TÜBİTAK

Research Article

Turk J Bot
36 (2012) 519-528
© TÜBİTAK
doi:10.3906/bot-1103-14

Trace metal contents of some wild-growing mushrooms in Bigadiç (Balıkesir), Turkey

İsmail ŞEN[1], Hakan ALLI[1,*], Bekir ÇÖL[1], Mustafa ÇELİKKOLLU[2], Ahmet BALCI[3]

[1]Biology Department, Science Faculty, Muğla University, 48170 Muğla - TURKEY

[2]Zihni Derin Laboratory, Office of Provincial Agriculture, 48000 Muğla - TURKEY

[3]Chemistry Department, Science Faculty, Muğla University, 48170 Muğla - TURKEY

Received: 23.03.2011 ● Accepted: 27.03.2012

Abstract: In this study, heavy metal (Cd, Cr, Cu, Mn, and Zn) contents of wild-growing mushrooms and soil samples collected from Bigadiç (Balıkesir) were determined. A total of 38 fungal taxa were found in the study area. Among the mushroom samples analysed, minimum and maximum metal contents were 0.11-2.58 mg kg^{-1} for Cd, 1.01-19.55 mg kg^{-1} for Cr, 2.61-72.44 mg kg^{-1} for Cu, 1.38-47.52 mg kg^{-1} for Mn, and 5.75-97.55 mg kg^{-1} for Zn. For all elements, values are within the acceptable levels as reported by several researchers. *Hohenbuehelia petaloides* (Bull.) Schulzer had the lowest elemental composition for all elements. Metal contents of the soil samples were also within acceptable levels. Therefore, the study area does not have heavy metal contamination. Nevertheless, the Cd, Cu, and Zn contents detected in the majority of mushroom samples were relatively higher than the contents in soil samples collected from beneath them.

Key words: Heavy metal, mushroom, Balıkesir, Turkey

Introduction

For a considerable length of time, trace element contents of wild-growing mushrooms have been investigated in numerous studies (Demirbaş, 2001; Yılmaz et al., 2003; Isildak et al., 2004; Turkekul et al., 2004; Yamaç et al., 2007; Chen et al., 2009; Gençcelep et al., 2009; Kaya & Bag, 2010; Radulescu et al., 2010; Şen et al., 2012). It is known that mushrooms can accumulate some metals, such as cadmium, mercury, and lead (Kalač & Svoboda, 2000). Although factors governing the accumulation of heavy metals in mushrooms are not well known, environmental factors (metal concentrations in soils, pH, and contamination by atmospheric deposition) and fungal factors (fungal structure, morphological portion, development of mycelium and fruit bodies, biochemical composition, and decomposition activity) may play important roles in the ability of mushrooms to accumulate metals (Kalač & Svoboda, 2000; Işiloğlu et al., 2001). In particular, the mushrooms collected near highways, metal smelters, or mining areas have relatively higher levels of some elements. Işiloğlu et al. (2001) showed that traffic pollution has an important effect on the Pb contents of some mushrooms. Similar results have been found in several other studies (García et al., 1998; Kalač et al., 2004; Carvalho et al., 2005; Chen et al., 2009). In

* E-mail: hakanalli@gmail.com

addition, Nikkarinen and Mertanen (2004) reported that natural geochemistry has a significant influence on the trace element contents of wild-growing mushrooms.

Turkey has great mushroom-producing potential due to climate conditions (Solak et al., 2007; Allı, 2011; Allı et al., 2011; Doğan et al., 2012). In light of the literature cited above, the aim of this study was to determine the heavy metal contents of wild-growing mushrooms collected from Bigadiç in the province of Balıkesir (Figure 1) and to compare the heavy metal contents of the mushrooms with soil samples taken from beneath the sampled mushrooms.

Material and methods

Collection and preparation of samples

Mushroom samples were collected in the autumn of 2009 in Balıkesir, and soil samples were taken from depths of 0-30 cm beneath randomly selected mushroom samples.

The habitat and morphological characteristics of the mushrooms were recorded and photographed, and mushroom samples were brought to the laboratory. Samples were identified by examining their macroscopic and microscopic features, using the references of Phillips (1981), Moser (1983), Breitenbach and Kränzlin (1984-2000), Hansen and Knudsen (2000), and Knudsen and Vesterholt (2008).

Mushroom samples were air-dried in laboratory conditions and cleaned with deionised water. Dried and washed samples were homogenised and stored in polyethylene bottles until analysis.

Soil samples were air-dried in the laboratory and sieved with a 2-mm sieve (Kacar, 1998). The pH and conductivity of the soil (1:2, soil:soil mixture) were measured as described by Radojevic and Bashkin (1999), and organic matter content was determined using burning methods (Kacar, 1998).

