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Pollution of garden soils and vegetables in the Šalek valley

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Abstract. Soil pollution and accumulation of heavy metals in the most common vegetables were investigated in the Šalek Valley, where the largest Slovenian thermal power plant of Šoštanj (ŠTPP) is located. Methods were chosen according to international and Slovenian standards. Heavy metal content in soils and plants was determined by ICP-MS, ETAAS and hydride technique after appropriate digestion of samples. Results revealed that garden soils in the Šalek Valley are not polluted in general with heavy metals. On the contrary, some plant species exceeded permitted levels of Cd. Our results showed that the most sensitive group of plants are still affected, although emissions of heavy metals markedly decreased after the desulfurisation device was built at the ŠTPP.

Key words: Vegetables, Pollution, Heavy metal accumulation, Cadmium, Lead, Mercury, Arsenic.

Introduction

High quantities of heavy metals are released into the environment by anthropogenic activities, such as mining, combustion of fuels and waste materials as well as other industrial processes. The fate and transformation of metals in a soil – plant system depends very much on soil type and prevailing soil conditions (Ross 1996). In general availability of metal decreases as the pH level rises and the contents of clay and humus increase (Miller & Donahue 1990). Besides uptake from soils, plants can also derive significant amounts of some elements through foliar absorption. It depends on the plant species, its nutritional status, the thickness of its cuticle, the age of the leaf, the presence of stomatal guard cells, the humidity at the leaf surface and the nature of the solutes (Alloway 1990). Heavy metals enter the biological cycle and are enriched in various plant organs (Bergman 1992). Plants in which roots or leaves are used for human or animal consumption are especially critical concerning the accumulation of heavy metals.

The main objective of the study was to assess the quality of soil and commonly grown vegetables which have been exposed to electricity production in the Šalek Valley.

Material and methods

The field experiment with lettuce (*Lactuca sativa*), endive (*Cichorium endiviae*) and carrot (*Daucus carota* – Nantes) as test plants was carried out. 28 locations in distances within 10 km from the ŠTPP where included in the experiment. Altitudes of experimental plots ranged between 312 and 778 m above sea level. Seedlings of lettuce and endive were grown in the greenhouse; afterwards, 15 plantlets were transplanted to each location. Carrot was sown directly on the experimental sites. Each species occuped approximately 3 m^2 at each site. For each test species 12 – 15 plants were sampled. Individual parts of plants were separated as washed roots of carrot, washed and unwashed leaves of endive and lettuce. Plant samples were dried at 36°C and ground in an agate mortar. 250-500 mg DW plant samples were treated with 65 % HNO_3 acid. Heavy metal concentrations were measured in three replicates. The electrothermal technique was used for the determination of Cd, As and Pb (Perkin Elmer SIMAA 6000), flame atomic absorption spectrometry for the determination of Zn content (Analyst 100) and hydride technique for the determination of Hg content in plant after the acid dissolution technique with microwave heating (CEM MSP 1000 – Varian). Quality control was performed by comparison of results with the standard reference material NIST SRM 1515 Apple Leaves.

Soil samples were taken from the topsoil (0 – 20 cm). An average soil sample from each sampling site was prepared as a composite of 25 sub-samples taken from an area 250 m^2 in size (ISO 10381-1 1996). Soil samples were homogenized and ground in a ceramic grinder, then passed through a 2 mm plastic sieve before soil analysis (ISO 11464 1994). Pedologic soil parameters were determined as follows: pH in 0.1 M KCl solution, the content of organic matter by the Walkley-Black method, soil texture by pipette method, respectively (Janitzky 1986). For the analysis of metals content, the samples were ground further in an agate mill for 10 minutes then passed through 150 μm sieve. Heavy metal (Pb, Cd, As, Zn) content in soils was determined using flame and electrothermal atomic absorption spectrometric methods, while the hydride technique (Perkin Elmer SIMAA 6000) was used for the determination of Hg. A standard reference material »Montana Soil« was used for analytical quality control.

Results and disscusion

A wide range of Pb, As, Cd, Zn and Hg content was determined in the garden soil of the Šalek Valley. Levels of heavy metal samples from the surface soil layer at the depth 0 – 20 cm are presented (Table 1).

Table 1: Heavy metals content of the surface soil (n = 28) in the Šalek Valley.

	n	Cd $mgkg^{-1}DW$	Pb $mgkg^{-1}DW$	Zn $mgkg^{-1}DW$	As $mgkg^{-1}DW$	Hg $mgkg^{-1}DW$
min. – max.	28	0.3 – 1.3	23.6 – 77.9	92.0 – 348.0	4.8 – 138.0	0.07 – 0.48
average	28	0.76	45.65	181.08	16.39	0.18
stdev	28	0.25	12.18	59.24	24.17	0.09
KV %	28	33.41	26.69	32.71	147.49	52.35

The critical value for As (55 mg kg^{-1}; Off. Gaz. Rep. Slov. 68/96) was exceeded twofold in the southern hilly margin of the Valley (Mali Vrh), thereofore this site has to be defined as polluted considering As. Levels of Cd, Pb, Hg and Zn do not exceed even warning values (Off. Gaz. Rep. Slov. 68/96), which were 2 mg kg^{-1}, 100 mg kg-1, 2 mg kg^{-1} and 300 mg kg^{-1}, respectively, thus soils are not treated as polluted considering Cd, Pb, Hg and Zn. Additionally, the pedological results suggest that soil characteristics do not induce high heavy metal accumulation in plants. pH levels ranged between 4.8 and 7.1 with an arithmetic mean of 6.5, content of organic matter ranged between 3.6 and 1.3 % with an arithmetic mean of 8.5, while the content of clay ranged between 5.4 and 18.4 % with an arithmetic mean of 8.2.

