CADMIUM, LEAD AND MERCURY CONTENTS IN ECOLOGICALLY GROWN CROPS*

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The cadmium, lead and mercury contents in caryopses and milling products of wheat, barley, rye, millet, buckwheat, peas and mixtures of some species and varieties ecologically grown according to the IFOAM principles (International Federation of Organic Agriculture Movement) and instructions of the Ministry of Agriculture of the Czech Republic were studied. In a wide assortment of varieties and products of milling processing (more than 140), the contents of these elements were determined by a certified laboratory and compared with prescribed limits of hygienic standards as well as average values of the contents of Cd, Pb and Hg in grain crops cultivated in conventional intensive agriculture. Higher values of these elements than prescribed by hygienic limits of permissible amount for foodstuffs in CR were found neither in caryopses, nor in their products and neither in limits determined by the European Union (EU). Species differences were found in the contents of Cd, Pb, Hg. Some varieties were apparently more susceptible in different years to uptake of these elements, but this could not be confirmed in the following year. A rather stronger influence of the year, particularly the weather pattern, on the uptake of heavy metals (HM) was identified. Greater varietal differences were expected and therefore we investigated mixtures of varieties and mixtures of species. In mixtures of varieties no significant difference to components of the mixture could be found. Mixtures of species offered greater possibilities for a certain combination of species to be used to achieve a decrease in HM contents. Lower HM contents were also found in larger caryopses and from thinner stands that can be used in practice. In conventional intensive agriculture, where the content of these elements was monitored, the contents of these elements in investigated years were higher than in grain crops of our trial.

grain crops; cereals; Cd, Pb, Hg contents; ecological agriculture; health safety

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INTRODUCTION

In addition to many other aspects, ecological agriculture is orientated towards production of healthy foodstuffs (so-called bioproducts). The principle of this way of management is established in advance and the growing system is controlled in order to eliminate the use of synthetic chemicals such as industrial fertilizers and pesticides (Petr, Dlouhý et al., 1992). However, ecological forms of management may also be affected by external influences from anthropogenic activities which may complicate the entire endeavour to achieve healthy production. Therefore, it depends on conditions in which this system operates. Opponents of ecological agriculture criticize this system for its possibility to take up certain heavy metals during its operation in exposed localities, e.g. from soil or from fallout, as well as the possibility for uptake of heavy metals in situation of insufficiency of major nutrients or some of the main nutrients, as a result of fertilizers not being used at all. Since 1992 we have oriented towards investigation of the quality of ecologically-grown products from all aspects. This study presents the results of an investigation into the contents of some heavy metals, particularly of cadmium, lead and mercury, in products of some ecologically grown grain crops.

Many specialists at the Czech University of Agriculture with a wide spectrum of publishing activities (Cibulka et al., 1991; Beneš, 1993, 1994; Kozák, 1991; Tlustoš, 1995, 1997, and others) have devoted their attention for more than 25 years to the problems of foreign substances. It follows from Beneš' (1994) studies that the greatest inputs of Cd, Pb and Hg come from atmospheric fallout. In lead and mercury these inputs amount to 80–90%, in cadmium to about 60%. The greatest input of this element (about 35–40%) is due to application of fertilizers.

During the trials we monitored average and maximum values of metal concentrations in dusty aerosols from the locality of trials based on the data of the Institute of Town Informatics of the capital of Prague and the Statistical Environmental Yearbook of the Czech Republic. Average values of emission limits were not found to contravene Act 309/1991. Staňo and Ševčík (1994) report the contents of heavy metals in fallout during 1992–1993 in neighborhood of Prague (Sedlec, Čáslav, Přerov nad Labem) to be 7.3 g per ha and year of mercury, 25–30 g of lead, and 0.8 g of cadmium. Beneš (1992) reports the following average values for atmospheric fallout: cadmium 9.3, mercury 2.2 and lead 181 g per ha/year.

However, knowledge of contents of heavy metals in ecologically grown crops is important in interpreting the results of our experiments. In ecologically obtained products we are looking for a way to decrease risk of consuming foodstuffs with over-limit contents of contaminants. The Czech Republic

was among countries with great load on the population through Cd, Pb and Cr in the food chain in some localities (Jedlička, 1995). Conventional intensive agriculture based on the use of fertilizers brings a lot of undesirable elements into the soil as well as to growing plants. For example, phosphorus fertilizers are accompanied by some elements dangerous to man and animals, such as Cd, Be, As, Sr, etc. The most serious in the present conditions is the input of cadmium into plants and the whole food chain. In the past, when mercury dips were used, it was also mercury. An immense development in the auto industry also leads to excessive contents of lead in some localities. Therefore, we studied whether ecological agriculture may provide products with below-limit values of these elements.

