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Research Note

Heavy Metal Levels in Some Macrofungi

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Abstract: This study was done on edible, inedible and poisonous macrofungi collected around the Balıkesir-Manisa highway from two different areas (roadside and background area) in 1998-1999. Cu, Zn, Fe, Mn, Co, Cd, Ni and Pb contents were determined by atomic absorption spectrophotometer in 256 samples belonging to 24 macrofungi species. The habitat, edibility and distribution of the taxa in the families were listed. According to mean dry weight (DW), Mn, Co and Cd contents were high in *Omphalotus olearius* (DC.: Fr.) Fr., which is a poisonous macrofungus species compared to the others; however, Fe levels were also extremely high. The lowest Cu, Mn and Fe contents were found in *Laetiporus sulphureus* (Bull.: Fr.) Murr., which is an edible macrofungus. The highest Pb and Zn contents were determined in *Lycoperdon perlatum* Pers. as 6.5 mg/kg and 274 mg/kg respectively. The contents of Ni and Cd seemed to be lower the near road.

Key Words: Heavy metals, macrofungi, Turkey

Bazı Makrofunguslarda Ağır Metal Seviyeleri

Özet: Bu çalışma 1998-1999 yıllarında, Balıkesir-Manisa karayolu çevresinde, iki farklı alandan toplanan (yol kenarı ve yola uzak alan), yenen, yenmeyen ve zehirli makrofunguslar üzerinde yapılmıştır. 24 makrofungus türüne ait 256 örnekte Cu, Zn, Fe, Mn, Co, Cd, Ni ve Pb içerikleri atomik absorpsiyon spektrofotometresiyle tespit edilmiştir. Taksonların familyalar içinde dağılışı, yenilebilirlikleri ve habitatları liste halinde verilmiştir. Ortalama kuru ağırlıklarına (DW) göre, zehirli bir mantar türü olan *Omphalotus olearius* (DC.: Fr.) Fr.'de Mn, Co ve Cd içerikleri diğer türlerle karşılaştırıldığında yüksek, Fe de ise aşırı yüksek bulunmuştur. En düşük Cu, Mn, Fe içerikleri yenebilen bir makrofungus olan *Laetiporus sulphureus* (Bull.: Fr.) Murr.'da bulunmuştur. En yüksek Pb ve Zn içerikleri *Lycoperdon perlatum* Pers.'de sırasıyla 6.5 mg/kg ve 274 mg/kg olarak tespit edilmiştir. Ni ve Cd içeriklerinin yola yakın alanda daha düşük olduğu gözlenmiştir.

Anahtar Sözcükler: Ağır metaller, makrofunguslar, Türkiye

Introduction

Compared to green plants, mushrooms can build up large concentrations of some heavy metals (Stijve & Roschnic, 1974; Kuusi et al., 1981). An important factor is the absorption of these elements in the body after ingestion. It has been suggested that little or none of the Cd present in fungi is absorbed during passage through the intestinal tract (Schellman et al., 1980). However, other studies indicate that Cd uptake may be fairly high (Gast et al., 1988; Vetter, 1994; Melgar et al., 1998).

The fact is that the accumulation of metals by fungi has been shown primarily by the high Cd levels found in the *Agaricus* L.: Fr. genus (Kuusi et al., 1981). It was determined that some macrofungi have the ability to accumulate heavy metals such as Cd (Stijve & Besson, 1976; Schmitt & Meisch, 1985; Jorhem & Sundström, 1995; Kalac et al., 1996).

The description of the contents and factors influencing the accumulation of heavy metals in various macrofungi has been the target of many studies in recent years (Kojo & Lodenius, 1989; Falandysz & Chwir, 1997; Melgar et al., 1998; Garcia et al., 1998; Sesli & Tüzen, 1999; Falandysz et al., 2000; Demirbaş, 2001).

The concentrations of Al, Cd and Pb in 17 edible, inedible and poisonous species of mushrooms were determined in the eastern part of Slovenia by Mandic et al. (1992). According to their results, although the mean content of Cd in edible mushrooms was lower than it was in inedible, poisonous and deadly poisonous mushrooms, the mean content of lead in edible mushrooms was higher than it was in inedible mushrooms (Mandic et al., 1992).

The concentrations of Pb in 95 samples of 13 species (seven mycorrhizals and six saprophites) collected from two different areas (polluted and unpolluted) in NW Spain were determined by Garcia et al. (1998). The following factors were considered; species and ecology, as well as morphological portion and traffic pollution. The average lead concentration of the samples was 1 ppm dry weight. Saprophite species presented higher levels than mycorrhizal ones. *Coprinus comatus* (Müll.: Fr.) S.F.Gray reached the maximum mean concentration of 2.06 and 2.79 ppm of dry weight in the hymenophore and the rest of the fruit body. The morphological portion statistically did not show a significant difference between the two portions (Garcia et al., 1998). This species, as other researchers have indicated, can be considered a bioindicator for lead contamination (Quinche, 1992).

The highest Pb levels found in samples collected near roads were 2.35 mg/kg for the species *Agaricus bitorquis* (Quél.) Sacc. and 7.00 mg/kg for *Hypholoma fasciculare* (Huds.: Fr.) Kummer. The highest mean concentration of Cu was 51.0 mg/kg for *Tricholoma terreum* (Schaeff.: Fr.) Kummer and the highest mean Mn concentration was 35.9 mg/kg for *Laccaria laccata* (Scop.: Fr.) Bk & Br. (Tüzen et al., 1998).

Hg, Pb, Cd, Fe, Cu, Mn, Zn, Co and As contents were determined spectrometrically in the fruiting bodies of 109 wild and two cultivated macrofungi specimens by Sesli & Tüzen (1999). The macrofungi specimens were collected from the East Black Sea region of Turkey. According to this study, no difference between sapropytic and mycorrhizal forming species was observed. Trace element concentrations were highest in the macrofungi of the family *Tricholomataceae*. The highest Pb content was 5.64 µg/g dry weight found in *Hypholoma fasciculare* collected from a roadside (Sesli & Tüzen, 1999).

Seventeen different species of wild mushrooms growing in the East Black Sea region and one cultivated mushroom were analysed spectrometrically for trace element (Pb, Cd, Hg, Cu, Mn and Zn) levels by Demirbaş. According to the results, the highest mean Pb level was 6.88 mg/kg for the species *Hypholoma fasciculare* collected from a roadside (Demirbaş, 2001).

Turkey has a very rich flora of mushrooms because it possesses favourable environmental conditions for the growth of edible, inedible and poisonous macrofungi. However, the Turkish public rarely consumes wild edible macrofungi. In many European countries fungi collection is very popular though the amount collected is quite insignificant (Jorhem & Sundström, 1995).

