CADMIUM, LEAD, MERCURY AND CAESIUM LEVELS IN WILD MUSHROOMS AND FOREST BERRIES FROM DIFFERENT LOCALITIES OF THE CZECH REPUBLIC

J. Cibulka[1], L. Šišák[2], K. Pulkrab[2], D. Miholová[1], J. Száková[1], A. Fučíková[1], A. Slámová[1], I. Stěhulová[1], S. Barláková[1]

[1] *Czech University of Agriculture, Faculty of Agronomy, Prague, Czech Republic*

[2] *Czech University of Agriculture, Faculty of Forestry, Prague, Czech Republic*

Samples of wild mushrooms (9 common species) and forest berries (4 species) were collected during their growing seasons in 1995 on three different localities in Northern (Dubí, locality A), Eastern (Choceň, locality B) and Western (Zbiroh, locality C) regions of the Czech Republic. These localities are classified according to the forest decline and general environmental burden as heavily (locality A) and medium (locality B) impaired areas with locality C as intact environment. Collected samples were analysed for cadmium, lead, mercury and caesium contents using routine techniques (dry ashing, flame AAS, radiocounter) in specialised laboratories respecting GLP system. The results obtained showed obvious mushrooms species dependent capacity of cumulating toxic elements. Environmental burden of the monitored localities was not generally reflected in higher toxic element levels in the local wild mushrooms and forest berries. Hygienic normative was generally exceeded by cadmium and mercury levels in majority of analysed mushroom samples.

cadmium; lead; mercury; caesium; wild mushrooms; forest berries; environmental monitoring

INTRODUCTION

A habit of picking up wild grown forest berries and mushrooms belongs in the Czech Republic (CR) among popular seasonal activities (K a l a č, 1989). These commodities are used for supplementing menus (fresh and frozen berries, home canned jams and fruits, fresh and dried mushrooms). The most common are forest blueberries and strawberries, less frequent are cranberries and blackberries. *Agaricus*, *Boletus* and *Xerocomus* fungi species dominate among edible mushrooms. These berries and mushrooms can be also bought at the local seasonal markets and in case of their contamination they should be considered as a potential source of burden of consumer health. Average per capita consumption of these food items is not known and Hygienic Service in CR has a lack of detailed information on their natural contamination.

There are recent articles published on blueberries hygienic quality in the existing scientific literature reviewed by Cunio (1994) and The Research Agricultural Centre in Beltsville, Maryland, USA (Dr. R. Korcak) has been dealing with mineral composition of berries grown on cultivated blueberry bushes for several years. Research reports published by Beran et al. (1993, 1994, 1995) are the most valuable literature sources for the purposes of this study. These authors, jointly with the others from abroad (Surdel, 1991; Cieslinski et al., 1993, 1994; Zehnder et al., 1993; Malikov et al., 1992; Paasikalio et al., 1994), have proved that risk elements (e.g. cadmium, lead, mercury and caesium) could penetrate into plant organs (roots, leaves, fruits) from contaminated environment (namely via contaminated soil).

Detailed overview on existing scientific literature dealing with contamination of edible and other mushrooms with risk elements was published by Cibulka et al. (1991) and Sova (1994). Mushrooms could be used as biological indicators of the environmental contamination (Gast et al., 1988; Lepšová, 1992). However, different mushrooms species have individual different capacity of concentrating risk elements in their fruiting bodies. This partially reduces such a use. Based on literature data, it is obvious that the maximum availability of cumulating risk elements have (among edible mushrooms) *Agaricus*, *Boletus* and *Xerocomus* species and the most contaminated fruiting body parts are spore bearing organs (tubes or gills) and spores themselves. A pilot study dealing with contamination of common edible and non edible wild mushrooms from CR was performed by Cibulka et al. (1995). Their results did not prove significant relationship between environmental impairment of the forest ecosystem and higher heavy metal levels in local mushrooms, however, the highest intake of risk elements was repeatedly proved for *Amanita*, *Boletus*, *Xeronomus* and *Lycoperdon* species.

There are official permitted maximum levels of risk elements in foodstuffs listed in the Czech legislative (Anonymous, 1986) and the limits are shown in Tab. I. However, food items are not unified and not for all monitored elements there are limits set for fresh mushrooms. Using literature data (Lepšová, Mejstřík, 1989), mushroom average dry matter is 10% or less), we recalculated fresh matter normative to get limits expressed for dry matter and to compare our analytical results with the normative. There is no

I. Permitted maximum levels of the risk elements in foodstuffs (mg.kg^{-1} of fresh or dry matter, Anonymus, 1986)

Commodity	Cadmium	Lead	Mercury
Vegetables	0.03	0.50	0.01
Dried vegetables	0.30	4.00	0.10
Fruits	0.03	0.40	0.01*
Dried fruits	0.50	3.00	0.05
Fresh mushrooms	0.07**	0.50	0.05***
Dried mushrooms (calculated****)	0.70	5.00	0.50
Other foodstuffs (generally)	0.05	1.00	0.02

* produced locally 0.005 mg.kg^{-1}
** canned mushrooms
*** even canned mushroom
**** calculated into 10% of dry matter

legislation regulating permitted caesium level in foodstuffs in CR. Soil levels measured in our study were evaluated using a normative listing maximum permitted contents of risk elements in Czech soils based on different analytical approach.