MATERIAL AND METHOD

Within the State Varieties Official Trials of the Central Control and Testing Institute for Agriculture (ÚKZÚZ), a whole set of tested varieties for the List of Recommended Varieties in Ecological Conditions is cultivated by us, as the only ones in the CR, at the Experimental Station of the Czech University of Agriculture in Praha-Uhříněves without application of fertilizers and pesticides and in harmony with IFOAM principles (International Federation of Organic Agriculture Movements) and the Methodological Instruction for Ecological Agriculture issued by the Ministry of Agriculture of CR No. 655/1993 and further amendments. Based on these instructions the Experimental Station is certified to carry out these experiments. Establishment of the trials was preceded by conversion from conventional into ecological management, which is stock-less on the experimental plot. The pedological survey was performed to evaluate balance of the plot and content of heavy metals in soil (Table I).

Dusty fallout is investigated by Hygienic Station of the capital of Prague of the site of the trials, which amounted to 7.13 g/m^2 at the Measuring Station in Praha-Uhříněves. In 1994 it was 6.63 g/m^2 and in 1995 6.05 g/m^2.

Staňo and Ševčík (1994) report that at Sedlec (at a distance of 8 km) fallout for Cd was 0.8 g/ha, for Pb 25 g/ha, and for Hg 0.2 g/ha, and for CR 12.5 g/m. Composition of wet deposition is presented in Table II.

Beneš (1994) reports inputs of hazardous elements into soils by atmospheric rainfall in the CR (range of annual precipitation 410–680 mm): Cd 0.04–0.7, Pb 41–68, and Hg 0.2–0.34 g/ha/year.

The Experimental Station Praha-Uhříněves lies in a fertile beet-growing region at an altitude of 295 m above sea level, with luvisol clay soils and a production capacity of 84 points. The contents of available nutrients in the experimental soil (Mehlich II) during the experiments were (mg/kg): P 94–96,

I. Contents of cadmium, lead and mercury in soils of the experimental plot in Praha-Uhříněves

Specification of plot	Content in 1993 (in $mg.kg^{-1}$)			Content in 1994 (in $mg.kg^{-1}$)		
	Cd^{+}	Pb^{+}	Hg^{*}	Cd	Pb	Hg
I.	0.15	12.5	0.082	0.16	14.3	0.091
II.	0.15	16.4	0.083	0.16	21.5	0.094
III.	0.14	15.7	0.088	0.15	16.9	0.086
IV.	0.14	19.5	0.090	0.16	16.3	0.103
V.	0.15	16.5	0.083	0.17	16.7	0.090
VI.	0.15	15.6	0.081	0.16	16.2	0.086
Average	0.15	16.0	0.084	0.19	16.9	0.092
Permissible limits of CR according to the Decree of the Ministry of the Environment 13/1994				1.0	70.0	0.8
Permissible limits of the European Union				1.0–3.0	50–300	1.0–1.5

$^{+}$ extract 2 M HNO_3 cold, * by AAS method

II. Heavy metals in wet deposition ($\mu g/m^3$/year)

Year	Pb	Cd	Zn	Cr	Ni	As
1993	0.056	0.007	0.184	0.011	0.224	0.0006
1994	0.042	0.002	0.156	0.003	0.162	0.0004
1995	0.041	0.0006	0.113	0.006	0.048	0.0024
1996	0.038	0.001	0.192	0.006	0.027	0.0098
Average	0.044	0.0026	0.161	0.006	0.115	0.0033
Average of CR	0.018	0.009	Hg – 0.022			
Limit of CR	0.5	0.01				

K 173–188, Mg 112–129, Ca 2, 730–3263, pH 6.88–7.23. Humus content fluctuated from 1.6 to 2.5%, and the content of $N_{min.}$ in the spring (in March) in both years was around 12 mg/kg down to a depth of 30 cm (S t e h n o, 1998). Average annual temperature was 8.3 °C and the sum of annual precipitation was 575 mm. The soils were clearly well supplied with nutrients.

In the year 1992–1993 trials were established after the mixture was ploughed down for green manure (mammoth red clover, white clover, crimson clover, alfalfa, vetch, ryegrass, woolly blue curls, rape). A varietal trial with wheat was sown on 4 October 1992, winter barley on 25 September 1992. Spring barley was sown on 13 April 1993, the other trials with spring

barley and oats on 22 April 1993, whereas millet and buckwheat were sown in the last week of April to 4 May 1993.

