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Lead, Cadmium, and Mercury Contents of Fungi in the Helsinki Area and in Unpolluted Control Areas

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Blei-, Cadmium- und Quecksilbergehalt wild wachsender Pilze im Gebiet von Helsinki und in unbelasteten Kontrollgebieten

Zusammenfassung. Es wurde der Blei-, Cadmium- und Quecksilbergehalt wild wachsender Pilze in Finland untersucht. Die Gesamtzahl der Proben betrug 326, davon kamen 242 vom Stadtgebiet Helsinki und 84 aus unbelasteten ländlichen Gegenden. Ein Teil der Pilze waren Humuszersetzer, ein Teil mycorrhizatragende (symbiotische) Arten. Mehr als 40 Arten wurden untersucht; der größte Teil davon waren eßbare Pilze, die allgemein gesammelt und verzehrt werden.

Der Bleigehalt variierte zwischen <0,5 und 78 mg/kg Trockensubstanz. In den Kontrollgebieten lagen die Mittelwerte der verschiedenen Arten zwischen <0,5 und 1,3 mg/kg, im Stadtgebiet zwischen 0,5 und 16,8 mg/kg. Der Unterschied zwischen städtischem und ländlichem Gebiet ist sowohl für abbauende als auch für symbiotische Arten statistisch signifikant. Der Unterschied ist im Stadtgebiet signifikant, nicht aber auf dem Lande. Den höchsten Gehalt hatten die *Agaricus*-Arten und die Gruppe *Gasteromycetes*.

Der Cadmiumgehalt variierte zwischen <0,2 und 101 mg/kg Trockensubstanz. In den Kontrollgebieten variierten die Mittelwerte der verschiedenen Arten von <0,2 bis 16,8 mg/kg, im Stadtgebiet von <0,2 bis 17,3 mg/kg. Der Unterschied zwischen städtischem und ländlichem Gebiet ist für abbauende Arten nicht signifikant, für Symbionten beinahe signifikant. Dagegen ist der Unterschied im städtischen Gebiet beinahe signifikant, nicht aber im ländlichen Gebiet. Die absolut höchsten Werte wurden bei *Agaricus*-Arten und *Amanita muscaria* festgestellt.

Der Quecksilbergehalt variierte zwischen <0,01 und 95 mg/kg Trockensubstanz. In den Kontrollgebieten betrugen die Mittelwerte der verschiedenen Arten zwischen 0,03 und 4,2 mg/kg, im Stadtgebiet zwischen 0,02 und 14,2 mg/kg. Der Unterschied zwischen städtischem und ländlichem Gebiet ist stark signifikant für Zersetzer, für Symbionten dagegen nicht signifikant. Der Unterschied zwischen Zersetzern und Symbionten ist sowohl im städtischen als auch im ländlichen Gebiet stark signifikant. Von den verschiedenen Arten hatten die *Agaricus* Arten, gefolgt von *Lyophyllum connatum*, *Coprinus comatus*, *Marasmius oreades* und *Boletus edulis*, die höchsten Werte.

Daraus kann gefolgert werden, daß Pilze aus unverseuchten Gegenden kein Risiko bedeuten, besonders wenn sie zu den symbiotischen Arten gehören. Im Stadtgebiet ist das Risiko etwas größer. Die *Agaricus*-Arten zeigen die höchsten Gehalte an den besagten Metallen, so daß beim Verzehr eine gewisse Vorsicht geboten scheint.

Summary. Wild-growing fungi in Finland have been investigated with regard to their contents of lead, cadmium and mercury. A total of 326 samples was studied, 242 being from the urban area of Helsinki and 84 from unpolluted rural areas. One group of fungi were lawn decomposers, the rest mycorrhizal symbionts of trees. More than 40 species were included in the study, most of these being edible species commonly used as food. The lead content ranged from <0.5 to 78 mg/kg of dry matter. In the control areas the mean contents for the different species ranged from <0.5 to 13 mg/kg, and in the urban area from 0.5 to 16.8 mg/kg. The difference between the urban and rural areas was significant for both the decomposers and the mycorrhizal fungi. The difference between the decomposers and the mycorrhizal fungi was highly significant in the urban area, but in the rural area it was not significant. The amount of lead was highest in *Agaricus* species and in the *Gasteromycetes*.