The purpose of this study was to determine the contents of eight heavy metals in 24 macrofungi collected from roadside and background areas. The other aim was to compare the toxicity of heavy metals, the habitat and edibility of species and traffic pollution.

Materials and Methods

The macrofungi samples were collected from a roadside ecosystem (Balıkesir-Manisa highway) between autumn 1998 and summer 1999. The study area (Figure 1) includes forest and lawns that have been exposed to pollutants from automobile traffic for many years. The samples were classified and evaluated in two categories: roadside and background area. The sampling was done between 0 and 200 m from the road (roadside) and more than 200 m (as background area). Metal levels in 256 samples from 24 species of edible, inedible and poisonous mushrooms were analysed.

To identify the specimens, the habitat and morphological characteristics of the macrofungi found in the localities were recorded and photographed. The macrofungus specimens were then brought to the laboratory and their spore prints were extracted and measured. Specimens were identified by reference books (Moser, 1983; Breitanbach & Kranzlin, 1984).

The samples were cleaned without washing, cut and dried at 40 ºC in an oven for 48 h after being air dried for 5 days. A sample with a mass of 0.5-2 g was weighed and placed into a porcelain crucible and ashed at 450 ºC for 15-24 h, then the ash was dissolved in 2 mL conc. HNO_3, evaporated to dryness, heated again at 450 ºC for 3 h and dissolved in 1 mL conc. H_2SO_4, 1 mL conc. HNO_3 and diluted with deionised water up to a volume of 25 mL. All samples were run in duplicate.

A Perkin Elmer model SIM AA 900 graphite furnace atomic absorption spectrophotometer with Zeeman background correction at wavelengths of 283.3 nm for Pb, 228.8 nm for Cd, 232.0 nm for Ni and 240.7 nm for Co and a Pye Unicam 929 flame atomic absorption spectrophotometer with deuterium background correction at 213.9 nm for Zn, 279.5 nm for Mn, 248.3 nm for Fe and 324.8 nm for Cu were used.

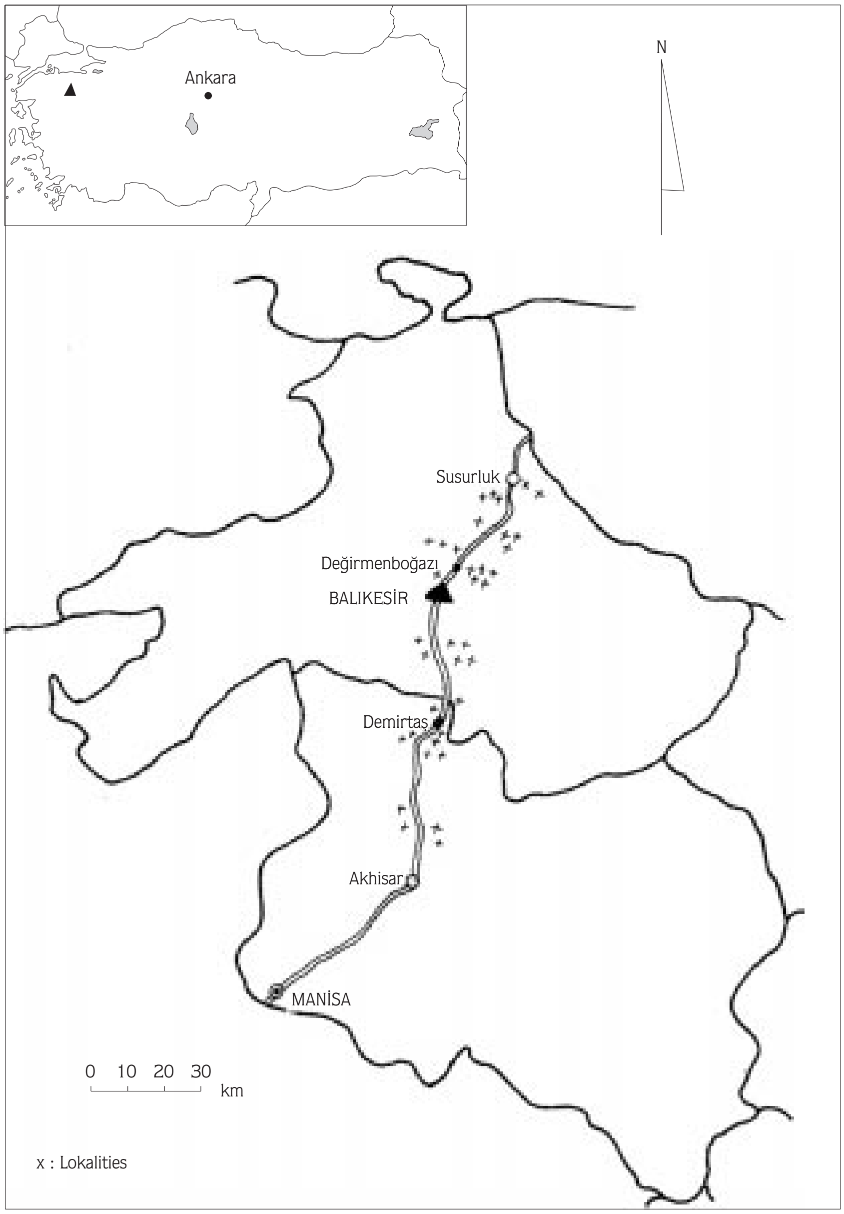

Figure 1. Map of the study area.

Table 1. Levels of elements in certified reference material analysed as samples (mg/L).

Metal	Green algea (n = 5)	Metal	Green algea (n = 5)
Cu found	18.9 ± 1.2	Co found	19.1 ± 1.3
Certified	19.6	Certified	19.9
Cd found	0.042 ± 0.006	Zn found	41.5 ± 1.7
Certified	0.045	Certified	40.2
Ni found	1.28 ± 0.15	Mn found	34.5 ± 2.3
Certified	1.23	Certified	32.8
Pb found	1.26 ± 0.22	Fe found	352 ± 13
Certified	1.23	Certified	339

A certified reference material (CRM) consisting of green algae (MBH, reference materials) was developed for survey and analysed together with the samples (Table 1).

Detection limits were calculated as 3 times the standard deviation of a large number of blanks taken through the entire analytical procedure. Detection limits for each element were 0.015 µg/L for Mn, 2.2 x 10^{-4} µg/L for Cd, 0.009 µg/L for Cu, 0.009 µg/L for Co, 0.038 µg/L for Zn, 0.085 µg/L for Fe and 0.0048 µg/L for Pb.

Correlations between metal concentrations were tested by regression analysis. Metal concentrations from the test were compared statistically by two-tailed tests.

Results and Discussion

Twenty-four species of wild macrofungi were collected. The total number of samples from the roadside was 127 and from the background area 129.

The result of the CRM analysis showed good agreement with the certified levels in Table 1. The habitat and edibility of macrofungi are shown in Table 2.