In the year 1993–1994, the varietal trial was established after potatoes. The trial included 18 winter wheat varieties. The trial was sown on 7 October 1993. The varietal trial with spring barley was established after winter wheat and was sown on 7 April 1994.

After the harvest of wheat on 10 August, of barley on 16 August 1993 and 22 July 1994, grain samples were taken for analysis for the contents of heavy metals. Analyses were carried out by the laboratory of the State Veterinary Administration Praha 4-Písnice which was accredited for these analyses. Mercury was determined by the method of atomic absorption spectrometry (AAS) on a single-purpose device TMA 254, with a detection limit of 0.001 ppm.

Cadmium and lead were determined by the AAS method on the device Spektr AA 30 manufactured by the company Varian. Samples were mineralized on a dry path and ignited in a muffle furnace at 450 °C (for 16–20 hours). Ash was dissolved in 1 M HNO_3. The detection limit was 0.005 ppm for Cd and 0.05 ppm for Pb, the size of the weighed sample was 150 mg. The differences were ± 8–10% against the control (reference) samples.

RESULTS AND DISCUSSION

Several sets of grain crops were examined from the harvest of 1993 for the content of heavy metals. These were winter wheat varieties as well as spring barley varieties (Table III) and the mixtures of spring barley varieties. In addition spring barley of various large caryopses used as seed was also examined (Table IV). We investigated also the mixtures of cereal species (Table V). Furthermore, the content of heavy metals was evaluated in winter barley of whole and hulled grains, in a way similar to that in the above-mentioned grain crops.

In a two-year investigation of ecologically grown winter wheat and spring barley varieties (Tables III and IV) an excess of limit values as determined by the Decree of Ministry of Health of CR No. 298/1997 could not be found in the average content of heavy metals, where the permissible amounts in grain crops are: cadmium 0.1, lead 0.3, and mercury 0.05 mg/kg of dry matter.

In the second year (1994), however, the content of investigated metals in both cereal species was higher. Fallout in the given year, however, was not higher, only the contents of these elements on soils of the plots, where the trials were conducted were higher than in the previous year (plot II for winter wheat and plot IV for spring barley) – Table I. For example, Domažlická (quoted by C i b u l k a et al., 1991) reports on the effect of the amount of

III. The contents of cadmium and mercury in caryopses of winter wheat (left) and spring barley varieties (right) (in mg/kg) from the harvest of 1993 – Praha-Uhříněves

Variety	Cd	Pb	Hg	Variety	Cd	Pb	Hg
Ilona	0.013	0.11	0.002	Akcent	0.011	0.20	2.21
Viginta	0.006	0.10	0.001	Rubín	0.013	0.28	0.005
Senta	0.010	0.07	0.001	Jaspis	0.013	0.29	0.002
Hana	0.016	0.21	0.004	Profit	0.008	0.44	0.001
Regina	0.002	0.17	0.002	Galan	0.005	0.28	0.001
Simona	0.013	0.17	0.004	Orbit	0.015	0.38	0.003
Livia	0.012	0.18	0.002	Garant	0.011	0.21	0.001
Sofia	0.014	0.35	0.002	ST 149	0.016	0.24	0.002
Sparta	0.012	0.08	0.002				
Sida	0.011	0.09	0.003				
Zdar	0.009	0.17	0.004				
Samanta	0.006	0.31	0.005				
Average	0.008	0.16	0.003		0.011	0.29	0.002
Limit	0.1	0.3	0.05		0.1	0.3	0.05

cadmium in the environment, i.e. in soil, on its content in vegetables. The main reason is, however, the effect of weather, particularly the high temperatures and drought that prevailed at the time of the trial in June and July, 1994. The precipitation amounted to 50% of the long-term average, and the average daily temperature was higher by 4 °C in July.

Although above-average values in some varieties were found in the results, these were not confirmed in other years of study, so we cannot say that some varieties accept heavy metals more than anothers. At the same time, some authors report varietal differences in uptake of studied elements (Chang et al., 1982; Isermann et al., 1983). Rather it could be said that individual varieties take up more under certain weather patterns in a given year.