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The cadmium content ranged from <0.2 to 101 mg/kg of dry matter. In the control areas the mean contents for the different species ranged from <0.2 to 16.8 mg/kg, and in the urban area from <0.2 to 17.3 mg/kg. The difference between the urban and rural areas for the decomposers was not significant, for the mycorrhizal fungi it was almost significant. The difference between the decomposers and mycorrhizal fungi was almost significant in the urban area, but in the control area it was not significant. The highest values were found in *Agaricus* species and *Amanita muscaria.*

The mercury content ranged from <0.01 to 95 mg/kg of dry matter. In the rural areas the mean contents for the different species ranged from 0.03 to 4.2 mg/kg, and in the urban area from 0.02 to 14.1 mg/kg. The difference between the urban and rural areas was highly significant for the decomposers, but for the mycorrhizal fungi it was not significant. The difference between the decomposers and mycorrhizal fungi was highly significant in both the urban and rural areas. The values were highest in *Agaricus* species, and next in *Lyophyllum connatum*, *Coprinus comatus*, *Marasmius oreades* and *Boletus edulis.*

In conclusion, consumption of those fungi that grow in unpolluted rural areas carries no risk, particularly when they belong to mycorrhizal species. In urban areas the risk is somewhat greater. The *Agaricus* species show the highest contents of the metals studied and their use as food requires caution.

Introduction

In different parts of Europe it has been stated that some fungi may contain disquieting levels of heavy metals [lead, see 1–3; cadmium, see 1, 4–9; mercury, see 10–14]. In Finland, some related investigations have also been performed [15–19]. It has been noticed that the various species differ in their tendency to accumulate heavy metals. However, industry [20] and traffic [17, 21] may increase the amounts.

Since Finland is situated far from the densely populated parts of Europe, it has been suggested that heavy metal levels in fungi might be low here. However, high levels of heavy metals have been found even in places where pollution appeared unlikely (e.g. [13]). Hitherto, few studies have attempted to clarify these questions in Finland and it was considered necessary to make a wider survey of the lead, cadmium, and mercury contents of fungi in Finland. Two types of sample were of interest, on the one hand, fungi from densely populated areas, where there is exposure to pollution, and on the other hand those from rural areas, where fungi are most commonly collected. The aim was to obtain basic information about which fungi may be eaten without danger of heavy metal intake.

Material and Methods

The bulk of the fungi (242 samples) were collected in the Helsinki area, a city with approximately 700,000 inhabitants and dense traffic; however, this area has no heavy industry. The unpolluted control areas were represented by altogether 84 samples mainly from Mäntyharju, a rural commune in southeastern Finland with less than 10,000 inhabitants, and from Veikkola, a rural village 30 km west of Helsinki, and in addition three small rural areas in southern Finland. The total number of samples was thus 326. More than 40 fungi were included, most of which were identified to species. However, the genus *Agaricus* and *Gasteromycetes* were identified only to groups. Some of the species were lawn decomposers and others mycorrhizal fungi living as symbionts of forest trees.

The bulk of the samples were collected in autumn 1979. They were cleaned and dried immediately at 50 °C. Some samples were collected in summer 1978, cleaned and deep-frozen, and dried after storage. Dry matter content was measured in one part.

For lead and cadmium analysis about 0.5 g of the dried and homogenized sample was digested in a SLP-INFERNO aluminium hot block with sulphuric and nitric acids, followed by addition of hydrogen peroxide. The digestion residue was transferred to a beaker and the pH was adjusted to 2–3 with ammonium hydroxide. The solution was extracted twice with 10 ml of APDC/$CHCl_3$ (0.1% ammonium pyrrolidine dithiocarbamate in chloroform). The chloroform solutions were evaporated and digested with 2 ml of nitric acid until dry, and the residue was dissolved in 5 ml of 0.5 *M* hydrochloric acid. The lead and cadmium concentrations were measured with a Perkin-Elmer 603 atomicabsorption spectrometer using an air-acetylene flame. For mercury analysis the samples were digested with 10 ml of sulphuric and nitric acids (4+1) at 60 °C in a water bath for 4 h. The mercury contents were measured by cold vapour atomicabsorption spectrometry (Coleman MAS-50).