Element concentrations in the mushroom species

Table 2. Habitat and edibility of macrofungi species.

No	Family and species	Habitat	Edibility
	Rhizopogonaceae		
1.	*Rhizopogon luteolus* Fr.	Sandy conifer woods	Edible
	Lycoperdaceae		
2.	*Lycoperdon perlatum* Pers. Woodland	Edible	
	Polyporaceae		
3.	*Laetiporus sulphureus* (Bull.: Fr.) Murr.	On living and dead wood of broadleaf trees	Edible
	Bolataceae		
4.	*Suillus bellinii* (Inz.) Watl.	In conifer forests	Edible
	Paxillaceae		
5.	*Omphalotus olearius* (DC.: Fr.) Fr.	On the roots or at the base of certain trees	Poisonous
	Hygrophoraceae		
6.	*Hygrophorus hedyricii* Vel.	Under pine and betula	Inedible
	Tricholomataceae		
7.	*Clitocybe dealbata* (Sow.: Fr.) Kummer	In grassy area	Poisonous
8.	*C. subspadicae* (Lge.) Bon&Chevassut	In conifer forests	Inedible
9.	*Laccaria laccata* (Scop.: Fr.) Bk & Br.	In hardwood and coniferous forest	Edible
10.	*Marasmius oreades* (Bolt.: Fr.) Fr.	In meadows and pastures, in grassy forests	Edible
11.	*Tricholoma auratum* (Fr.) Gill.	In sandy pine woods	Poisonous
12.	*T. batschii* Gulden	In conifer forests	Inedible
13.	*T. stans* (Fr.) Sacc.	In conifer forests	Inedible
14.	*T. terreum* (Schaeff.: Fr.) Kumm.	On calcerous soils in coniferous forests	Edible
	Lepiotaceae		
15.	*Lepiota alba* (Bres.) Sacc.	Meadows	Inedible
16.	Leuco*agaricus* pudicus Bull.	Grassy places	Inedible
	Agaricaceae		
17.	*Agaricus placomyces* Peck.	On wood	Poisonous
18.	*A. subperonatus* (Lge.) Sing.	In grassy woods	Edible
	Strophoriaceae		
19.	*Hypholoma fasciculare* (Huds : Fr.) Kummer.	On dead decidious and coniferous woods	Poisonous
	Cortinariaceae		
20.	*Hebeloma sinapizans* (Paulet: Fr.) Gill.	Decidious and coniferous woods	Poisonous
21.	*Inocybe geophylla* (Sow.: Fr.) Kumm. var. *violacea*e Pat.	In mixed and coniferous woods	Poisonous
	Russulaceae		
22.	*Lactarius deliciosus* Fr.	Under coniferous tress, especially pine	Edible
23.	*Russula delica* Fr.	Under both broad-leaved and coniferous trees	Edible
24.	*R. foetens* Fr.	Under broad-leaved trees or conifers	Inedible

Table 3. Metal content in individual macrofungi species (mg/kg, dry weight). Data are represented as means (M), standard deviations (SD) and minimum-maximum (MM).