Contamination of foodstuffs with caesium 137 (and other isotopes and radionuclides) was a hot topic after Černobyl accident in April 1986. Consequences of the accident in CR were regularly published by the State Hygienic Service (Anonymous, 1987, 1992) and it is obvious that there are several geographic regions in CR contaminated with the accident radioactive fallout (Strakonice, Česká Třebová, Vysoké Mýto and others). A dose of 100 000 Bq from Cs 137 still represents an acceptable yearly amount of radiation per head. A dose of 600 Bq.kg^{-1} is considered as a maximum limit acceptable for exporting Czech foodstuffs abroad to the European Community (EC). *Boletus* species were mainly found to be contaminated by elevated Cs content in the past years with an average level of 680 Bq.kg^{-1} (Malátová, 1994 – personal communication).

Recent data on agricultural soil contamination with cadmium, lead and mercury were published by Kozák (1991) and Beneš (1993, 1994). According to Reinds et al. (1993), European forest soils are critically contaminated with lead and copper and cadmium burden reaches 95% of forest soil saturation capacity. Berthelsen et al. (1993) state for Norwegian forest soils that cadmium, zinc and copper are cumulated mostly in the most upper soil horizon as a consequence of elemental bioacumulation of fungi mycelium. This phenomenon can be partially observed also in lead deposition in forest soil. Lasota (1988) and Wondratschek, Roder (1993) studied relationship between forest soil mercury level and content of mercury in fruiting bodies of higher mushrooms. *Agaricus* species had 100 times higher Hg level in caps and stalks compared to Hg soil level. However, the authors stressed that high risk element level in mushrooms might not be just simple reflection of high landscape environmental contamination.

MATERIAL AND METHODS

Three localities were selected in March 1995 for mushrooms and forest berries sampling according to the official forest classification (Anonymous, 1988). Locality A – Dubí, North Bohemian region is generally considered as significantly disturbed environment with distinct forest die back, locality C – Zbiroh, West Bohemian region is classified as nearly intact environment with healthy forests and locality B – Choceň, East Bohemian region is area with marked, but not heavy, environmental burden and only partly impaired forest quality.

Mushroom samples were collected in the appropriate growing season during May–November 1996. Sampling techniques were identical with those for wild mushrooms and forest berries picking. Apart from manual cleaning of mushroom caps and stalks, no washing was applied neither for mushrooms, nor the berries. List of collected wild mushrooms and berries with their English, Czech and Latin names is shown in Tab. II. One sample represented 150–200 g of fresh material stored in a labelled paper bag and refrigerated till laboratory analysis. Simultaneously with mushrooms and forest berries picking, soil samples of forest upper soil horizon (0–5 cm, after removing superficial layer of organic detritus) were also collected at appropriate sampling places.

Contents of cadmium and lead in mushrooms and berries were determined employing flame atomic absorption method (Varian SpectrAA 400) after sample mineralisation by dry ashing in quartz beakers. Triplicate analyses were performed for each sample and they were corrected against background contamination using 20% of measured blank samples. Detection limit was calculated as three values of blank sample standard deviation. Final results for mushrooms and berries were expressed in mg of an element in 1 kg of sample dry matter. Content of mercury in the fresh samples was measured using AMA 254 (Altec, ČR) apparatus. The results were recalculated to mg of Hg in 1 kg of sample dry matter. Quality of analytical data was assessed by simultaneous analysis of standard reference material CRM 12-02-01 with acceptable results.

II. Occurrence of the sampled mushrooms at different localities (locality A – Dubí, locality B – Choceň, locality C – Zbiroh)

English, Czech and Latin names of the sampled mushrooms	Locality A	Locality B	Locality C
Parasol mushroom, bedla vysoká, *Macrolepiota procera* (Scop. ex Fr.) Sing.	*	+	+
Oak boletus, hřib dubový, *Boletus aestivalis* (Paulet) ex Fr.	+	+	+
Butter mushroom, klouzek slizký, *Suillus viscidus* Fr.	+	+	+
Orange cap boletus, křemenáč osikový, *Krombholziella aurantiaca* (Bull. ex St. Amans) R. Maire	+	+	*
Birch mushroom, kozák březový, *Kromholzielalla scabra* (Bull. ex Fr.) R. Maire	+	+	+
Fly amanita, muchomůrka červená, *Amanita muscaria* (L. ex Fr.) Hook.	+	+	+
Reddish amanita, muchomůrka růžovka, *Amanita rubescens* (Pers. ex Fr.) S. F. Gray	+	+	+
Puff ball, pýchavka bradavičnatá, *Lycoperdon perlatum* (Pers. ex Pers.)	+	+	+
Bay boletus, suchohřib žlutomasý, *Xerocomus chrysenteron* (Bull. ex Amans) Quél.	+	+	+
Polish boletus, suchohřib hnědý, *Xerocomus badius* (Fr.) Gilb.	+	+	+
Honey agaric, václavka obecná, *Armillaria mellea* (Vahl ex Fr.) Kumm.	+	+	+

* not found on the locality

Levels of soil cadmium, lead and mercury were determined employing procedure published by K o z á k (1990). It is a screening determination of the elements in soil eluate. The results were expressed as mg of an element in 1 kg on soil.

