (ppm).

(Anon. 2002; Governing Council of the United Nations Environment Programme 2002).

The values of lead were lower than the amounts reported by Parveen et al. (2003), while the present values for cadmium and lead were higher than those found Pennington et al. (1995a, b) in similar fruit vegetables. The mean level of lead in cauliflower from Germany and Greece was given as 0.46 and 0.26 mg kg<sup>-1</sup> by Engst et al. (1983) and Fytianos et al. (2001), while the USA and British Columbia recorded values of 0.013 and 0.36–0.38 mg kg<sup>-1</sup> by Pennington et al. (1995a, b) and De Pieri et al. (1996), respectively. On the other hand, the mean levels of cadmium and lead in cauliflower were higher than those found in Ethiopia (Rahlenbeck et al. 1999). The present values of the rest of the samples analysed for cadmium in eggplant were found to be within the range reported for similar samples from Pakistan (Parveen et al. 2003). The mean level of cadmium in leek samples (0.05–0.13 mg kg<sup>-1</sup>) in the present study was comparatively lower (1.22 mg kg<sup>-1</sup>) than those found by Fytianos et al. (2001).

## Conclusions

The results of this study show that significant differences exist in the cadmium and lead concentrations across and between vegetable samples from urban (heavy traffic, industrial activities) and rural areas. This is largely related to the environmental conditions and structures of plants. This might be related to industrial activities such as battery, textile, chemical industries and painting, which

can cause contamination in the urban area. Clearly, differences in concentrations rates for cadmium and lead in plants are related to the degree of concentration of the site from which the samples are collected. For the environment, the present finding indicates that motor vehicles seem to be the responsible source of cadmium and lead pollution in the vegetables near the roadside. The main source of lead pollution in Turkey is leaded gasoline, while industrial and municipal sources (galvanization operations, batteries, fertilizers, incineration of oil products, etc.), transportation, and construction work might be the most significant sources of cadmium pollution.

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