Family and species	Area	Value	Elements							
			Cu	Zn	Mn	Fe	Co	Cd	Ni	Pb
1. *R. luteolus*	R(6)	M ± SD	13 ± 7	30 ± 3	13 ± 3	620 ± 30	1.6 ± 0.2	0.26 ± 0.23	4.6 ± 0.2	2.8 ± 0.2
		MM	10-26	26-33	10-16	580-640	1.5-1.9	0.08-0.32	2.4-4.8	4.5-1.1
	B(6)	M ± SD	15 ± 6	37 ± 11	17 ± 4	410 ± 30	1.9 ± 0.6	1.5 ± 0.3	4.0 ± 0.3	2.8 ± 0.3
		MM	11-23	24-52	13-22	375-435	1.4-2.5	1.2-1.8	3.7-4.3	2.5-3.1
2. *L. perlatum*	R(7)	M ± SD	86 ± 19	274 ± 53	24 ± 5	356 ± 21	2.2 ± 1.0	1.3 ± 0.3	3.4 ± 1.0	5.5 ± 2.2
		MM	65-102	164-331	20-30	335-377	1.103.4	1.0-1.9	2.5-4.5	2.6-7..8
	B(7)	M ± SD	115 ± 16	199 ± 26	27 ± 9	747 ± 84	3.6 ± 0.6	1.2 ± 0.4	6.6 ± 2.7	6.5 ± 1.1
		MM	97-135	70-217	19-42	688-807	1.9-4.1	1.1-1.9	4.7-9.2	5.5-8.0
3. *L. sulphureus*	R(1)	M ± SD	6.5	38	3.7	162	1.6	0.36	2.7	3.3
	B(2)	M ± SD	5.6 ± 0.9	33 ± 2	5.6 ± 2.6	90 ± 3	1.8 ± 1.2	0.44 ± 0.18	4.7 ± 1.9	3.8 ± 2.4
		MM	5.0-6.2	32-34	3.8-7.5	88-92	1.0-2.7	0.31-0.56	3.3-6.1	2.1-5.5
4. *S. bellinii*	R(5)	M ± SD	82 ± 3	98 ± 5	11 ± 4	485 ± 42	1.5 ± 0.5	0.60 ± 0.38	2.7 ± 0.5	2.7 ± 0.7
		MM	75-88	93-103	9-17	452-532	0.91-1.9	0.35-1.0	1.9-3.1	1.8-3.4
	B(4)	M ± SD	41 ± 6	57 ± 6	16 ± 4	616 ± 69	2.1 ± 0.3	0.44 ± 0.24	5.3 ± 3.1	4.1 ± 0.5
		MM	31-48	49-61	13-19	542-678	1.7-2.4	0.25-0.77	2.1-8.4	3.8-4.8
5. *O. olearius*	R(5)	M ± SD	21 ± 1	27 ± 3	36 ± 5	9518 ± 235	5.0 ± 0.8	1.0 ± 0.2	8.6 ± 2.3	5.2 ± 2.9
		MM	23-20	24 -30	32-42	7702-9685	3.9-5.8	0.86-1.2	3.4-8.7	2.6-8.5
	B(4)	M ± SD	40 ± 4	25 ± 11	15 ± 2	1544 ± 235	1.3 ± 0.7	3.9 ± 0.6	2.2 ± 1.1	2.2 ± 1.1
		MM	36-43	15-36	14-17	769-1711	0.86-2.5	3.1-4.9	1.4-4.0	1.2-3.8
6. *H. hedrychii*	R(4)	M ± SD	37 ± 5	97 ± 13	11 ± 2	393 ± 52	1.2 ± 0.5	0.41 ± 0.14	2.0 ± 0.6	2.7 ± 1.3
		MM	30-44	87-112	8.9-13	336-437	0.56-1.7	0.27-0.55	1.3-2.7	1.3-4.2
	B(4)	M ± SD	46 ± 3	137 ± 26	17 ± 2	588 ± 122	1.3 ± 0.4	0.46 ± 0.21	2.4 ± 0.7	3.1 ± 1.5
		MM	42-52	107-153	14-18	470-713	0.72-1.8	0.23-0.64	1.6-3.3	1.0-4.7
7. *C. dealbata*	R(6)	M ± SD	41 ± 3	115 ± 7	30 ± 4	386 ± 30	1.5 ± 0.7	0.48 ± 0.31	1.5 ± 0.6	3.2 ± 1.1
		MM	37-43	108-120	24-32	359-414	0.77-2.5	0.26-0.89	0.89-2.2	2.2-4.6
	B(7)	M ± SD	37 ± 4	120 ± 3	21 ± 3	188 ± 13	1.6 ± 0.4	1.7 ± 0.3	2.7 ± 0.8	2.7 ± 0.9
		MM	32-40	118-123	17-23	178-197	1.4-1.9	1.5-1.9	2.2-3.2	2.0-3.3
8. *C. subspadicae*	R(5)	M ± SD	60 ± 8	95 ± 3	12 ± 1	360 ± 15	1.4 ± 0.4	0.61 ± 0.10	2.5 ± 0.7	4.1 ± 1.7
		MM	54-68	92-97	11-13	343-367	0.87-1.9	0.50-0.69	1.7-3.4	2.0-6.0
	B(6)	M ± SD	59 ± 15	88 ± 10	17 ± 3	428 ± 29	1.6 ± 0.5	0.67 ± 0.16	3.4 ± 1.9	4.4 ± 13
		MM	48-70	81-95	15-20	408-450	1.0-2.1	0.56-0.79	1.5-5.3	3.0-5.7
9. *L. laccata*	R(9)	M ± SD	186 ± 32	120 ± 10	23 ± 2	486 ± 140	1.4 ± 0.4	0.72 ± 0.30	2.0 ± 0.4	6.4 ± 1.33
		MM	175-239	112-132	21-24	386-646	1.0-1.8	0.42-1.02	1.6-2.7	4.9-7.9
	B(9)	M ± SD	150 ± 42	113 ± 24	24 ± 5	488 ± 74	2.0 ± 0.4	0.54 ± 0.27	4.4 ± 2.2	4.8 ± 3.0
		MM	119-179	96-140	18-30	437-573	1.7-2.6	0.30-0.76	2.4-7.0	2.1-7.8
10. *M. oreades*	R(7)	M ± SD	73 ± 6	116 ± 12	30 ± 4	842 ± 35	2.0 ± 0.5	0.84 ± 0.20	4.3 ± 1.7	4.0 ± 2.2
		MM	67-79	102-130	25-34	803-870	1.2-2.3	0.61-0.98	2.6-6.5	2.1-6.5
	B(7)	M ± SD	275 ± 7	132 ± 11	21 ± 2	412 ± 75	1.7 ± 0.9	0.92 ± 0.39	5.5 ± 1.3	6.4 ± 1.1
		MM	270-280	122-144	18-23	358-466	1.1-2.3	0.45-1.3	4.6-6.5	4.7-6.5
11. *T. auratum*	R(6)	M ± SD	115 ± 4	115 ± 10	20 ± 2	482 ± 33	1.0 ± 0.4	0.68 ± 0.30	2.9 ± 1.4	3.6 ± 1.4
		MM	112-118	104-123	18-21	451-516	0.55-1.4	0.30-1.0	1.6-5.0	1.6-4.9
	B(5)	M ± SD	30 ± 4	158 ± 13	15 ± 2	310 ± 12	1.2 ± 0.5	0.17 ± 0.75	1.6 ± 0.6	1.2 ± 0.6
		MM	27-34	141-175	14-17	265-354	0.67-1.8	0.69-2.6	0.87-2.2	0.57-1.9
12. *T. batschii*	R(5)	M ± SD	21 ± 7	66 ± 15	22 ± 5	991 ± 15	2.2 ± 0.4	0.84 ± 0.11	5.5 ± 0.5	3.0 ± 0.4
		MM	16-26	61-70	18-25	925-1030	1.7-2.5	0.77-0.97	6.0-7.8	2.6-3.2
	B(5)	M ± SD	8.4 ± 3.1	54 ± 10	12 ± 2	251 ± 19	1.6 ± 0.5	0.5 ± 1.31	2.5 ± 0.6	1.6 ± 0.5
		MM	6.8-10	36-68	11-14	209-294	1.1-2.0	0.53-1.62	1.7-3.2	0.75-2.1

Table 3. Continued.