Caesium level was measured using standardised methodology being employed by the Institute of National Health in Prague and the results obtained were expressed in becquerels (Bq) in 1 kg of fresh matter.

The results in Tabs. III–VII expressed as values „lower than – <" were, for the purposes of this study, treated as maximum numbers, mean is arithmetic mean with calculated standard deviation (SD). Figs. 1–3 do not contain SD and are constructed only using mean values for each element and locality.

RESULTS AND DISCUSSION

The results obtained are shown in Tabs. III–VII and Figs. 1–3. Evaluation and discussion of the results is to be done from three points of view: a) related to the individual localities, b) related to the mushroom species and c) related to the valid hygienic normative regulating maximum permitted levels of risk elements in foodstuffs.

Figs. 1–3 show an obvious fact that the levels of analysed elements are different in the mushrooms collected at the three different localities. It was our hypothesis that contents of the elements followed were higher in mushrooms collected at places with higher environmental burden expressed in more obvious forest decline. However, cadmium, lead, mercury and caesium contents in Dubí mushrooms (the most impaired forest locality) were not generally higher compared to the others. Even more, cadmium level was the highest in the Choceň mushrooms grown in relatively good environment.

On the other hand, the highest lead level was determined in *Boletus aestivalis* sampled at Dubí (9.86 Pb mg.kg^{-1}) in comparison with the *Boletus aestivalis* values for Choceň and Zbiroh (2.46 and 0.41 Pb mg.kg^{-1}) and *Lycoperdon perlatum* (Dubí – 24.12; Choceň – 8.40; Zbiroh – 9.01 mg.kg^{-1}). High lead content in Dubí *Boletus* and *Lycoperdon p.* could be partially explained by close vicinity of a busy road to the sampling places with heavy traffic. It is a well known fact that car petrol exhausts contain massive amount of lead. However, this conclusion was not fully confirmed by the expected highest soil lead level found in Dubí where only 73.57 mg Pb.kg^{-1} was recorded compared to 119.37 mg Pb.kg^{-1} found in Zbiroh soil.

The highest cadmium level was found on all localities in *Amanita muscaria* (8.25 up to 14.07 Cd mg.kg^{-1}). The highest lead content was everywhere in *Lycoperdon perlatum* (8.40 up to 24.12 Pb mg.kg^{-1}) and the highest mercury contents were also in *Lycoperdon perlatum* (2.61 up to 8.82 Hg mg.kg^{-1}) and

III. Cadmium levels (mg.kg^{-1} of dry matter)

	Locality A – Dubí		Locality B – Choceň		Locality C – Zbiroh	
	mean	SD	mean	SD	mean	SD
Blueberries	< 0.141		< 0.162		< 0.173	
Strawberries	*		0.381	0.015	0.109	0.008
Raspberries	0.099	0.020	0.212	0.057	0.299	0.041
Blackberries	< 0.132		0.172	0.066	0.219	0.058
max.	0.141		0.381		0.299	
min.	0.099		0.162		0.109	
on average	0.124		0.232		0.200	
Boletus aestivalis	4.665	1.016	12.149		3.546	0.056
Macrolepiota procera	*		0.612	0.153	0.998	0.092
Suillus viscidus	2.752	0.079	7.482	1.047	2.109	0.080
Kromholziella scabra	3.012	0.771	6.195	0.222	2.400	0.118
Kromholziella aurantiaca	3.273	0.183	1.193	0.157	*	
Amanita muscaria	12.611	4.547	8.251	0.748	14.071	6.639
Lycoperdon perlatum	0.759	0.016	1.927	0.071	0.850	0.447
Amanita rubescens	1.058	0.818	1.899	0.384	1.715	0.042
Xerocomus ch. et b. **	3.464	0.541	2.023	0.792	4.509	0.549
Armillaria mellea	3.774	0.761	3.365	0.721	3.079	0.336
max.	12.611		12.149		14.071	
min.	0.759		0.612		0.850	
on average	3.930		4.510		3.697	