However, we have compare the average contents of these elements with corresponding values from conventional agriculture. Such a comparison is given by Beneš (1994), who reports average contents in winter wheat grain of 0.080 mg for cadmium, 0.470 mg for lead, 3.85 mg for copper, and 0.014 mg/kg for mercury. In spring barley the concentrations were 0.068 in Cd, 0.450 in Pb, 4.30 in Cu, and 0.010 mg/kg in Hg. It is evident from this comparison, where Beneš' data represent average values of several authors

IV. The contents of cadmium, lead and mercury in caryopses of winter wheat and spring barley varieties from ecological growing in 1994 (in mg/kg)

Winter wheat				Spring barley			
Variety	Cd	Pb	Hg	Variety	Cd	Pb	Hg
Rexia	0.01	0.27	0.004	Krystal	0.025	0.10	0.002
Livia	0.014	0.11	0.005	Rubín	0.008	0.09	0.003
Ilona	0.029	0.16	0.009	Jaspis	0.011	0.09	0.005
Hana	0.019	0.16	0.004	Orbit	0.010	0.17	0.009
Vlada	0.021	0.2	0.001	Jarek	0.021	0.11	0.003
Sparta	0.005	0.41	0.008	Malvaz	0.041	0.15	0.015
Sida	0.018	0.27	0.003	Jubilant	0.009	0.11	0.002
Vega	0.034	0.19	0.003	Terno	0.020	0.13	0.005
Blava	0.015	0.35	0.002	Akcent	0.019	0.09	0.003
Samanta	0.021	0.21	0.005	Sladko	0.017	0.19	0.005
Torysa	0.033	0.36	0.005	Svit	0.019	0.05	0.003
Asta	0.031	0.19	0.005	Stabil	0.005	0.12	0.004
Siria	0.017	0.27	0.002	Pax	0.015	0.17	0.003
Trane	0.005	0.35	0.004	Novum	0.015	0.31	0.019
Bruta	0.033	0.21	0.012	Ladik	0.013	0.30	0.005
Regina	0.027	0.17	0.005	Forum	0.017	0.11	0.005
Simona	0.017	0.09	0.005	Viktor	0.019	0.16	0.002
Mona	0.015	0.15	0.003	**Average barley**	**0.017**	**0.144**	**0.005**
Slavie	0.015	0.10	0.003	Dankowskie n.	0.25	0.09	0.003
Diana	0.015	0.15	0.002	Albedo	0.021	0.11	0.003
Mironovska	0.009	0.10	0.002	Rapid	0.005	0.11	0.005
Average	**0.019**	**0.21**	**0.004**	**Average winter rye**	**0.017**	**0.10**	**0.003**
Limit	0.1	0.3	0.05		0.1	0.3	0.05

studying heavy metals in wheat and barley grain, that the contents of Cd, Pb, Hg and Cu from our ecological cultivation are far below contents found in conventional growing.

Mixtures of varieties aimed at possible combinations of varieties with higher and lower contents of heavy metals were also studied (Table V). In some combinations of varieties this prerequisite has been confirmed. Average

V. The contents of cadmium, lead and mercury in grain of barley mixture varieties – Praha-Uhříněves 1993 (mg/kg)

Mixture of varieties	Cd	Pb	Hg	Pure varieties	Cd	Pb	Hg
Akcent + Rubín	0.016	0.20	0.004	Malvaz	0.005	0.22	0.003
Rubín, Orbit, Malvaz	0.007	0.14	0.003	Stabil	0.005	0.17	0.011
Akcent, Rubín, Stabil, Novum	0.005	0.22	0.009	Terno	0.005	0.52	0.007
Svit + Sladko	0.007	0.07	0.009	Orbit	0.005	0.25	0.009
Terno + Donum	0.005	0.23	0.005	Galant	0.005	0.18	0.011
Donum, Svit, Terno	0.005	0.24	0.006	Novum	0.005	0.21	0.015
Stabil, Novum, Sladko	0.005	0.36	0.018	Rubín	0.005	0.09	0.004
Malvaz, Orbit, Stabil, ST44	0.005	0.21	0.001	Donum	0.005	0.15	0.002
				Svit	0.005	0.17	0.020
				Sladko	0.005	0.08	0.010
				ST 4404	0.007	0.16	0.012
Average	0.007	0.20	0.007		0.005	0.22	0.010
Limit	0.1	0.3	0.05		0.1	0.3	0.05

contents of lead and mercury, too, were lower in mixtures of varieties. However, the differences were small. Considering the fact that the values did not exceed the permissible amount, cultivation of mixtures of varieties for reducing the content of heavy metals have insignificant results.