The significance of the differences was evaluated by Student's *t*-test.

Results

Lead

The results are given in Table 1.

Irrespective of area, the amounts of lead were highest in the *Agaricus* spp. and the *Gasteromycetes.* Some other relatively high values may depend on the influence of road traffic *(Cantharellus tubaeformis)* or the sewage content of the soil *(Psathyrella candolleana)*. In all other species the level was less than 5 mg/kg of dry matter.

This material was used to assess the differences between the fungi of the urban and rural areas, and between the lawn decomposers and the symbionts (Table 2).

In nearly all cases the lead content of the fungi was higher in the urban area than in the rural areas. For the lawn decomposers this difference was almost significant ($p \leq 0.05$), and for the mycorrhizal symbionts significant ($p \leq 0.01$). When the *Agaricus* species were ex-

Table 1. Lead contents of the various fungus species in the Helsinki (urban) area and the control (rural) areas

Species	mg Pb/kg dry matter					
	Urban area			Rural areas		
	Number of samples	Mean content	Range	Number of samples	Mean content	Range
Lawn decomposers						
Agaricus spp.	53	9.2	<0.5–30	2	13.0	8.0–18
Albatrellus ovinus				4	< 0.5	
Lepista sordida	1	3.8				
Lyophyllum connatum	15	3.0	0.7–8.7	2	1.6	1.0–2.1
Marasmius oreades	47	3.7	1.1–14	2	1.8	1.4–2.1
Volvariella speciosa	1	1.7				
Macrolepiota procera				2	0.7	0.6–0.8
Macrolepiota rhacodes				1	1.7	
Coprinus comatus	36	3.8	0.8–14	3	1.3	0.9–1.5
Coprinus atramentarius	10	3.3	<0.5–8.5	1	1.1	
Psathyrella candolleana	1	8.3				
Gasteromycetes	14	16.8	1.3–78	1	12.1	
Mycorrhizal fungi						
Cantharellus cibarius	4	1.7	0.6–3.2	4	0.7	<0.5–1.0
Cantharellus tubaeformis	1	8.9		1	1.4	
Hydnum repandum	1	0.5		3	0.9	0.7–1.2
Boletus edulis	6	0.9	<0.5–2.5	6	0.9	<0.5–2.0
Other *Boletaceae*	7	1.1	<0.5–3.3	17	0.9	<0.5–4.3
Amanita muscaria	2	0.7	0.5–0.9			
Inocybe sp.	1	1.6				
Rozites caperata				1	< 0.5	
Russula spp.	12	4.6	1.2–15	9	3.6	0.7–9.7
Lactarius necator	5	2.2	0.8–2.9	6	0.7	<0.5–1.1
Other *Lactarius* spp.	11	3.3	<0.5–8.9	11	1.8	<0.5–8.5

cluded from the former group, the difference was significant ($p \leqq 0.01$).

The decomposers had higher lead contents than the symbionts. This difference was highly significant ($p \leqq 0.001$) in the urban area, but not significant in the control area. When the *Agaricus* species were omitted from the lawn decomposers, the difference was still significant in the urban area ($p \leqq 0.01$). In the rural area the values were low both for the decomposers except *Agaricus* and for the symbionts. In the urban area the mean value was significantly higher ($p \leqq 0.01$) for the *Agaricus* species than that for the other lawn decomposers.

Table 2. The lead contents of the different types of fungi. – N = number of specimens

	mg Pb/kg dry matter			
	Urban area		Rural areas	
	N	Mean ± S.D.	N	Mean ± S.D.
Lawn decomposers	177	6.4 ± 8.2	8	3.0 ± 4.8
Lawn decomposers *Agaricus* spp. excluded	124	5.1 ± 8.3	16	1.8 ± 2.8
Mycorrhizal symbionts	50	2.7 ± 3.0	58	1.4 ± 1.7

Cadmium

The results are given in Table 3.

Among the fungus species investigated the *Agaricus* spp. had clearly the highest cadmium contents. In addition, *Amanita muscaria* had a high value. All the other fungi had values lower than 5 mg/kg of dry matter.