* not found on the locality
** mixture of *X. chrysenteron* and *badius*

IV. Lead levels (mg.kg^{-1} of dry matter)

	Locality A – Dubí		Locality B – Choceň		Locality C – Zbiroh	
	mean	SD	mean	SD	mean	SD
Blueberries	< 0.773		< 0.889		< 0.950	
Strawberries	*		< 0.783		< 0.654	
Raspberries	< 0.504		< 0.701		< 0.520	
Blackberries	< 0.724		< 0.621		< 0.649	
max.	0.773		0.889		0.950	
min.	0.504		0.621		0.520	
on average	0.667		0.748		0.693	
Boletus aestivalis	9.858	1.900	2.456		< 0.407	
Macrolepiota procera	*		2.129	0.631	3.794	0.403
Suillus viscidus	0.715	0.007	0.810	0.516	1.462	0.202
Kromholziella scabra	0.848	0.164	1.373	0.257	2.315	0.411
Kromholziella aurantiaca	0.818	0.102	< 0.538		*	
Amanita muscaria	0.894	0.315	1.319	0.634	0.765	0.221
Lycoperdon perlatum	24.117	8.443	8.402	0.227	9.014	5.124
Amanita rubescens	1.304	0.139	0.934	0.328	1.473	0.195
*Xerocomus ch. et b.***	0.765	0.269	0.729	0.114	0.375	0.020
Armillaria mellea	< 0.640		0.526	0.106	0.334	0.027
max.	24.117		8.402		9.014	
min.	0.640		0.526		0.334	
on average	4.440		1.922		2.215	

* not found on the locality
** mixture of *X. chrysenteron* and *badius*

V. Mercury levels (mg.kg^{-1} of dry matter)

	Locality A – Dubí		Locality B – Choceň		Locality C – Zbiroh	
	mean	SD	mean	SD	mean	SD
Blueberries	0.014	0.014	0.005	0.002	0.006	0.003
Strawberries	*		0.006	0.001	0.004	0.002
Raspberries	0.005	0.001	0.008	0.002	0.007	0.003
Blackberries	0.011	0.002	0.027	0.009	0.011	0.008
max.	0.014		0.027		0.011	
min.	0.005		0.005		0.004	
on average	0.010		0.012		0.007	
Boletus aestivalis	3.929	0.980	4.018	1.232	6.154	3.396
Macrolepiota procera	*		3.336	1.265	7.807	0.578
Suillus viscidus	0.757	0.261	0.796	0.213	1.025	0.630
Kromholziella scabra	0.377	0.178	0.666	0.274	0.717	0.577
Kromholziella aurantiaca	2.749	0.983	3.212	1.075	*	
Amanita muscaria	0.734	0.330	1.415	0.135	10.632	1.143
Lycoperdon perlatum	2.606	0.283	4.712	0.661	8.823	1.355
Amanita rubescens	0.578	0.200	1.154	0.305	2.062	0.919
*Xerocomus ch. et b.***	0.267	0.100	0.447	0.143	2.918	0.498
Armillaria mellea	0.179	0.036	0.349	0.030	0.299	0.116
max.	3.929		4.712		10.632	
min.	0.179		0.349		0.299	
on average	1.353		2.011		4.493	

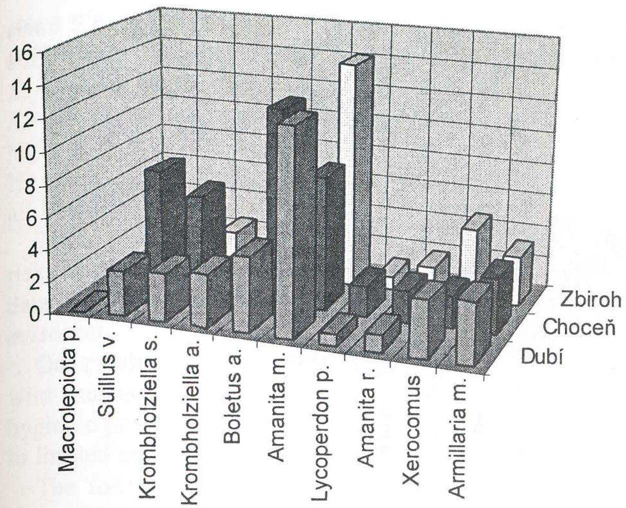
* not found on the locality
** mixture of *X. chrysenteron* and *badius*

VI. Cs 137 content in *X. chrysenteron* and *badium* ($Bq.kg^{-1}$ of fresh matter)

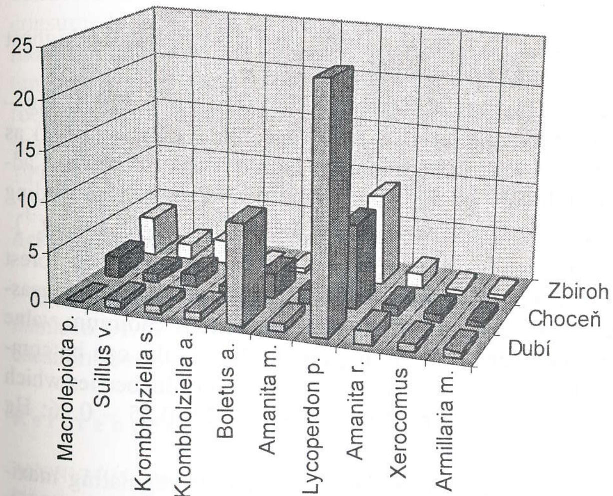
	Locality A - Dubí		Locality B - Choceň		Locality C - Zbiroh	
	mean	SD	mean	SD	mean	SD
Xerocomus	250.0	11.0	902.0	31.0	122.0	6.0