However, the difference given in Table VI is significant, where tendencies in cadmium content show that the content is decreased in harvested grain in thinner stands. In larger caryopses in the fraction remaining above the 2.8 mm sieve, the contents of cadmium, lead and mercury are lower, whereas in smaller caryopses above the 2.5 sieve they are rather higher.

In the mixtures of oats and barley (with a larger proportion of barley), there is also an indication of lower Cd and Pb contents. In the mixtures of the varieties (barley plus peas and oats plus peas), the contents of Cd and Pb were lower but some further replications should be needed for confirmation of this. Peas as a component of species mixtures had higher contents of cadmium, lead and mercury but they did not exceed permissible amounts for legumes. Therefore the mixtures with peas had higher contents of these elements than those of barley and oats.

Special attention has been paid to investigation of the contents of Cd, Pb and Hg in millet and buckwheat (see Table VII).

VI. The contents of cadmium, lead and mercury in barley grain (mg/kg) cultivated at various stand densities and in grain of different sizes and from grain of species mixtures (Praha-Uhříněves, 1993)

Sowing rate Seed size	Number per 1 m^2	Cd	Pb	Hg
Stand density	400	0.026	0.25	0.003
	500	0.023	0.26	0.005
	600	0.022	0.22	0.011
Caryopsis size				
Caryopses > 2.5	400	0.028	0.15	0.005
	500	0.021	0.20	0.006
	600	0.018	0.20	0.003
Caryopses > 2.8	400	0.021	0.18	0.006
	500	0.017	0.12	0.005
	600	0.016	0.18	0.005
Average		0.021	0.19	0.005
Limit		0.1	0.3	0.05
Species mixtures		Cd	Pb	Hg
Barley		0.021	0.13	0.021
Oats		0.024	0.21	0.015
Pea		0.027	0.32	0.013
Species mixtures – representation of different components in the mixture in % at sowing				
Barley 66%, oats 33%		0.020	0.26	0.013
Barley 33%, oats 66%		0.018	0.12	0.020
Barley 33%, oats 33%, pea 33%		0.020	0.11	0.012
Barley 66%, pea 33%		0.022	0.24	0.011
Oats 66%, pea 33%		0.015	0.11	0.002
		0.020	0.17	0.013
Limit for cereals		0.1	0.3	0.05
Limit for legumes		0.3	0.5	0.003

Note: Stand density at sowing of 400, 500, 600 caryopses per 1 m^2, size of caryopses (2.8 mm and 2.5 mm sieve mesh) in stand of different density

The contents of cadmium, lead and mercury in millet were studied in the whole caryopses, hulled caryopses – millets and husks. In caryopses as well as in millets the contents were almost identical and far below the boundary

VII. The contents of cadmium, lead and mercury in grain of millet, millets, and millet husks (mg/kg)

Variety – product		Cd	Pb	Hg
Saratovské	– grain	0.059	0.15	0.004
Saratovské	– husked millet	0.075	0.18	0.009
Saratovské	– husks	0.095	0.38	0.022
Unikum	– grain	0.064	0.18	0.004
Unikum	– husked millet	0.064	0.18	0.004
Unikum	– husks	0.103	0.58	0.024
Used seed				
Hanácká Mana	– grain	0.065	0.24	0.006
Hanácká Mana	– husked millet	0.059	0.22	0.002
Hanácká Mana	– husks	0.103	0.31	0.040
Harvested in our trial from the above-mentioned seed				
Hanácká Mana	– grain	0.075	0.16	0.004
Hanácká Mana	– husked millet	0.073	0.18	0.007
Hanácká Mana	– husks	0.138	0.54	0.024
Average millet	– grain	0.065	0.18	0.004
	– husked millet	0.068	0.19	0.005
	– husks	0.110	0.45	0.027
Limit	– grain	0.1	0.3	0.02
	– husked millet	0.05	0.3	0.02
Buckwheat	– achenes	0.02	0.19	0.005
Buckwheat	– groats	0.059	1.45	0.008
Buckwheat	– crushed grain	0.026	0.80	0.009
Average		0.035	0.81	0.007
Limit for foodstuffs B		0.05	8.0	0.05

of permissible limits for cereals, but in the case of husked millet the limit for special amounts was exceeded in cadmium in all investigated varieties. This limit is mostly determined for infant food. Millet husks are very rich in the studied elements but they largely form non-food proportions, not used for high content of silicon even for feeding purposes.