Family and species	Area	Value	Elements							
			Cu	Zn	Mn	Fe	Co	Cd	Ni	Pb
13. *T. stans*	R(5)	M ± SD	60 ± 16	83 ± 5	10 ± 2	337 ± 11	2.2 ± 0.5	0.35 ± 0.35	5.5 ± 0.5	3.7 ± 0.5
		MM	46-77	78-85	9.0-12	330-349	1.8-2.8	0.12-0.61	4.9-6.0	3.4-4.3
	B(5)	M ± SD	86 ± 25	82 ± 5	12 ± 3	375 ± 15	1.8 ± 0.4	0.55 ± 0.16	2.8 ± 0.3	2.6 ± 1.2
		MM	67-114	77-85	9.6-15	359-388	1.6-2.2	0.38-0.69	2.5-3.2	1.8-4.0
14. *T. terreum*	R(7)	M ± SD	25 ± 3	179 ± 3	19 ± 4	741 ± 202	2.6 ± 1.5	0.56 ± 0.14	5.6 ± 2.1	4.4 ± 1.5
		MM	22-28	175-182	15-22	508-872	1.5-4.6	0.41-0.69	2.9-7.3	2.3-6.0
	B(7)	M ± SD	39 ± 7	228 ± 57	20 ± 2	1042 ± 70	2.5 ± 1.2	1.2 ± 0.6	9.4 ± 2.1	5.4 ± 1.6
		MM	32-46	188-427	18-21	966-1105	1.4-4.8	0.37-1.6	7.3-12	3.1-7.6
15. *L. alba*	R(3)	M ± SD	29 ± 5	86 ± 8	22 ± 11	779 ± 35	3.0 ± 0.9	0.83 ± 0.59	5.8 ± 1.4	5.8 ± 1.0
		MM	18-34	88-102	14-36	750-798	2.4-3.7	0.22-1.8	4.8-6.8	4.7-6.4
	B(2)	M ± SD	35 ± 9	86 ± 17	21 ± 5	1039 ± 98	4.2 ± 1.6	1.0 ± 0.3	8.3 ± 4.0	6.0 ± 2.5
		MM	28-41	74-98	17-24	969-1108	3.0-5.3	0.80-1.2	5.4-11	4.3-7.8
16. *L. pudicus*	R(6)	M ± SD	36 ± 7	90 ± 8	11 ± 6	318 ± 44	1.9 ± 1.0	1.2 ± 0.2	3.2 ± 1.5	3.7 ± 1.1
		MM	28-1.8	100-182	9.4-22	274-362	1.2-2.6	1.0-1.5	2.1-4.2	3.0-4.7
	B(6)	M ± SD	27 ± 16	100 ± 34	9.4 ± 3.6	270 ± 121	2.1 ± 0.8	1.4 ± 0.7	3.8 ± 1.4	2.9 ± 1.1
		MM	11-49	70-149	5.7-14	116-406	0.58-2.1	0.67-1.4	1.5-4.5	2.0-5.4
17. *A. placomyces*	R(4)	M ± SD	54 ± 3	68 ± 10	20 ± 5	892 ± 27	2.3 ± 1.0	0.60 ± 0.42	4.4 ± 3.1	3.7 ± 1.3
		MM	52-57	58-77	15-25	854-934	1.4-3.8	0.36-0.96	2.3-9.0	2.0-5.2
	B(3)	M ± SD	59 ± 3	69 ± 3	23 ± 6	939 ± 36	2.7 ± 0.5	0.93 ± 0.29	11 ± 3	3.6 ± 1.4
		MM	57-63	66-72	18-27	903-975	2.2-3.3	0.61-1.16	4.8-12	2.2-4.8
18. *A. subperonatus*	R(4)	M ± SD	63 ± 18	67 ± 8	32 ± 2	1452 ± 296	2.4 ± 0.3	0.69 ± 0.34	4.3 ± 0.3	3.5 ± 1.2
		MM	42-77	57-78	31-35	1187-1771	2.1-2.6	0.35-0.82	4.1-4.5	2.3-5.0
	B(4)	M ± SD	91 ± 3	76 ± 10	37 ± 6	750 ± 364	2.2 ± 0.3	0.56 ± 0.30	5.0 ± 2.0	3.0 ± 1.1
		MM	87-94	66-85	31-42	329-970	1.9-2.5	0.48-0.81	2.8-7.0	1.9-4.4
19. *H. fasciculare*	R(5)	M ± SD	31 ± 2	66 ± 26	20 ± 5	704 ± 12	2.1 ± 0.9	0.58 ± 0.17	4.0 ± 0.8	3.5 ± 1.2
		MM	29-34	36-171	15-23	612-795	1.1-3.3	0.39-0.71	2.9-4.8	2.1-5.0
	B(7)	M ± SD	36 ± 3	143 ± 30	18 ± 2	388 ± 20	1.9 ± 0.7	0.80 ± 0.30	3.5 ± 1.2	3.3 ± 1.3
		MM	3.4-40	79-147	15-19	365-404	1.3-2.9	0.45-0.96	2.4-5.2	2.2-5.0
20. *H. sinapizans*	R(5)	M ± SD	162 ± 46	178 ± 9	20 ± 7	535 ± 101	1.6 ± 0.5	2.0 ± 1.5	3.8 ± 1.0	3.2 ± 1.1
		MM	109-192	168-187	14-32	423-621	1.1-2.1	1.0-3.7	2.8-5.2	2.2-4.4
	B(5)	M ± SD	144 ± 19	115 ± 6	13 ± 10	303 ± 23	1.2 ± 0.4	0.49 ± 0.24	3.5 ± 1.9	2.8 ± 0.5
		MM	132-158	108-127	9.0-38	279-326	0.79-1.7	0.22-0.67	1.6-5.7	2.3-3.4
21. *Inocybe geophylla* var. *violacea*	R(8)	M ± SD	26 ± 8	116 ± 6	15 ± 8	376 ± 144	2.4 ± 1.1	1. ± 0.5	4.0 ± 1.0	3.5 ± 1.8
		MM	20-32	111-120	8.2-17	274-478	1.2-3.4	0.60-1.4	3.2-5.1	1.6-5.2
	B(10)	M ± SD	24 ± 3	132 ± 9	24 ± 9	1020 ± 182	2.5 ± 1.4	1.4 ± 0.7	11 ± 6	4.0 ± 2.0
		MM	22-33	123-144	13-35	866-1217	1.3-4.2	0.98-2.3	2.4-17	1.9-6.9
22. *L. deliciosus*	R(5)	M ± SD	47 ± 8	88 ± 5	12 ± 6.8	493 ± 23	2.3 ± 0.6	0.39 ± 0.23	3.8 ± 1.9	3.0 ± 0.1
		MM	44-70	82-91	8.0-19	466-510	1.9-3.1	0.27-0.71	1.7-5.8	2.8-3.0
	B(5)	M ± SD	24 ± 10	83 ± 8	29 ± 6	412 ± 12	3.2 ± 0.9	0.50 ± 0.19	15 ± 3	3.3 ± 0.5
		MM	17-39	73-88	22-33	401-425	2.0-4.0	0.33-0.74	13-19	3.0-4.0
23. *R. delica*	R(4)	M ± SD	73 ± 8	57 ± 12	9.6 ± 3.7	244 ± 12	1.5 ± 0.7	0.31 ± 0.46	3.2 ± 0.9	2.7 ± 0.8
		MM	66-82	49-72	7.8-15	223-265	0.65-2.0	0.16-0.75	2.2-4.0	1.8-3.4
	B(4)	M ± SD	75 ± 7	67 ± 16	14 ± 4	698 ± 79	3.0 ± 0.4	0.84 ± 0.53	2.8 ± 1.4	4.1 ± 0.4
		MM	67-83	49-78	10-21	621-780	2.6-3.2	0.23-1.2	1.2-3.6	3.6-4.4
24. *R. foetens*	R(5)	M ± SD	58 ± 7	82 ± 16	12 ± 5	238 ± 44	2.2 ± 1.5	1.4 ± 0.5	3.6 ± 1.3	2.4 ± 0.5
		MM	53-66	89-95	7.6-19	196-284	0.57-3.3	1.1-2.0	2.2-4.7	1.8-2.8
	B(5)	M ± SD	57 ± 10	72 ± 10	18 ± 69	382 ± 10	2.0 ± 0.6	1.9 ± 0.5	4.0 ± 0.9	5.2 ± 1.9
		MM	45-64	62-86	12-29	372-393	1.3-2.5	1.2-2.4	2.8-4.6	3.0-7.2

R: Roadside, B: Background area

Table 4. Significant correlations (r) between metal pairs in mushrooms.