VII. Forest soil cadmium. lead and mercury levels ($mg.kg^{-1}$)

Locality		Cadmium		Lead		Mercury	
		mean	SD	mean	SD	mean	SD
Choceň		0.219	0.020	78.900	21.300	0.088	0.010
		0.122	0.006	18.700	0.500	0.119	0.002
		0.079	0.010	14.300	1.000	0.083	0.008
	on average	0.140		37.300		0.097	
Dubí		0.139	0.026	138.000	5.300	0.408	0.003
		0.312	0.021	35.100	1.000	0.177	0.026
		0.206	0.015	47.600	6.200	0.116	0.011
	on average	0.219		73.567		0.234	
Zbiroh		0.436	0.021	129.100	51.100	0.756	0.013
		1.142	0.038	170.600	3.600	0.529	0.009
		0.109	0.030	58.400	2.900	0.335	0.013
	on average	0.229		119.367		0.540	
	max.	0.229	Zbiroh	119.367	Zbiroh	0.540	Zbiroh
	min.	0.140	Choceň	37.300	Choceň	0.097	Choceň

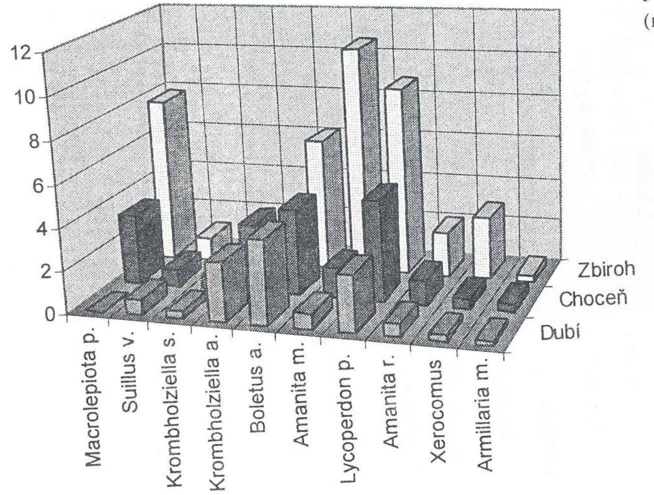


1. Cadmium levels ($mg.kg^{-1}$ of dry matter)



2. Lead levels ($mg.kg^{-1}$ of dry matter)

in *Boletus aestivalis* (3.93 up to 6.15 Hg $mg.kg^{-1}$). Fortunately, these species are not edible (*Amanita muscaria*) or rarely collected (*Lycoperdon perlatum*) by mushroom pickers or, usually, they are not a major portion of picked up mushrooms (*Boletus aestivalis*) and so, they do not represent serious hygienic threat to human health. Our results correspond to literature data published by



3. Mercury levels ($mg.kg^{-1}$ of dry matter)

S o v a et al. (1991) and B e r a n et al. (1993) who also found the highest risk element levels in *Amanita* and *Boletus* species.

Soil contamination was highest at Zbiroh (Cd – 0.6; Pb – 119.4; Hg – 0.5 $mg.kg^{-1}$). Soil lead level at Zbiroh is evaluated by B e n e š (1993) as very high. A source of this lead contamination is currently unknown. Cadmium and mercury soil levels at the three localities were not exceeding average normative values for Czech soils (Cd – 1.0 and Hg – 0.8 $mg.kg^{-1}$).

Similar situation compared to mushrooms was also observed in forest berries contamination, where the highest levels of contaminants were measured in berries collected at Zbiroh and Choceň (maximum cadmium value was in strawberries from Choceň – 0.381 $mg.kg^{-1}$). Our results can be compared to those published by B e r a n et al. (1994, 1995) for blueberries which are generally slightly lower than ours (Cd 0.09 – 0.1; Pb 0.25 – 0.26; Hg 0.02 $mg.kg^{-1}$).

Comparing our results to the valid hygienic normative regulating maximum permitted levels of risk elements in foodstuffs (A n o n y m o u s, 1986), it is obvious that only one cadmium value (0.61 Cd $mg.kg^{-1}$ in *Macrolepiota procera* from Choceň) respected the valid normative (0.7 Cd $mg.kg^{-1}$). The highest cadmium level was always measured in *Amanita muscaria*, regardless its sampling locality (8.25–14.07 Cd $mg.kg^{-1}$). Lead limit (5.0 Pb $mg.kg^{-1}$) was mostly respected apart from *Lycoperdon perlatum* collected at all localities (8.40–24.12 Pb $mg.kg^{-1}$) jointly with *Boletus aestivalis* from Dubí

(9.85 Pb $mg.kg^{-1}$). Majority of mushroom samples exceeded with their mercury levels the valid normative for mushrooms (0.5 Hg $mg.kg^{-1}$) apart from *Xerocomus chrysenteron* and *Xerocomus badius* from Dubí and Choceň and *Armillaria mellea* from all localities (from 0.18 up to 0.35 Hg $mg.kg^{-1}$). The highest mercury levels were measured in *Lycoperdon perlatum* (2.61–8.82 Hg $mg.kg^{-1}$) and in *Boletus aestivalis* (3.93–6.15 Hg $mg.kg^{-1}$) collected on all localities.