The different groups were compared in the same way as for case of lead (Table 4).

In most cases the cadmium content of the fungi was higher in the urban area than in the rural areas. This difference was not significant for the lawn decomposers, but for the mycorrhizal symbionts it was almost significant ($p \leqq 0.05$). When the *Agaricus* species were excluded, the differene from the other decomposers was highly significant ($p \leqq 0.001$). In regard to cadmium, the high proportion of *Agaricus* species has a

Table 3. Cadmium content of the various fungus species in the Helsinki (urban) area and the control (rural) areas

Species	mg Cd/kg dry matter					
	Urban area			Rural areas		
	Number of samples	Mean content	Range	Number of samples	Mean content	Range
Lawn decomposers						
Agaricus spp.	53	11.9	0.4–101	2	16.8	0.6–33
Albatrellus ovinus				4	0.8	0.5–1.9
Lepista sordida	1	3.5				
Lyophyllum connatum	15	2.9	0.5–11	2	1.0	0.8–1.2
Marasmius oreades	47	1.5	0.4–4.8	2	0.3	0.2–0.3
Volvariella speciosa	1	0.5				
Macrolepiota procera				2	1.2	1.1–1.3
Macrolepiota rhacodes				1	0.5	
Coprinus comatus	36	4.4	0.9–27	3	2.6	1.6–3.3
Coprinus atramentarius	10	0.8	0.3–1.7	1	0.2	
Psathyrella candolleana	1	2.2				
Gasteromycetes	14	3.9	0.2–7.5	1	0.5	
Mycorrhizal fungi						
Cantharellus cibarius	4	1.0	0.4–2.0	4	0.5	0.2–0.9
Cantharellus tubaeformis	1	0.7		1	1.2	
Hydnum repandum	1	<0.2		3	0.3	<0.2–0.6
Boletus edulis	6	2.9	<0.2–5.7	6	1.3	0.4–2.9
Other *Boletaceae*	7	5.3	0.3–25	17	1.3	0.4–4.0
Amanita muscaria	2	17.3	9.5–25			
Inocybe sp.	1	1.0				
Rozites caperata				1	4.1	
Russula spp.	12	2.2	0.6–7.7	9	0.4	<0.2–0.7
Lactarius necator	5	0.4	0.2–0.6	6	0.4	<0.2–0.6
Other *Lactarius* spp.	11	1.0	0.5–1.5	11	0.8	0.3–1.5

Table 4. The cadmium contents of the different types of fungi

	mg Cd/kg dry matter			
	Urban area		Rural areas	
	N	Mean±S.D.	*N*	Mean±S.D.
Lawn decomposers	177	5.3±14.2	18	2.9±7.6
Lawn decomposers *Agaricus* spp. excluded	124	2.8± 3.7	16	1.1±0.9
Mycorrhizal symbionts	50	2.7± 5.0	58	0.9±0.8

strong influence on the mean values. In the Helsinki area the difference in the content between the *Agaricus* species and the other decomposers was clearly significant ($p \leqq 0.01$).

The values for the decomposers were higher than those for the symbionts, and the difference was almost significant ($p \leqq 0.05$) in the Helsinki area, but not in the control area. When the *Agaricus* species are omitted, neither of the differences is significant.

It is interesting that for the lawn decomposers the difference in cadmium content between the urban and rural areas was not significant, when the *Agaricus* species were included, but when they were omitted the difference was highly significant. For the symbionts a corresponding difference existed, but at a somewhat lower level.

Mercury

The results are given in Table 5.

The mercury content was highest in the *Agaricus* species, and then among the lawn decomposers in the species *Lyophyllum connatum*, *Coprinus comatus* and *Marasmius oreades*, and among the mycorrhizal fungi in *Boletus edulis*.

Comparison of the different groups was again performed (Table 6).