Most of metals in plants originate from root uptake, but foliar uptake of some metals (especially Cd) may be relatively high as well (KABATA PENDIAȘ & PENDIAS 1984). Leafy vegetables are especially sensitive to foliar heavy metal absorption (ZUPAN & al. 1995). Results of our study revealed that the highest content of heavy metals was observed in edible green parts of lettuce (Table 2). Statistical analysis confirmed a significantly higher concentration of Cd in lettuce in comparison with other vegetables (MannWhitney U test: $U = 3.5023$, $p < 0.001$).

Table 2: Ranges of heavy metals in vegetables from garden soils in the Šalek Valley.

Vegetable			n	Cd mgkg^{-1}DW	Pb mgkg^{-1}DW	As mgkg^{-1}DW	Hg mgkg^{-1}DW
endive leaves	unwashed	min. – max.	28	0.14 – 1.78	0.08 – 3.64	0.05 – 1.46	0.01 – 0.06
(*Cichorium endivae*)		average		0.40	0.83	0.31	0.01
		stdev		0.33	0.78	0.33	0.005
		KV %		84.34	93.90	107.88	30.79
	washed	min. – max.	28	0.12 – 2.2	0.08 – 2.0	0.04 – 1.0	0.01 – 0.05
		average		0.42	0.36	0.11	0.03
		stdev		0.44	0.45	0.10	0.04
		KV %		105.68	124.83	94.65	175.05
lettuce leaves	unwashed	min. – max.	23	0.3 – 4.4	0.53 – 5.9	<1.0 – 5.86	0.04 – 0.08
(*Lactuca sativa*)		average		0.88	1.61	/	0.06
		stdev		0.88	1.19	/	0.01
		KV %		99.94	73.60	/	23.78
	washed	min. – max.	28	0.2 – 4.0	0.33 – 3.37	<1.0 – 1.53	0.05 – 0.08
		average		0.96	0.97	/	0.07
		stdev		1.21	0.77	/	0.01
		KV %		125.60	79.57	/	14.85
carrot roots	washed	min. – max.	28	0.19 – 1.4	0.41 – 1.03	< 0.1	< 0.05
(*Daucus carota*)		average		0.48	0.57	/	/
		stdev		0.30	0.12	/	/
		KV %		61.95	21.71	/	/

Over 95 % of washed lettuce samples exceeded the prescribed value for Cd in vegetables, which is 0.3 mgkg^{-1} DW (Off. Gaz. Soc. Fed. Rep. Yug. 59/83). Differences between Cd content in washed and unwashed edible green parts of vegetable were trivial, which suggest that a small fraction of Cd penetrates through the leaf cuticle (Figure 1A).

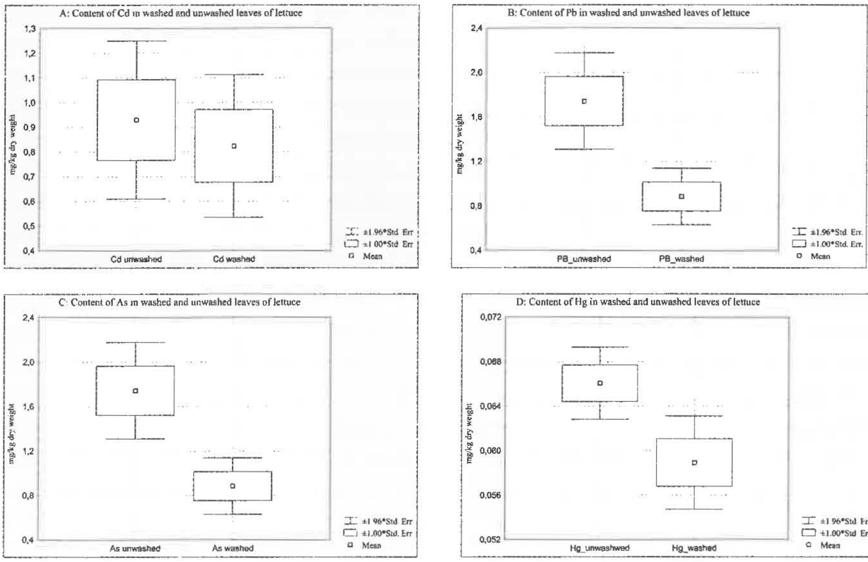

Figure 1(A – D): Differences between Cd, Pb, As and Hg content in washed and unwashed edible green parts of lettuce (*Lactuca sativa*).

On the contrary, Pb, As and Hg content significantly differed between washed and unwashed leaves and roots of carrot (Figure 1 B – D). Results also revealed that vegetable is not polluted in general with Pb, As and Hg, although on some plots (Topolšica, Mali Vrh) even washed lettuce leaves exceeded prescribed values, which are 3 $mgkg^{-1}$ and 1 $mgkg^{-1}$ DW for Pb and As, respectively (Off. Gaz. Soc. Fed. Rep. Yug. 59/83).

Conclusions

It was estimated that ŠTPP had emitted 0,2 t of Cd, 22,1 t of Pb, 4,5 t of As, 0,3 t of Hg and 298 t of Zn in the period 1981 – 2001 (POKORNY 2003). After the desulfurisation device was built in 1995 the annual dust emission decreased from 8121 t in 1994 to 1077 t in 1999 (SEVŠEK 2000). Although exact data on heavy metal emissions are not known, our results revealed that atmospherical inputs, enriched with Cd, still affect the most sensitive group of plants. A high content of Cd in test plants is consistent with the data, which confirmed a significantly higher content of Cd in the surface layer of soil (0 – 5 cm) in comparison with deeper layers (5 – 20 cm, 20 – 30 cm) (KUGONIČ & STROPNIK 2001).

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