These results, showing species dependent differences in accumulation of risk elements in fungi fruiting bodies, correspond to the published literature data. S o v a et al. (1991) also found the highest cadmium content in *Amanita muscaria*.

Our results show that elevated cadmium and mercury contents in analysed wild mushrooms collected on three different localities represent a certain hygienic problem. However, human health burden is probably minimised due to limited seasonal and irregular consumption of wild mushrooms.

The following rules should be respected to avoid higher intake of risk elements due to wild mushrooms consumption: 1) mushrooms grown and collected near frequented communications and in city parks should not be consumed, as well as 2) mushrooms with the highest species dependent cumulating capacity (for example, *Agaricus species*), 3) removing highly contaminated mushrooms reproduction organs (tubes or gills with spores) is recommended. Mushroom contamination with caesium can be minimised by soaking mushrooms twice in saline solution for 30 minutes (S o v a et al., 1991).

Acknowledgement

This research was granted by GA CR 504/94/0291. Authors would like to thank to Dr. I. Malátová, Institute of National Health, Prague, for measuring caesium levels in mushrooms samples.

R e f e r e n c e s

ANONYMUS: Směrnice, kterými se doplňují směrnice Ministerstva zdravotnictví ČSR – hlavního hygienika ČSR č. 50/1978 Sb. Hygienické předpisy o cizorodých látkách v poživatinách, ve znění směrnic č. 63/1984 Hygienické předpisy. Ministerstvo zdravotnictví ČSR, Hygienické předpisy, sv. 61/1986 (Directions Amending Directions of the Ministry of Health of CSR – the Head Hygienist of CSR No. 50/1978. Hygienic Regulations on Foreign Substances in Foodstuffs in Wording of Directions No. 63/1984 Hygienic Regulations. Ministry of Health of CSR, Hygienic Regulations, Vol. 61/1986).

ANONYMUS: Využití rostlin jako bioindikátoru těžkých kovů (Use of plants as bioindicator of heavy metals). Ochr. Tvorba život. Prost., 1987 (5): 28–32.

ANONYMUS: Metodický návod pro klasifikaci poškození lesních porostů imisemi (Methodology for classification of forest stands damaged by immissions). Věstník MLVH ČSR, Part 5–6/1988.

ANONYMUS: Zpráva o radiační situaci na území ČR a SR v roce 1992 (Report on radiation in the territory of the Czech and Slovak Republics in 1992). Praha, Státní zdravotní ústav, Centrum hygieny záření (State Health Institute, Centre for Hygiene of Radiation) 1992.

BENEŠ, S.: Obsahy a bilance prvků ve sférách životního prostředí (Contents and balance of elements in environment). Ministerstvo zemědělství ČR (Ministry of Agriculture of CR), 1993, Part 1.

BENEŠ, S.: Obsahy a bilance prvků ve sférách životního prostředí (Contents and balance of elements in environment). Ministerstvo zemědělství ČR (Ministry of Agriculture of CR), 1994, Part 2.

BERAN, M. – KELNAR, L. – ŠÁRA, V. – POLOCZEKOVÁ, A. et al.: Monitoring umělých radionuklidů a toxickych a esenciálnich prvků v některych lesních plodech a příprava referenčních materialů pro zabezpečeni jakosti analytických dat (Monitoring of artificial radionuclides, toxic and essential elements in some forest fruits and preparation of reference materials for providing the quality of analytical data). [Report of Project GA/5/93.] Řež, Ústav jaderného výzkumu 1993.

BERAN, M. – KELNAR, L. – KRÁL, R. – POLOCZEKOVÁ, A. et al.: Monitoring umělých radionuklidů a toxických a esenciálních prvků v některých lesních plodech a příprava referenčních materiálů pro zabezpečeni jakosti analytických dat (Monitoring of artificial radionuclides, toxic and essential elements in some forest fruits and preparation of reference materials for providing the quality of analytical data). [Report of Project GA/5/93.] Řež, Ústav jaderného výzkumu 1994.

BERAN, M. – KRÁL, R. – POLOCZEKOVÁ, A. – SUCHÁ, E. et al.: Monitoring umělých radionuklidů a toxických a esenciálních prvků v některých lesních plodech a příprava referenčních materiálů pro zabezpečeni jakosti analytických dat (Monitoring of artificial radionuclides, toxic and essential elements in some forest fruits and preparation of reference materials for providing the quality of analytical data). [Report of Project GA/5/94.] Řež, Ústav jaderného výzkumu 1995..

BERTHELSEN, B. O. – OLSEN, R. A. – STEINNES, E.: Ectomycorhizal heavy metal accumulation as a contributing factor to heavy metal levels in forest soils. In: Int. Conf. Heavy Metals in the Environment, Toronto, Canada, September 1993.

CIBULKA, J. – DOMAŽLICKÁ, E. – KOZÁK, J. – KUBIZŇÁKOVÁ, J. et al.: Pohyb olova, kadmia a rtuti v biosféře (Movement of lead, cadmium and mercury in biosphere). Praha, Academia 1991.