The mercury content was higher in the urban area than in the rural areas. This difference was highly significant ($p \leqq 0.001$) for the decomposers, but for the symbionts, for which the values are low, the difference was not significant. When the *Agaricus* species were ex-

Table 5. Mercury content of the various fungus species in the Helsinki (urban) area and the control (rural) areas

Species	mg Hg/kg dry matter					
	Urban area			Rural areas		
	Number of samples	Mean content	Range	Number of samples	Mean content	Range
Lawn decomposers						
Agaricus spp.	53	14.1	0.29–95	2	4.2	1.6 –6.8
Albatrellus ovinus				4	0.07	0.07–0.09
Lepista sordida	1	1.3				
Lyophyllum connatum	15	6.1	0.77–29	2	1.9	0.7 –3.1
Marasmius oreades	54	3.5	0.05–20	7	1.7	0.26–6.4
Volvariella speciosa	1	0.11				
Macrolepiota procera				2	0.96	0.92–1.0
Macrolepiota rhacodes				1	2.0	
Coprinus comatus	37	4.7	0.68–17	3	2.7	2.5 –2.9
Coprinus atramentarius	11	0.43	0.06–2.1	1	0.12	
Psathyrella candolleana	1	2.5				
Gasteromycetes	19	2.0	0.02–8.7	1	2.2	
Mycorrhizal fungi						
Cantharellus cibarius	4	0.09	0.04–0.22	4	0.02	0.02–0.03
Cantharellus tubaeformis	1	0.13		1	0.09	
Hydnum repandum	1	0.55		4	0.46	0.29–0.62
Boletus edulis	6	4.14	0.36–19	7	0.72	0.01–1.5
Other *Boletaceae*	7	0.34	0.07–0.61	22	0.18	0.07–0.34
Amanita muscaria	2	0.28	0.25–0.30			
Inocybe sp.	1	0.02				
Rozites caperata				1	0.73	
Russula spp.	12	0.19	<0.01–0.79	12	0.03	<0.01–0.07
Lactarius necator	5	0.20	0.05–0.42	6	0.07	0.02–0.20
Other *Lactarius* spp.	10	0.24	0.03–0.93	11	0.09	<0.01–0.31

cluded, the value for the other lawn decomposers was much lower, but the significance of the difference remained unchanged.

The value for the lawn decomposers was very significantly ($p \leqq 0.001$) higher than that for the symbionts in both urban area and the rural areas. The result was the same even when the *Agaricus* species were excluded. In the urban area the level was very much higher in *Agaricus* species than in the other lawn decomposers ($p \leqq 0.001$).

Table 6. The mercury contents of the different types of fungi

	mg Hg/kg dry matter			
	Urban area		Rural areas	
	N	Mean ± S.D.	*N*	Mean ± S.D.
Lawn decomposers	191	6.6 ± 10.8	23	1.7 ± 1.9
Lawn decomposers *Agaricus* spp. excluded	137	3.6 ± 4.5	21	1.4 ± 1.5
Mycorrhizal symbionts	48	0.7 ± 2.7	69	0.2 ± 0.3

Discussion

It is interesting to compare the *lead* values obtained here with those found by Seeger [22] in her extensive series of fungi collected from unpolluted rural areas in Germany. Many of the fungi taken from rural areas in Finland had a lead content distinctly lower than that obtained by Seeger, the levels found in Germany being ten times as high as in Finland in such ordinary edible species as *Cantharellus cibarius*, *Hydnum repandum*, *Boletaceae*, and *Lactarius* species. By contrast, the higher values presented here correspond well with those found by Seeger, for instance in *Agaricus* species, *Gasteromycetes*, and *Psathyrella*.

In Finland, the highest permitted lead content of fresh foods, fungi included, is 1 mg/kg [23]. Values for fresh weight calculated on the basis of our own measurements of dry matter showed that the mean value exceeded this limit only in *Agaricus* species and the *Gasteromycetes* (*Agaricus* in rural areas 1.0, urban area

0.8 mg/kg fresh weight; *Gasteromycetes* in rural areas 1.7,urban area 2.4 mg/kg fresh weight). In the urban area, values higher than 0.5 mg/kg fresh weight were found in *Cantharellus tubaeformis* and in *Russula* species. The proportions of samples in which the content exceeds the limit were as follows: *Agaricus* species 21/55, *Gasteromycetes* 8/15, *Coprinus comatus* 1/39, *Marasmius oreades* 1/61 and *Russula* species 1/21. Thus, as far as the lead content is concerned, most fungi could safely be collected, but the risk was greatest from *Agaricus* species and the *Gasteromycetes*. One factor increasing the risk of lead contamination was the influence of motor traffic.