Species	Co-Ni	Cd-Co	Mn-Co	Pb-Ni	Cd-Ni	Cu-Ni
	r					
R. luteolus	0.87c					
L. sulphureus		0.60a	0.79c			
S. bellinii		0.50a		0.70b	0.75b	0.73b
H. hedrychii	0.78c					
T. batschii	0.90d			0.85c		
T. stans		0.86c	0.73a		0.81c	
A. placomyces	0.79c			0.90d		0.64a
A. subperonatus			0.76b			0.74b
H. sinapizans				0.82c	0.87d	0.78c

Species	Cd-Pb	Mn-Ni	Zn-Co	Zn-Pb	Fe-Zn	Cu-Zn
	r					
R. luteolus					0.73a	
L. perlatum		0.71b				
L. sulphureus			0.72b	0.79c		
S. bellinii	0.75b					
T. batschii	0.60a					
T. stans	0.83d	0.79b		0.71a	0.54a	0.77b
A. placomyces	0.62b					
A. subperonatus			0.75b			
H. sinapizans	0.78b					

Species	Cu-Cd	Zn-Mn	Co-Pb	Cu-Co	Cu-Ni	Co-Ni
	r					
O. olearius	0.78c					
L. laccata		0.77b				
M. oreades			0.77c			
T. auratum				0.77c	0.75b	
T. terreum			0.80d			0.82d
L. pudicus		0.67a				
H. fasciculare	0.73b				0.79c	
L. deliciosus			0.82d			0.80d
R. delica		0.78b				
R. foetens				0.81b		

Species	Cd-Co	Mn-Pb	Mn-Ni	Cd-Ni	Zn-Cd	Cu-Pb
	r					
T. terreum	0.82c					
L. pudicus					0.60a	
H. fasciculare		0.62a	0.73b	0.82c		0.66a
R. delica			0.79b		0.78b	
R. foetens	0.74a			0.74b	0.69a	

a: $P < 0.10$, b: $P < 0.05$, c: $P < 0.02$, d: $P < 0.01$

were analysed and the results are given in Table 3. In this table, the number of samples (n), mean concentrations and standard deviations (M ± SD), and minimum-maximum (MM) levels are indicated for both groups.

The significant linear correlations found for metal concentrations in mushrooms from the roadside are indicated in Table 4.

Cu concentrations ranged from 2 to 239 mg/kg for samples from the roadside and from 4.96 to 280 mg/kg for samples from the background area. The highest mean level was found in *Marasmius oreades* (Bolt.: Fr.) Fr. from the background area and the lowest mean levels for both areas in *Laetiporus sulphureus*. The variation within the two studied areas was fairly low except for *Marasmius oreades* and *Tricholoma auratum* (Fr.) Gill. (Figure 2).

Zn content in mushrooms ranged from 24 to 331 mg/kg for samples from the roadside and from 15 to 427 mg/kg for background area samples. The highest Zn contents were found in *Lycoperdon perlatum* for roadside *Tricholoma terreum* for background areas. The lowest zinc content was found in *Omphalotus olearius* for both areas. Poisonous mushrooms were generally higher in zinc content in background areas (Figure 3). The correlation between Zn and Pb was significant in *Laetiporus sulphureus* ($P < 0.02$).

The minimum and maximum concentrations of Mn in collected samples ranged from 3.7 to 42 mg/kg for roadside and from 3.8 to 42 mg/kg for background areas. The highest mean concentrations were found in *Omphalotus olearius* for roadside areas and *Agaricus subperonatus* (Lge.) Sing. The lowest mean concentrations were found in *Laetiporus sulphureus* for both areas. The Mn content of edible mushrooms was higher in background areas (Figure 4). The correlation between Mn and Co was significant in *L. sulphureus* ($P < 0.02$).

In this study, it was found that the trace metal concentrations were statistically significant lowest in *L. sulphureus*, which is edible. Its habitat is on the living and dead wood of broadleaf trees. Fungal species growing on wood contain, in general, lower concentrations of heavy metals than fungi growing on soil (Mutsch et al., 1979).

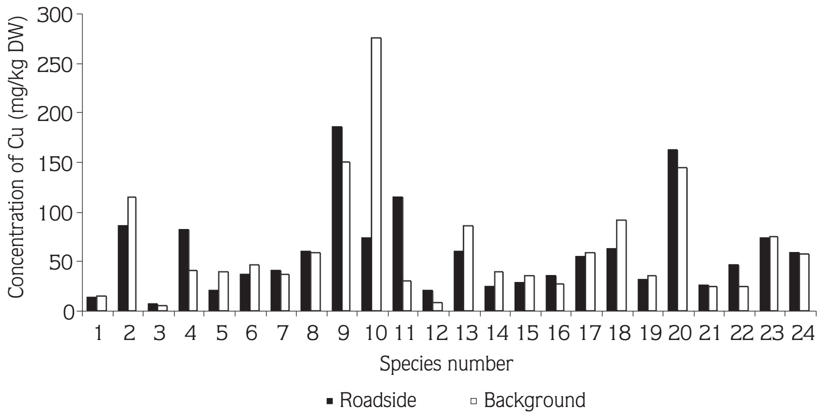

Figure 2. Comparison of mean concentrations of Cu (mg/kg dry weight) in 24 species of mushrooms from roadside and background areas.

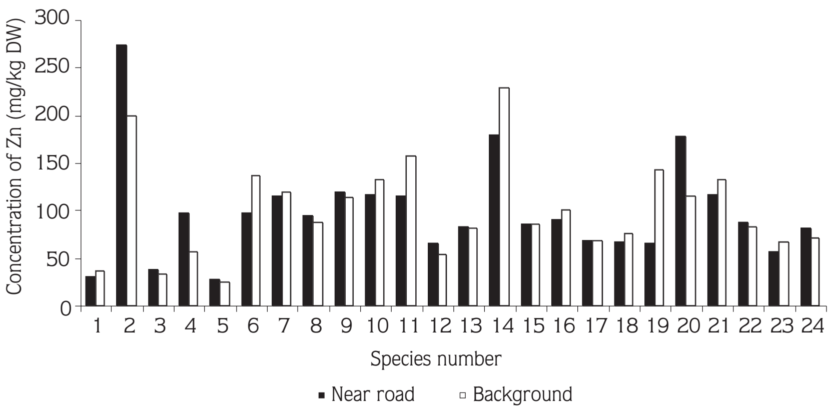

Figure 3. Comparison of mean concentrations of Zn (mg/kg dry weight) in 24 in species of mushrooms from roadside and background areas.