CIBULKA, J. et al.: Zpráva o výsledcích stanovení obsahu kadmia, olova, rtuti a cesia ve vzorcích lesních plodin a hub z různých lokalit Severočeského, Západočeského a Východočeského regionu (Report on results of determination of cadmium, lead, mercury and caesium contents in forest fruit and fungal samples from various localities of North Bohemian, West Bohemian and East Bohemian regions). [Final Report No. GAČR 504/94/0291.] Praha, Czech University of Agriculture 1995.

CIESLINSKY, G. – MERCIK, S. – NIELSEN, G.: Effect of soil application of cadmium contaminated lime on soil cadmium distribution and cadmium concentration in strawberry leaves and fruit. J. Plant Nutr., *17*, 1994: 1095–1110.

CIESLINSKY, G. – MERCIK, S. – MAAS, J. L. – GALLETTA, G. J.: Lead uptake and accumulation by strawberry plants. In: Second Int. Strawberry Symp., Maryland, USA, 13–18 September 1992. Acta Hort., *348*, 1993: 278–286.

CUNIO, L.: Vaccinium myrtillus. Austral. J. Med. Herbal., *5*, 1994: 81–85.

GAST, C. H. – JANSEN, E. – BIERLING, J. – HAANSTRA, L.: Heavy metals in mushrooms and their relationship with soil characteristics. Chemosphere, *17*, 1988: 789–799.

KALAČ, P. – WITTINGEROVÁ, M. – STAŠKOVÁ, I. – ŠIMÁK, M. et al.: Obsah rtuti, olova a kadmia v houbách (Mercury, lead and cadmium contents in fungi). Českoslov. Hyg., *34*, 1989: 568–576.

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

KOZÁK, J.: Retence těžkých kovů v půdě (Retention of heavy metals in soils). [Final Report.] Praha, Czech University of Agriculture 1990.

LASOTA, W.: Relationship between the occurrence of chemical contaminants in edible fungi and their levels in the soil. Przem. Ferm. Owoc. Warzyw., *32*, 1988: 21–23.

LEPŠOVÁ, A. – MEJSTŘÍK, V.: Trace elements in fruit bodies of fungi under different pollution stress. Agric. Ecosyst. Environm., *28*, 1989: 305–312.

LEPŠOVÁ, A.: Fungal carpophores as bioindicators. Proc. Int. Conf. Bioindicatores Deteriorisationis Regionis, České Budějovice, 1992.

MALIKOV, V. G. – YAKOVUK, V. A. – CHALYI, A. I. – LAZKO, V. E.: Characteristics of distribution in strawberry organs of radionuclides from atmospheric fallout and from soil. Sel.-choz. Biol., 1992: 143–146.

PAASIKALLIO, A. – RANTAVAARA, A. – SIPPOLA, J.: The transfer of cesium-137 and strontium-90 from soil to food crops after the Chernobyl accident. Sci. Total Environm., *155*, 1994: 109–124.

REINDS, G. J. – BRIL, J. – VRIES, W. – GROENENBERG, J. E. et al.: Critical and present loads of heavy metals for European forest soils. In: Int. Conf. Heavy Metals in the Environment, Toronto, September 1993.

SOVA, Z.: Cizorodé látky a toxiny v houbách (Foreign substances and toxins in fungi). EKO, 1994: 18–21.

SOVA, Z. – CIBULKA, J. – SZÁKOVÁ, J. – MIHOLOVÁ, D. et al.: Obsah kadmia, rtuti a olova v houbách v lokalitách Bakov nad Jizerou a Černý Vůl (Cadmium, mercury and lead contents in fungi at the localities Bakov nad Jizerou and Černý Vůl). Sbor. VŠZ Praha, AF České Budějovice, 1991 (1): 13–29.

SURDEL, M.: The content of mercury compounds in selected soft fruits derived from south-eastern Poland. Rocz. Gleboz., *42*, 1991: 237–240.

WONDRATSCHEK, I. – RODER, U.: Monitoring of heavy metals in soils by higher fungi. Plants as biomonitors. Weinheim, Germany, VCH Verlagsgesellschaft mbH 1993.

ZEHNDER, H. J. – KOPP, P. – OERTLI, J. J. – FELLER, U.: Uptake and transport of radioactive caesium and strontium into strawberries after leaf contamination. Gartenbauwissenschaft, *58*, 1993: 109–213.

Received for publication on April 16, 1996

CIBULKA, J. – ŠIŠÁK L. – PULKRAB, K. – MIHOLOVÁ, D. – SZÁKOVÁ, J. – FUČÍKOVÁ, A. – SLÁMOVÁ, A. – STĚHULOVÁ, I. – BARLÁKOVÁ, S. (Česká zemědělská univerzita, Agronomická fakulta, Lesnická fakulta, Praha, Česká republika):

Obsahy kadmia, olova, rtuti a cesia v houbách a lesních plodech z různých oblastí České republiky.

Scientia Agric. Bohem., 27, 1996 (2): 113–129.