A similar situation is also found in buckwheat where the content in whole achenes – fruits and crushed achenes was below the limit. In buckwheat hulled grain (achenes) the content of cadmium was higher (0.059) than generally for foodstuffs (B), where the limit is 0.05. Cereal hulled grain had, however, permissible amounts of cadmium (0.1 mg/kg) and also permissible special amount (0.05 mg/kg). From these and other trials for cadmium contents in buckwheat it may be stated that this crop has a disposition for greater uptake of this element. We have experienced that particularly on acid soils the uptake of these elements was high, as was confirmed by a series of crops and studies of Tlustoš et al. (1995, 1997) and by authors quoted in those studies, e.g. Tiller et al. (1984), Puls et al. (1991) and others.

Significant changes of content did not occur in hulled barley caryopses. In wheat, the content in hulled caryopses was even higher but not above the limit in any case.

The same results as in spring barley were found in winter barley, in whole caryopses as well as in groats (Tab. VIII). Analyses of whole caryopses, groats, fine flour and bran in three wheat varieties (Table IX) were conducted to evaluate the contents of cadmium, lead and mercury in different components of milling processing. The findings described above, that caryopses have the lowest cadmium content, with higher contents in flour, lower in groats and highest in bran, has been confirmed. This is in harmony with the finding of Oberlander, Roth (1987) and Kloke et al. (1984). A similar situation is found in the other varieties where the content of flour is again higher than in grain. All the values of cadmium contents are below the limit of 0.1 mg/kg. A similar situation is found for the lead content, including bran in the Hana variety. Grain and flour of the varieties Samanta and Sparta have above-limit lead contents. The mercury content is lower than the limit in all determinations given in Table IX.

VIII. The contents of cadmium, leads and mercury in grain and groats of winter barley (mg/kg)

Variety	Cd		Pb		Hg	
	grain	groats	grain	groats	grain	groats
LU 415	0.025	0.029	0.50	0.15	0.011	0.008
Okal	0.025	0.028	0.41	0.15	0.014	0.016
Kromos	0.030	0.035	0.13	0.12	0.015	0.015
Lunet	0.031	0.030	0.19	0.180	0.007	0.009
LU 149	0.033	0.032	0.10	0.26	0.011	0.012
Average	0.029	0.031	0.21	0.22	0.011	0.012
Limit	0.1	0.1	0.3	0.3	0.05	0.02

IX. The contents of cadmium, lead and mercury in wheat grain, flour and bran (mg/kg)

Variety – product	Cd	Pb	Hg
Hana – grain	0.016	0.21	0.004
Hana – fine flour	0.035	0.18	0.005
Hana – hulled grain	0.010	0.16	0.009
Hana – bran	0.080	0.22	0.009
Samanta – grain	0.006	0.31	0.005
Samanta – fine flour	0.032	0.38	0.014
Samanta – bran	0.073	0.45	0.005
Sparta – grain	0.012	0.28	0.002
Sparta – fine flour	0.039	0.53	0.013
Sparta – bran	0.084	0.29	0.008
Limit – grain	0.1	0.3	0.05
– fine flour	0.1	0.2	0.03
– hulled grain	0.1	0.3	0.02
– bran	0.2	0.7	0.03

References

ANONYM: Praha – životní prostředí 1995. Institut městské informatiky hlavního města Prahy (Praha – environment 1995. Institute of the Town Informatics of the capital of Prague). XI, 1995 (Prague environment 1995).

ANONYM: Statistická ročenka životního prostředí ČR (Statistical Environmental Yearbook of the Czech Republic). Prague, The Ministry of the Environment of the Czech Republic. Czech Statistical Office 1997.

BENEŠ, S.: Obsahy a bilance prvků ve sférách životního prostředí. Část I. Obsahy, akumulace a kriteria hodnocení prvků v zemědělských půdách. Část II. Vstupy prvků do půd (Contents and balance of elements in the spheres of environment. Part II. Contents, accumulation and criteria of evaluation of elements in agricultural soils). Praha, MZe ČR 1993 and 1994.

CIBULKA, J. et al.: Pohyb olova, kadmia a rtuti v zemědělské výrobě a biosféře (Mobility of lead, cadmium and mercury in agricultural production and biosphere). Praha, SZN 1986. 160 p.

CIBULKA, J. et al.: Pohyb olova, kadmia a rtuti v biosféře (Mobility of lead, cadmium and mercury in biosphere). Praha, Akademia 1991. 432 p.

CHANG, A. C. – PAGE, A. L. – FOSTER, K. W. – JONES, T. E.: A comparison of cadmium and zinc accumulation by four cultivars of barley in sludge amended soils. J. Environ. Qual., *11*, 1982: 409–412.

