Bull. Environ. Contam. Toxicol. (2003) 71:123–130

DOI: 10.1007/s00128-003-0138-6

Bulletin of Environmental Contamination and Toxicology

Contamination of Two Edible *Agaricus* spp. Mushrooms Growing in a Town with Cadmium, Lead, and Mercury

L. Svoboda, P. Kalač

Department of Chemistry, Faculty of Agriculture, University of South Bohemia, CZ-370 05 České Budějovice, Czech Republic

Received: 26 September 2002/Accepted: 11 April 2003

Wild mushrooms have been a very popular delicacy widely consumed in several countries of both Central and Eastern Europe and the Far East. Nevertheless, some edible species, mainly from genera *Agaricus*, *Macrolepiota*, *Lepista* and *Calocybe* accumulate in their fruiting bodies high levels of cadmium, mercury and lead even in unpolluted and mildly polluted areas. The element contents are primarily species-dependent (for reviews see Michelot et al. 1998; Kalač and Svoboda 2000). There has been a consensus that mushroom fruiting bodies are not the exact bioindicator of environmental contamination with heavy metals. However, in heavily polluted areas the observed metal contents have been considerably elevated (Wondratschek and Röder 1993).

Contaminated mushrooms occur mainly along roads with extensive traffic (e.g. Kuthan 1979; Cuny et al. 2001), in the emission areas of metal smelters (reviewed by Kalač and Svoboda 2000) and also within towns. Considerably elevated levels of cadmium and lead as compared with mushrooms from rural areas were reported from large cities of north London (Thomas 1992), Helsinki (Kuusi et al. 1981) and Gdańsk (Falandysz and Bona 1992). Similarly, high mercury levels were found in mushrooms growing in lawns of inner cities of Helsinki (Laaksovirta and Lodenius 1979) and Gdańsk (Falandysz et al. 1995).

However, fruiting bodies growing within towns, mainly *Agaricus* species, have been consumed by a part of the population, e.g. by seniors due to their limited possibility to collect mushrooms in forests. The aims of our present work are therefore to determine cadmium, lead and mercury levels in two commonly growing species *A. arvensis* and not yet reported *A. maleolens* and consider the effect of differently polluted sites on the level of contamination of fruiting bodies from a town of medium size.

MATERIALS AND METHODS

Two mushroom species with saprophytic nutritional strategy commonly growing within the town of České Budějovice were collected from several sites with different traffic intensity during 1999 and 2000. *Agaricus arvensis* Schaeff. ex Fr. has been a species widely distributed in grasslands and fields. *Agaricus*

Correspondence to: P. Kalač

maleolens Moel. is a species related to *A. bisporus* group (which includes a widely cultivated white mushroom). Its occurrence has been increasing along streets and pavements due to its ability to grow in soils containing salt from winter treatment.

České Budějovice is the administrative and economic center of the South Bohemia with a population of about 100,000. Pollution level has been relatively low. Brown coal has been the main fuel used. Data on monthly dust fall in a checking point adjacent to five of the testing sites during both the years are given in Table 1. A scale characterizing traffic intensity is given in Table 2. Over 400 passenger cars and 40 commercial vehicles per thousand of inhabitants were registered in the town in 2000. Use of leaded petrol decreased steadily during the 90's and its distribution finished at the end of 2000. The observed sites are described in Table 3.

Table 1. Monthly dust fall (g/m^2) monitored near the sampling sites 2-6 (see Table 3). Data of the Regional Public Health Office, České Budějovice.

Month	1999	2000
I	5.7	4.9
II	4.6	7.2
III	7.1	7.2
IV	6.9	8.1
V	7.6	6.4
VI	3.1	3.5
VII	5.2	3.9
VIII	6.6	3.7
IX	2.5	3.5
X	1.5	3.3
XI	2.1	3.2
XII	2.5	3.4

Fruiting bodies were collected 3-11 times from the individual sites during the both years. Each fruiting body was used as a sample. The mushrooms were cleaned

Table 2. Characteristics of a five-degree scale of traffic intensity.

Degree	Traffic intensity
1	Very low level at local streets and parking lots in residential areas.
2	Low level at local streets and parking lots in residential areas.
3	Medium level.
4	High level including municipal buses and lorries, peak intensity between 06 - 08 and 15 – 18.
5	Very high level. Continuous transit of all types of vehicles between 06 – 18.

Table 3. Characteristics of mushroom sampling sites within the town of České Budějovice.