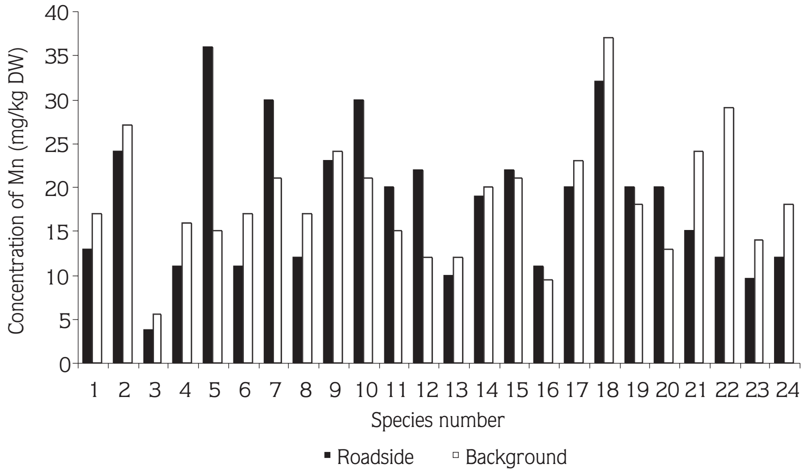

Figure 4. Comparison of mean concentrations of Mn (mg/kg dry weight) in 24 species of mushrooms from roadside and background areas.

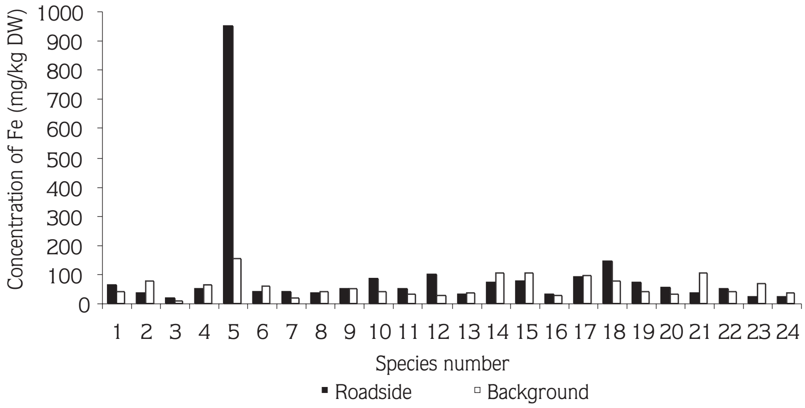

Figure 5. Comparison of mean concentrations of Fe (mg/kg dry weight) in 24 species of mushrooms from roadside and background areas.

The Fe contents of mushrooms ranged from 162 to 9685 mg/kg for roadside and from 88 to 1711 mg/kg for background areas. The highest concentration of Fe was found in *Omphalotus olearius*, with a mean of 9518 mg/kg (roadside) and 1544 mg/kg (background area). Concentrations of Fe in the other species were very low (Figure 5).

The values of Co concentrations in samples ranged from 0.55 to 5.8 mg/kg for roadside and from 0.67 to 5.3 mg/kg for background areas. Relatively high concentrations were found in *Omphalotus olearius* for roadside but Lepiota alba (Bres.) Sacc., *Lycoperdon perlatum*, *Lactarius deliciosus* Fr. and *Russula delica* Fr. for background areas (Figure 6).

Cadmium concentrations ranged from 0.08 to 3.7 mg/kg for samples from roadside and from 0.22 to 4.9 mg/kg for samples from background areas. The highest mean concentration was determined in *Omphalotus olearius* to be 3.9 mg/kg for background areas. The ability to accumulate cadmium appeared highest for *Hebeloma sinapizans* (Paulet: Fr.) Gill. in roadside areas (Figure 7). The level of samples from the background area were found statistically significant higher than the other area. The correlation between Cd and Ni was significant in *H. sinapizans* ($P < 0.01$). There were also significant correlations between Cd and Ni for *Hypholoma fasciculare* and Cd and Co for *Tricholoma terreum* ($P < 0.02$).

Omphalotus olearius is a wood-decaying poisonous macrofungus. Its habitat is on the roots or at the base of certain trees like *Pinus* sp. and *Olea* sp. Wood decaying fungi take up heavy metals absorption from the substrate. Literature data indicate that heavy metal content decreases from the soil through the roots to the stems (Salt et al., 1995).

Very high concentrations of cadmium have been found in the genus *Agaricus* (Lodenius et al., 1981; Schmitt & Meisch, 1985; Quinche, 1987; Kojo & Lodenius, 1989; Vetter, 1994). Tyler (1980) also found no correlation

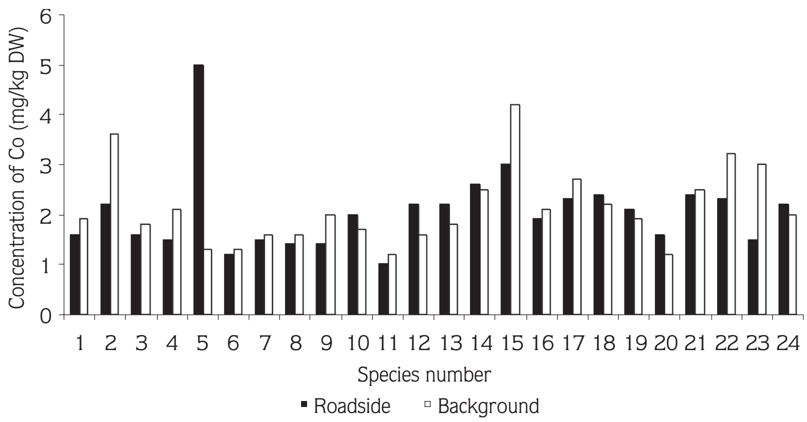

Figure 6. Comparison of mean concentrations of Co (mg/kg dry weight) in 24 species of mushrooms from roadside and background areas.

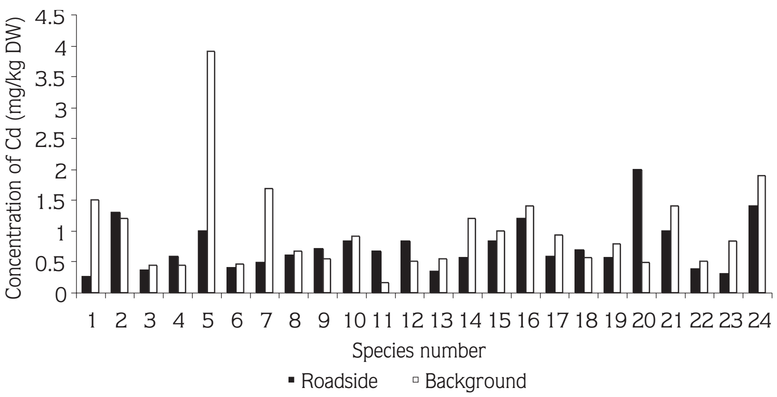

Figure 7. Comparison of mean concentrations of Cd (mg/kg dry weight) in 24 species of mushrooms from roadside and background areas.

between the cadmium contents of mushrooms and that of the soil or substrate. Because it has been suggested that Cd could be a growth stimulation factor, this phenomenon proved to be of taxonomical value and was not the result of environmental contamination with Cd from the soil (Tyler, 1980). Traffic pollution was not a significant factor for cadmium accumulation in fungi (Melgar et al., 1998).