ISERMANN, V. K. – KARCH, P. – SCHMIDT, J. A.: Cadmium-gehalt das Erntegutes verschiedener Sorten mehrere Kulturpflanzen bei Anbau auf stark mit Cadmium belasten neutralem Lehmboden. Landw. Forsch., *36*, 1983: 283–294.

JEDLIČKA, J.: Kontaminace půdy nežádoucími prvky z fosforečných hnojiv (Soil contamination with undesirable elements from phosphorus fertilizers). In: Proc. Sem. Optimalizace hnojení se zřetelem na kvalitu produktů a ekologii půdního prostředí, SZŠ Humpolec, 1995.

KLOKE, A. – SAUERBECK, D. R. – VETTER, H.: The contamination of plants and soils with heavy matals and the transport of metals in terrestrial food chains. Changing Metal Cycles and Human Health, 1984: 113–141.

KOLEKTIV: Kontaminace potravních řetězců cizorodými látkami Situace 1993–1995. (Contamination of food chains by foreign substances. Situation 1993–1995). Státní veterinární správa ČR, Česká zemědělská a potravinářská inspekce. Liberec, IC SVS ČR 1994–1996.

KOZÁK, J.: Těžké kovy v půdách (Heavy metals in soils). In: CIBULKA, J. et al.: Pohyb olova, kadmia a rtuti v biosféře (Movement of lead, cadmium and mercury in biosphere). Praha, Akademia 1991: 62–74.

KOZÁK, J. – JANKŮ, J. – JEHLIČKA, J.: The problems of heavily polluted soils in the Czech Republic: A case study. In: SOLOMONS W. – FORSTENER, U. – MADER, P. (eds.): Heavy Metals Problems and Solutions. Chapter 17. Berlin, Springer Verlag 1995: 287–300.

OBERLÄNDER, H. E. – ROTH, K.: Uptake and distribution on labelled, soil applied heavy metals in cereals plants and their milling products. Bodenkulture, *38*, 1987: 287–298.

PETR, J.– DLOUHÝ, J. et al.: Ekologické zemědělství (Ecological agriculture). Praha, Zem. nakl. Brázda 1992. 312 p.

PULS, R. W. – POWELL, R. M. – CLARK, D. – ELDRED, C. J.: Effects of pH solid/solution ratio, ionic strength, and organic acids on Pb, and Cd sorption on kaolinite. Wat. Air Soil Pollut., *57-58*, 1991: 423–430.

STAŇO, J. – ŠEVČÍK, T.: Bazální monitoring zemědělských půd České republiky (1992–1993) (Basal monitoring in ecological agriculture). Brno, SKZÚZ 1994.

STEHNO, L.: Bilance živin v ekologickém zemědělství (Balance of nutrients in ecological agriculture). [PhD Dissertation.] Praha, 1998. – Czech University of Agriculture. 163 p.

TILLER, K. G. – GERTH, J. – BRUMMER, G.: The relative affinities of Cd, Ni and Zn for different soil clay fractions and goethite. Geoderma, *34*, 1984: 17–34.

TLUSTOŠ, P. – VOSTÁL, J. – SZÁKOVÁ, J. – BALÍK, J.: Přímá a následná účinnost vybraných opatření na obsah Cd a Zn v biomase špenátu (Direct and subsequent efficiency of selected measures on the Cd and Zn content in the biomass of spinach). Rostl. Výr., *41*, 1995: 31–37.

TLUSTOŠ, J. – BALÍK, J. – PAVLÍKOVÁ, D. – SZÁKOVÁ, J.: Příjem kadmia, zinku, arzenu a olova vybranými plodinami (The uptake of cadmium, zinc, arsenic, and lead by chosen crops). Rostl. Výr., *43*, 1997: 487–494.

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Obsah kadmia, olova a rtuti v ekologicky vypěstovaných plodinách.

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V ekologickém způsobu pěstování podle zásad IFOAM a Metodického pokynu MZ ČR pro ekologické zemědělství jsme po dva roky prověřovali obilní druhy na

obsah rizikových prvků – kadmia, olova, a rtuti. U širokého souboru odrůd ozimé pšenice, jarního i ozimého ječmene, ozimého žita, prosa a pohanky jsme nezjistili vyšší obsahy výše uvedených prvků, než stanoví hygienické limity nejvyššího přípustného množství, přípustného množství a speciálního množství pro potraviny a skupiny potravin (Vyhláška Ministerstva zdravotnictví ČR č. 298/97 z 12. 12. 1997).