Site no.	Characteristics	Distance from carriage-way (m)	Traffic intensity (see Table 2)
1	Lawn in a small park encircling historical centre.	5-20	5
2	Lawn between carriageway and pavement.	0-2	4
3	Lawn between carriageway and pavement.	0-2	4
4	Lawn between carriageway and pavement.	2-5	4
5	Lawn within university campus.	150	1
6	Lawn within university campus.	180	1
7	Lawn between carriageway and pavement.	0-2	5
8	Lawn around a church.	0-2	2
9	Lawn in a municipal quarter.	2-5	2
10	Fourteen sites from different parts of the town.	Different	Different

with a stainless knife of all surface contaminants by a manner usual for fruiting bodies preparation for culinary purposes. No washing or cap peeling was used. Mushrooms were sliced and dried at an ambient temperature.

Sample homogenization and ashing, cadmium, lead and mercury determination by atomic absorption spectrometry measurements, detection limits and the used reference material were the same as described in our previous reports (Kalač et al. 1996; Svoboda et al. 2000). Mean differences between duplicates were up to 5%. Differences between experimentally determined and certified contents in the reference material were up to 3% for mercury and up to 5% for cadmium and lead. Detection limits were 0.04 mg, 0.4 mg and 0.1 μg per kg dry matter for cadmium, lead and mercury, respectively.
Differences in the metal contents among the sites were tested by analysis of variance (ANOVA) including Duncan´s test at significance level $P < 0.05$.

RESULTS AND DISCUSSION

Contents of the metals in 177 samples of *A. maleolens* collected from six sites are given in Table 4. Data for 94 samples of *A. arvensis* from seven sites with at least five fruiting bodies and for 31 samples from fourteen sites with only 1-4 fruiting bodies are given in Table 5. The observed contents of all three metals varied widely. However, such variations up to one order of magnitude within a species are common for mushrooms due to numerous, often so far poorly understood factors.

Metal levels in fruiting bodies are generally species-dependent. Species of saprophytic genus *Agaricus* are known as accumulators of the observed metals. Substrate composition is an important factor, but great differences exist in the

Table 4. Metal content (mg/kg dry matter) in *Agaricus maleolens.*

Site (see Table 3)	1	2	3	4	5	7	Total [1]
Number of samples	8	77	21	16	16	39	177
Cadmium							
x	106[a,2]	5.8[c]	7.3[c]	8.2[c]	28.5[b]	22.7[b]	16.5
S_x	23.2	8.1	3.3	3.4	29.5	11.1	24.7
x_{min}	77.2	1.2	2.9	2.4	3.3	1.2	1.2
x_{max}	153	64.3	17.9	14.2	114	45.6	153
Lead							
x	58.7[a]	12.8[b,c]	13.5[b,c]	20.7[b]	15.9[b,c]	8.5[c]	15.0
S_x	17.7	7.2	6.2	11.0	10.3	2.6	12.7
x_{min}	25.9	1.2	3.6	2.2	5.6	3.1	1.2
x_{max}	78.6	36.2	25.6	45.3	42.7	14.0	78.6
Mercury							
x	34.6[a]	16.4[b]	14.7[b,c]	17.2[b]	8.1[c]	6.4[c]	14.1
S_x	6.0	7.4	4.9	12.0	3.7	1.9	9.0
x_{min}	25.9	5.7	7.4	6.2	3.1	3.7	3.1
x_{max}	45.2	44.9	27.2	39.5	17.2	12.7	45.2

[1] Means and standard deviations are calculated from all samples.
[2] Different letters in a line mean significant difference at $P < 0.05$. The letters are given in alphabetical order with decreasing content of the metal.

uptake of the individual metals. Cadmium and mercury are accumulated in fruiting bodies, while contents of lead are considerably lower in fruiting bodies than in relevant substrate. The reported bioconcentration factors are 50-300 and 30-500 for cadmium and mercury, respectively, while only 0.1-0.01 for lead (as reviewed by Kalač and Svoboda 2000).

Age of a fruiting body or its size is of less importance. Some authors observed higher metal levels in younger fruiting bodies. This is explained by the transport of a metal from mycelium to the fruiting body during the beginning of fructification. Metal levels decrease during the period of fruiting body mass increase. The proportion of metal contents from atmospheric depositions seems to be of less importance due to the short lifespan of a fruiting body, which is usually 10-14 days. Jorhem and Sundström (1995) reported that lead content in *A. arvensis* fruiting bodies growing along a frequented Swedish road was derived from the contaminated roadside soils rather than from atmospheric deposition.

In our opinion, metal levels in fruiting bodies of wild growing mushrooms are considerably affected by the age of mycelium and by the interval between the fructifications. The highest metal levels are observed in the initial harvest wave of cultivated common mushroom (*A. bisporus*). The metal levels reported in wild growing *A. bisporus* are considerably higher than those in cultivated mushrooms.