As regards the *cadmium* content the high levels in *Agaricus* species and *Amanita muscaria* are in accord with the literature (e.g. [6, 4, 24, 25]). The other values obtained similarly correspond well with earlier reports. According to the results obtained here, the cadmium level of fungi in Finland is thus not lower than in other countries.

For cadmium in foods no limit has been set. According to the recommendation of FAO/WHO [26] the acceptable maximum weekly intake for adults is maximally 0.5 mg. When the amounts obtained here are calculated for fresh weight, it is possible to evaluate how much of each species can be eaten per week without exceeding this value. Such calculations assume that no cadmium is derived from other sources. Since the *Agaricus* species have an average cadmium level of approximately 1 mg/kg fresh weight, the maximum amount would be 0.5 kg per week, but if the species happens to be one of the most effective accumulators of cadmium, only 50–100 g would be acceptable. In *Gasteromycetes*, where the cadmium content is 0.55 mg/kg fresh weight, 0.9 kg/week would be the maximum amount; for *Boletus edulis*, with 0.32 mg/kg fresh weight, the limit would be 1.5 kg. These calculations are based on the figures for the Helsinki area; in the unpolluted rural areas the amounts permitted are greater. According to a recent study by Schellman et. al. [27], cadmium appears to be poorly resorbed in the human intestine which would give a somewhat wider margin of safety.

Concerning *mercury*, the content in fungi depends greatly on the species and the habitat. When the species does not specifically accumulate mercury and the habitat is rural, the values presented here are somewhat lower than those published in the literature. Some of the present values, however, are higher than those reported by Seeger [28]. This may be because Seeger's samples were collected from unpolluted rural areas, whereas in the present study a high percentage of samples was from the urban Helsinki area. The differences between the species examined in the present study may be clearcut, for instance between *Coprinus comatus* (an accumulator) and *Coprinus atramentarius* (not an accumulator), likewise *Boletus edulis* (high value) and other Boletaceae (low values).

In Finland a limit of 0.8 mg/kg fresh weight has been set for the mercury content of fungi. When the values obtained, on the basis of dry matter content, have been converted to fresh weights, it is found that only *Agaricus* species exceed this limit (mean in the Helsinki area 1.1 mg/kg fresh weight). For the other species the highest mean values so calculated are as follows: *Lyophyllum connatum* 0.55, *Boletus edulis* 0.46, *Marasmius oreades* 0.36, *Coprinus comatus* 0.32, and *Gasteromycetes* 0.28 mg/kg fresh weight. In the rural areas the values are far below the limit, the values being highest for *Agaricus* 0.33 and for *Gasteromycetes* 0.31 mg/kg fresh weight. If, in addition, a check is made on which species included samples that exceeded the limit, the proportion of such samples is as follows: for *Agaricus* species 26/57, *Coprinus comatus* 6/39, *Marasmius oreades* 5/61, *Lyophyllum connatum* 3/17, and *Boletus edulis* 1/12. Thus, most of the edible fungi may be safely eaten, but those species, that do accumulate mercury should not be collected when they grow in polluted habitats.

As a general conclusion it may be stated that the location of Finland far from the centre of Europe is reflected in the low levels of lead and mercury in the rural areas. In the urban area the higher level of pollution increases the contents of heavy metals. Ecological features are also of importance: mycorrhizal fungi have been found to contain far smaller amounts of heavy metals than lawn-decomposing fungi. The bulk of the fungi collected in Finland are mycorrhizal. Thus in Finland the risk of heavy metal intake from fungi is lessened both by the mycorrhizal type of fungi collected and by the fact that the bulk of the collecting places are rural.

In the present study the highest levels of heavy metals were found in *Agaricus* species. The different species of *Agaricus* are known to vary greatly, particularly in their content of cadmium. However, it is not easy to identify the different *Agaricus* species reliably. Consequently, moderation is necessary in the use of *Agaricus* as food.

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