V roce 1995 se realizoval sběr celkem 9 druhů hub (hřib, bedla, klouzek, kozák, křemenáč, muchomůrka červená, pýchavka, růžovka, suchohřib a václavka) a dalších lesních plodin (borůvky, jahody, maliny a ostružiny) na lokalitách v severočeském, západočeském a východočeském regionu, které jsou podle platných metodik klasifikovány do různých stupňů zátěže lesů imisemi. Jednalo se o lokality Dubí (pásmo ohrožení A a B – nejvyšší ohrožení), Zbiroh (pásmo ohrožení D – nízké), Choceň (pásmo ohrožení C – nižší ohrožení). Z těchto lokalit byly odebrány i vzorky lesních půd.

Šlo především o houby jedlé a další lesní plodiny, které se v českých lesích sezónně tradičně sbírají a konzumují a v případě masivní kontaminace cizorodými prvky by mohly představovat zátěž pro lidský organismus.

Ve vzorcích byl v renomovaných analytických laboratořích stanoven obsah kadmia, olova, rtuti a u vybraných vzorků hub i cesia 137 (suchohřib).

Celkově lze říci, že na základě vyhodnocení průměrného obsahu sledovaných prvků ve všech druzích hub sebraných na jednotlivých lokalitách se klasifikace lokalit, pokud jde o jejich celkovou zátěž imisemi, zcela jednoznačně neprojevila. Podobná situace byla i u dalších lesních plodin, kde se ani výrazně neprojevily druhové odlišnosti.

U vzorků hub se prokázala různá schopnost druhů hub kumulovat cizorodé prvky. Mezi houby s největšími obsahy kadmia patřila muchomůrka červená, a to na všech lokalitách (8,25 až 14,07 mg Cd.kg^{-1}). Nejvyšší obsahy olova byly na všech lokalitách naměřeny u pýchavky (8,40 až 24,12 mg Pb.kg^{-1}) a nejvíce rtuti kumulovaly na všech lokalitách pýchavka (2,61 až 8,82 mg Hg.kg^{-1}) a hřib dubový (3,93 až 6,15 mg Hg.kg^{-1}).

Klasifikace imisní zátěže jednotlivých lokalit se neprojevila ani v obsazích Cd, Pb a Hg v lesních půdách, kdy nejvyšší obsahy všech prvků byly naměřeny ve Zbirohu (Cd – 0,56; Pb – 119,37; Hg – 0,54 mg.kg-1).

Obsah Cs 137 ve vzorcích suchohřibů hnědých a žlutomasých byl nejvyšší na lokalitě Choceň (902,0 Bq.kg^{-1}) a nejnižší ve Zbirohu (122,0 Bq.kg^{-1}). Tyto hodnoty nepředstavují žádné zdravotní nebezpečí, ale je možné je dát do souvislosti se zasažením našeho území spady z černobylské havárie.

Vzhledem k platným hygienickým normám lze konstatovat, že pouze jedna hodnota, a to u bedly z Chocně (0,612 mg Cd.kg^{-1}), vyhovovala normě (0,7 mg Cd.kg^{-1}). Naopak obsah kadmia u ostatních lesních plodin této normě pro sušené ovoce

(0,5 mg Cd.kg^{-1}) vyhovoval. Rovněž obsah olova u lesních plodin vyhovoval platné normě (3,0 mg Pb.kg^{-1}) a z hub pouze pýchavka ze všech lokalit tuto normu pro houby (5,0 mg Pb.kg^{-1}) překračovala (8,4–24,1 mg Pb.kg^{-1}), spolu s hřibem dubovým z lokality Dubí (9,9 mg Pb.kg^{-1}). Lesní plodiny vyhovovaly i normě pro obsah rtuti v sušeném ovoci (0,05 mg Hg.kg^{-1}). Naopak většina vzorků hub svým obsahem Hg překračovala platné normy pro houby (0,5 mg.kg^{-1}), kromě suchohřiba z lokalit Dubí a Choceň (0,27 a 0,45 mg Hg.kg^{-1}) a václavky ze všech lokalit (0,179–0,349 mg Hg.kg^{-1}).

Výsledky z roku 1995 ve srovnání s výsledky z roku 1994 opakovaně potvrzují, že mezi imisně různě zatíženými lokalitami a obsahem cizorodých prvků v houbách není jednoznačná závislost a na lokalitách obecně klasifikovaných jako znečištěné či poškozené nemusí být houby s nejvyšším obsahem sledovaných kontaminantů. Porovnání výsledků, pokud jde o druhy hub, opakovaně prokázalo, že muchomůrka červená kumuluje nejvíce kadmia, pýchavka bradavičnatá nejvíce olova a spolu s hřibem dubovým i nejvíce rtuti.

Práce v roce 1995 umožnila shromáždit velké množství relevantní vědecké literatury a utřídit ji do jednotného počítačového systému pro využití při dalším výzkumu.

kadmium; olovo; rtuť; cesium; houby; lesní plodiny; monitoring

Contact Address:

Doc. Ing. Jiří Cibulka, DrSc., Česká zemědělská univerzita, Agronomická fakulta, katedra veterinárních disciplín, 165 21 Praha 6-Suchdol, Česká republika, tel./fax: 02/39 37 03