Table 5. Metal content (mg/kg dry matter) in *Agaricus arvensis*.

Site (see Table 3)	2	4	5	6	7	8	9	10	Total
Number of samples	5	5	10	40	20	7	7	31	125
Cadmium									
x	$24.3^{b,c}$	6.2^{c}	$39.5^{a,b}$	14.8^{c}	63.2^{a}	8.2^{c}	20.5^{c}	30.8	28.5
S_x	9.6	2.1	21.6	26.0	41.9	2.8	25.2	38.9	35.1
x_{min}	14.5	3.2	2.1	1.2	5.0	3.7	1.5	1.4	1.2
x_{max}	36.0	8.5	80.3	110	148	11.4	57.6	112	148
Lead									
x	$3.6^{c,d}$	$9.9^{a,b,c}$	8.3^{a}	12.1^{a}	17.3^{a}	$10.8^{a,b}$	2.4^{d}	15.7	12.5
S_x	2.4	2.5	6.5	6.0	13.3	5.8	1.3	15.7	11.0
x_{min}	1.0	6.4	1.4	3.3	4.7	4.6	1.1	2.3	1.0
x_{max}	6.2	12.6	21.4	40.0	48.6	19.6	4.4	64.2	64.2
Mercury									
x	2.4^{b}	10.8^{a}	$4.3^{a,b}$	14.4^{a}	$8.5^{a,b}$	14.5^{a}	$4.3^{a,b}$	14.7	11.5
S_x	1.3	3.1	2.1	10.2	3.7	3.6	8.3	11.0	9.3
x_{min}	1.0	7.5	0.4	1.6	2.2	9.0	0.3	1.5	0.3
x_{max}	4.6	14.9	7.9	56.5	15.8	19.2	23.0	46.9	56.5

See Table 4 for explanation.

This can be explained not only by the differences in substrate composition and atmospheric contamination, but also by the age of mycelium, which can be up to many years in nature, compared to only several months in a cultivation plant. Collecting samples within a site from up to several tens of square meters, it is not known if the fruiting bodies originate from one of more mycelia of different age. This could explain occurring variations in the metal levels among fruiting bodies collected from a site at the same day.

Moreover, situation has been rather complicated by municipal soils, which are not usually original. Repeated construction operations, excavations and reclamation works with soils of unknown origin seem to be an important factor affecting metal levels in mushrooms. For instance, mean mercury levels 0.06, 0.095, 0.16 and 0.47 mg/kg dry matter were reported from Poland for arable land, forest, municipal parks and lawns and for uncultivated municipal land soils, respectively (Falandysz et al. 1996).

Literature data indicate that road traffic, during the period when leaded petrol was used, affected the lead level in mushrooms. Kuthan (1979) reported 14-36, 2-10, 1-3 and 0.2-0.5 mg/kg dry matter for *Boletus aereus* growing in distance <10, 30-80, 80-120 and 250-300 m, respectively, from a frequented road. Lodenius et al. (1983) observed for lead content in mushrooms considerable decrease in distance between 10 and 25 m from a road and then only a low decrease up to a distance of 100 m, while cadmium levels were unaffected within these distances. No effect of a frequented road was also reported for cadmium (Melgar et al. 1998) and mercury (Alonso et al. 2000) levels in mushrooms growing up to a distance of 50 m.

Comparison of the sites with the expected highest level of contamination (sites 1 and 7) and the lowest ones (sites 5 and 6) showed for *A. maleolens* the worst situation in the site 1, while inconsistent metal levels in the sites 5 and 7, mainly for lead (Table 4). Similar situation was observed also for *A. arvensis* (Table 5). Combination of the above mentioned factors could explain the lack of conclusive and simple relations between the metal levels in the mushrooms and traffic intensity.

Usual background levels of the metals observed in *A. arvensis* fruiting bodies collected from unpolluted rural areas have been 5-20, 2-10 and 2-20 mg kg^{-1} dry matter for cadmium, lead and mercury, respectively (Kalač and Svoboda, 2000). Comparable contents were found in this work in only two sites for each of the metals. Fruiting bodies from all other sites had considerably elevated levels of the metals.

Andersen et al. (1982) reported that species of the genus *Agaricus* from the section *Flavescentes* (i.e. yellowing after tissue damage) have a high ability to accumulate cadmium as compared to section *Rubescentes* (i.e. becoming red). *A. arvensis* becomes to the former, while *A. maleolens* to the latter section. However, statistical analysis ($P < 0.05$) of all three metal contents in both the species growing together on four sites did not reveal any significant difference.