In this study, Cd contents were higher in *Omphalotus olearius*, *Lycoperdon perlatum*, *Hebeloma sinapizans*, *Clitocybe dealbata* (Sow.: Fr.) Kummer and *Russula foetens* Fr. than in *Agaricus* species and the traffic pollution factor did not show significant differences. High Cd concentrations were probably not caused by pollution but by species-dependent factors, so we agree with the opinion of other authors.

The minimum and maximum values of Ni in samples ranged from 0.89 to 8.7 mg/kg for roadside areas and from 0.87 to 19 mg/kg for background areas. Statistically significant highest mean concentrations of Ni were found in *Tricholoma terreum*, *Lepiota alba*, *Lactarius deliciosus*, *Agaricus placomyces* Peck. and *Inocybe geophylla* (Sow.: Fr.) Kumm. var. *violacea* Pat. for samples from background areas. The Ni level of samples from background areas was relatively higher (Figure 8). The correlation between Co and Ni was significant in *Lactarius deliciosus*, *Tricholoma batschii* Gulden and *T. terreum* ($P < 0.01$).

Lead concentrations in the samples ranged from 1.1 to 7.9 mg/kg for roadside and from 0.57 to 8 mg/kg for background areas. We found the highest concentrations of lead in *Laccaria laccata*, *Marasmius oreades*, *Lycoperdon perlatum* and *Lepiota alba*. Mean concentrations for *Omphalotus olearius*, *Laccaria laccata*, *Tricholoma stans* (Fr.) Sacc., *T. auratum* and *T. batschii* were higher in roadside areas (Figure 9). The correlation between Co and Pb was significant in *Lactarius deliciosus* and *Tricholoma terreum*. The correlation between Pb-Ni as well as Cd and Pb were significant for *Agaricus placomyces* and *Tricholoma stans* respectively ($P < 0.01$).

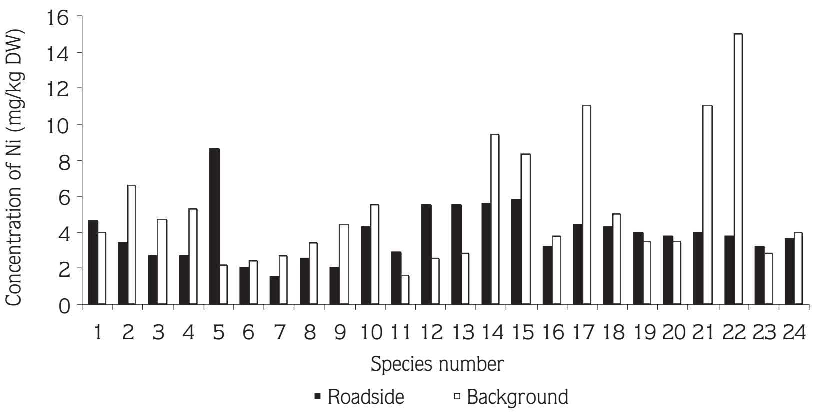

Figure 8. Comparison of mean concentrations of Ni (mg/kg dry weight) in 24 species of mushrooms from roadside and background areas.

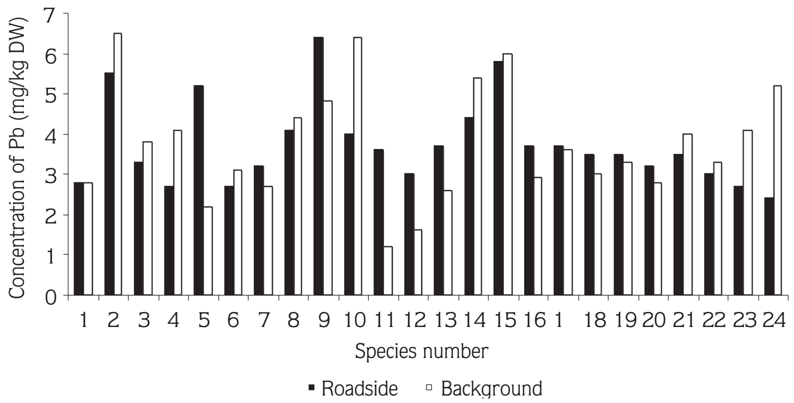

Figure 9. Comparison of mean concentrations of Pb (mg/kg dry weight) in 24 species of mushrooms from roadside and background areas.

Marasmius oreades and *Lacccaria laccata* are saprophite edible mushrooms. They live in grassy forests, on forest paths, in gardens and in parks. The lead content of saprophite mushrooms were higher than those of mycorrhizal species. The fruit bodies of mushrooms accumulate remarkably high concentrations of lead, especially in the vicinity of highways or other lead sources. Our results agree with the data of other authors (Laaksovirta & Alakuijaka, 1978; Mornand, 1990; Jorhem & Sundström, 1995). Mushrooms can be used as bioindicators for lead soil pollution (Lodenius et al., 1981; Quinche, 1987).

Other studies indicate that several species of *Lycoperdaceae* have a capacity for the bioaccumulation of Pb. In this study, the Pb content of *Lycoperdon perlatum* agree with other authors (Tyler, 1980; Jorhem & Sundström, 1995).

The highest Pb concentrations in studies by Sesli & Tüzen (1999) and Tüzen et al. (1998) were found in collected roadside mushrooms belonging to the family *Tricholomataceae*. Our study agreed with other studies (Sesli & Tüzen, 1998; Tüzen et al., 1998).

In relation to the pollution source near main roads, Jorhem & Sundström (1995) concluded that lead was derived mainly from the contaminated roadside soil rather than from atmospheric deposition. The exposure time for many mushrooms is very short, which makes the deposition of Pb from vehicle exhausts a small problem that is continuing to decrease as the use of leaded petrol is phased out (Jorhem & Sundström, 1995).

The occurrence and distribution of different toxic components in certain mushrooms is not only a mycological theoretical problem, but also has practical environmental and toxicological aspects (Vetter, 1994). According to FAO/WHO (1989, 1993) acceptable weekly intakes of cadmium and lead for adults are 0.42-0.49 and 1.5-1.75 mg, respectively. The Pb and Cd levels in all studied species from both areas can be considered to be high and mushrooms from these sites should not be consumed.

In this study, the metal contents of macrofungi collected from two different areas were determined to be statistically different. Element content differed according to edibility, habitat and collection areas but no relationship was observed among those factors. In this study element concentrations were primarily species-dependent. It was, therefore, rather difficult to determine the effect of environmental factors on the concentrations of elements. Similar studies which include the analysis of various elements on a group of macrofungi species should be performed in order to explain the effect of environmental factors.

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