Projevilo se kolísání obsahu těžkých kovů v jednotlivých letech, v našem případě to mohlo být vlivem rozdílného obsahu sledovaných prvků v půdě pozemku, na kterém byly založeny pokusy. Spíše to však bylo vlivem počasí, velmi teplého a suchého, které ovlivnilo vyšší příjem těchto prvků, jak tomu bylo v roce 1994.

Potvrdilo se, že jednotlivé druhy rostlin se liší v příjmu a obsahu kadmia, olova a rtuti. Sledovali jsme odrůdové rozdíly v obsahu těchto prvků – projevily se např. v roce 1993 ve vyšším obsahu olova u odrůd ozimé pšenice Samanta a Sofia (0,31 a 0,35 $mg.kg^{-1}$) v zrně i v mouce, nebo u jarního ječmene Orbit a Profit v zrně (0,38 a 0,44 $mg.kg^{-1}$). V druhém pokusném roce byl nadlimitní obsah olova u jiných odrůd (Sparta, Blava, Torysa, Trane) a u odrůd jarního ječmene Novum a Ladík. U ozimého žita odrůdy Dankowskie nowe byl vyšší obsah kadmia (0,25 $mg.kg^{-1}$). Nemůžeme tedy jednoznačně prokázat odrůdové rozdíly v příjmu a obsahu těchto rizikových prvků. Spíše by bylo možné říci, že je jednotlivé odrůdy přijímají více za podmínek určitého průběhu počasí v daném ročníku.

V konvenčním intenzivním pěstování např. pšenice byl obsah těžkých kovů podle souhrnného sledování (B e n e š , 1993, 1994) v České republice u kadmia 0,08, u olova 0,42, u rtuti 0,014 $mg.kg^{-1}$. U jarního ječmene byl v konvenčním pěstování obsah kadmia 0,068, olova 0,450 a rtuti 0,010 $mg.kg^{-1}$. Obsahy těchto rizikových prvků byly u ekologického pěstování v našich pokusech prokazatelně nižší.

Předpokládali jsme odrůdové rozdíly v příjmu a obsahu sledovaných prvků, a proto jsme založili pokusy směsí odrůd s vyšším a nižším obsahem těžkých kovů, s cílem snížení jejich obsahu v zrnu ze směsí. Výsledky přinesly naznačení tendence sníženého obsahu sledovaných prvků ve směsích odrůd, ale rozdíly jsou malé, a tak i s ohledem na to, že hodnoty nepřekračují přípustné množství, nebude tato cesta, tj. pěstování směsí odrůd pro snižování obsahu těžkých kovů, významná. Kromě kadmia byly obsahy ostatních prvků ve směsích nižší.

U směsí druhů je tato možnost prokazatelnější, např. ve směsi obilnin, ječmene a ovsa s hrachem, který má obecně vyšší obsah těžkých kovů, byly obsahy sledovaných prvků nižší než u některého komponentu směsi.

Také se prokázal nižší obsah rizikových prvků v řidších porostech obilnin, a rovněž u větších obilek byl nižší obsah, takže třídění obilek nad sítem 2,8 mm by mohlo přinést snížení obsahu těchto prvků. Vyžaduje to však ještě další ověření.

Obsahy sledovaných prvků v obilkách prosa a jáhlách (oloupané obilky prosa) byly pod hranicí obsahu přípustného pro obiloviny. U jáhel však je limit nižší, daný pro speciální množství, které se vztahuje většinou na dětskou výživu. Tento limit byl u jáhel překročen. Podobně u pohanky, kdy obsah těžkých kovů byl v nažkách a drcené pohance podlimitní, ale u pohankových krup byl vyšší obsah kadmia než pro

potraviny obecně. Pro běžné obilní kroupy je limit 0,1 $mg.kg^{-1}$, čemuž i pohankové kroupy odpovídají, pro speciální množství je však rovněž limit 0.05 $mg.kg^{-1}$, a tomu již zkoumané pohankové kroupy neodpovídají. U pohanky se projevuje větší náchylnost k příjmu těchto rizikových prvků, zejména při nízkých hodnotách pH.

Závěrem můžeme konstatovat, že za podmínek výše popsaného pokusu nebyl při ekologickém způsobu pěstování zvýšen obsah kadmia, olova a rtuti nad hranice stanovených limitů a nad průměrné hodnoty zjištěné v konvenčním intenzivním pěstování těchto druhů.

zrniny; obilniny; obsahy Cd, Pb, Hg; ekologické zemědělství; zdravotní nezávadnost

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