Contemporary Czech Statutory Limits of the metals differ for cultivated and wild growing mushrooms. The limits (mg/kg dry matter) are 2.0, 10.0 and 5.0 for cadmium, lead and mercury, respectively, in wild growing mushrooms. In *A. maleolens* 92.7, 54.8 and 94.3 % and in *A. arvensis* 94.4, 48.0 and 80.8 % of samples for cadmium, lead and mercury, respectively, exceed those limits.

Thus, cadmium, lead and mercury levels of both *A. maleolens* and *A. arvensis* growing within the town of České Budějovice have been so high that these species should not be consumed at all. It can be generalized that mushrooms, mainly those with saprophytic nutritional strategy, growing within towns are not ever desirable for consumption.

Acknowledgment. We thank Mr. Jan Bastl, Mr. Radovan Mikuláš and Mrs. Hedvika Štolcpartová for their technical assistance and Mr. Chris Ash for language correction of the manuscript.

REFERENCES

Alonso J, Salgado MJ, García MA, Melgar MJ (2000) Accumulation of mercury in edible macrofungi: influence of some factors. Arch Environ Contam Toxicol 38: 158-162

Andersen A, Lykke S-E, Lange M, Bech K (1982) Trace elements in edible mushrooms. Publ. Nr 68, Statens Levnedsmiddelinstitut, Denmark, 29 pp. (in Danish)

Cuny D, van Haluwyn C, Pesch R (2001) Biomonitoring of trace elements in air and soil compartments along the major motorway in France. Water Air Soil Pollut 125: 273-289

Falandysz J, Bona H (1992) Metal contents in wild growing Agaricus spp. from the city of Gdańsk and surrounding areas. Bromat Chem Toksykol 25: 251-256 (in Polish)

Falandysz J, Danisiewicz D, Galecka K (1995) Mercury in mushrooms and underlying soil in the city of Gdańsk and in the adjacent area. Bromat Chem Toksykol 28: 155-159 (in Polish)

Falandysz J, Kawano M, Danisiewicz D, Chwir A, Boszke L, Golebiowski M., Borylo A (1996) Investigations on the occurrence of mercury in soils in Poland. Bromat Chem Toksykol 29: 177-181 (in Polish)

Jorhem L, Sundström B (1995) Levels of some trace elements in edible fungi. Z Lebensm Unters Forsch 201: 311-316

Kalač P, Nižnanská M, Bevilaqua D, Stašková I (1996) Concentrations of mercury, copper, cadmium and lead in fruiting bodies of edible mushrooms in the vicinity of a mercury smelter and a copper smelter. Sci Total Environ 177: 251-258

Kalač P, Svoboda L (2000) A review of trace element concentrations in edible mushrooms. Food Chem 69: 273-281

Kuthan J (1979) Lead contents in Boletus aereus growing along a frequented road in Bulgaria. Česká Mykol 33: 58-59 (in German)

Kuusi T, Laaksovirta K, Liukkonen-Lilja H, Lodenius M, Piepponen S (1981) Lead, cadmium, and mercury contents of fungi in the Helsinki area and in unpolluted control areas. Z Lebensm Unters Forsch 173: 261-267
Lodenius M, Laaksovirta K, Kuusi T, Liukkonen-Lilja H, Piepponen S (1983) Lead and cadmium contents in roadside fungi. Ympäristö ja Terveys 14: 355-358 (in Finnish)
Laaksovirta K, Lodenius M (1979) Mercury content of fungi in Helsinki. Ann Bot Fennici 16: 208-212
Melgar MJ, Alonso J, Pérez-López M, García MA (1998) Influence of some factors in toxicity and accumulation of cadmium from edible wild macrofungi in NW Spain. J Environ Sci Health B 33: 439-455
Michelot D, Siobud E, Dore JC, Viel C, Poirier F (1998) Update of metal content profiles in mushrooms – toxicological implications and tentative approach to the mechanisms of bioaccumulation. Toxicon 36: 1997-2012
Svoboda L, Zimmermannová K, Kalač P (2000) Concentrations of mercury, cadmium, lead and copper in fruiting bodies of edible mushrooms in an emission area of a copper smelter and a mercury smelter. Sci Total Environ 246: 61-67
Thomas K (1992) Heavy metals in urban fungi. Mycologist 6:195-197
Wondratschek I, Röder U (1993) Monitoring of heavy metals in soils by higher fungi. In: Markert B (ed) Plants as Biomonitors. Indicators for Heavy Metals in the Terrestrial Environment. VCH, Weinheim, pp 346-363