Chemical analysis of samples

Both mushroom and soil samples were analysed using the method of Radojevic and Bashkin (1999). Aqua regia (15 mL) was added to 0.25 g of homogenised samples, and the samples were kept overnight. The next day, samples were incubated at 50 °C for 30 min, and the temperature was raised to 120 °C for an incubation of 2 h. After heating, samples were cooled to room temperature, 10 mL of 0.25 M HNO_3 was added, and then the mixture was filtered with Whatman No. 541. Filtrate was brought to a volume of 25 mL with 0.25 M HNO_3 (Radojevic & Bashkin, 1999).

Cd, Cr, Cu, Mn, and Zn were analysed with a PerkinElmer Optima 2000 ICP-OES with the appropriate standards, and calibration was carried out as described by the manufacturer. All experiments were done in triplicate.

Results and discussion

Heavy metal contents of mushroom samples

The habitat, edibility of mushroom species, and heavy metal contents are given in Table 1 and Table 2, respectively.

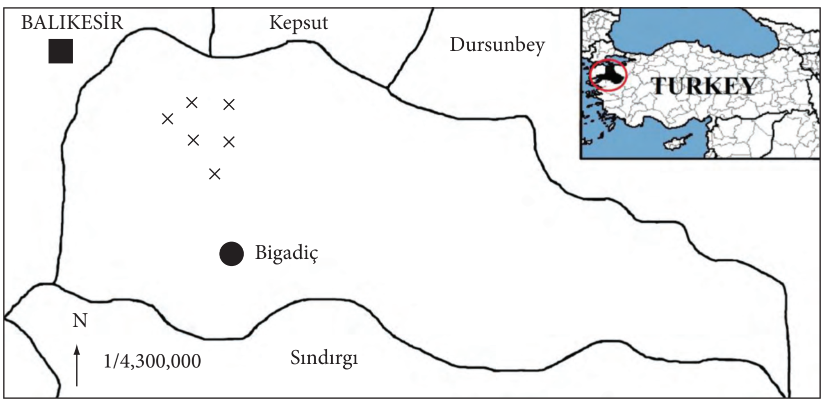

Figure 1. Map of the study area. Sampling sites indicated with x.

Table 1. The habitat and edibility of mushroom species.

Taxa	**Habitat**	**Edibility**
Agaricus aestivalis var. *veneris* (R.Heim & G.Becker) Wasser	In coniferous or mixed forests	Edible
Agaricus altipes (F.H.Møller) F.H.Møller	In coniferous or mixed forests	Edible
Amanita ovoidea (Bull.) Link	In or near mixed woodland, on calcareous soils	Edible
Chroogomphus rutilus (Schaeff.) O.K.Mill.	With conifers, usually *Pinus sylvestris* or other 2-needle pines	Edible
Clavulina cinerea (Bull.) J. Schröt.	On the ground in woods	Edible
Clitocybe costata Kühner & Romagn.	In coniferous forests	Not edible
Cystodermella cinnabarina (Alb. & Schwein.) Harmaja	On soil or among mosses and grasses	Not edible
Flavoscypha cantharella (Fr.) Harmaja	In broadleaved forests, under *Fagus* (beech), on mossy ground	Unknown
Geastrum fimbriatum Fr.	On rich humus under deciduous trees	Not edible
Geopora arenosa (Fuckel) S.Ahmad	On damp sandy ground, also around burned places	Unknown
Gloeophyllum trabeum (Pers.) Murrill	On dead, barkless wood of broadleaved trees and conifers	Not edible
Hohenbuehelia petaloides (Bull.) Schulzer	On stumps or decaying wood of deciduous trees	Edible
Hygrophorus discoxanthus Rea	In spruce forests on calcareous soils	Edible
Inocybe ayeri Furrer-Ziogas	In coniferous forests, on the remains of wood, and in acidic soil	Poisonous
Inocybe corydalina Quél.	In hardwood and coniferous forests, on calcareous soil	Poisonous
Inocybe geophylla (Fr.) P.Kumm.	On path sides in deciduous, mixed, and coniferous woods	Poisonous
Lactarius sp.	In coniferous forests	Edible
Lepiota cristata (Bolton) P.Kumm.	In woods, garden refuse, or leaf litter	Poisonous
Lepista nuda (Bull.) Cooke	In woodlands, hedgerows, and gardens	Edible
Leucocoprinus lanzonii Bon, Migl. & Brunori	In hot houses or tropical houses in peaty soils	Not edible
Lycoperdon lividum Pers.	On heaths, pastures, dunes, and waste ground in sandy soil	Unknown
Lycoperdon perlatum Pers.	In woodlands	Edible
Melanoleuca paedida (Fr.) Kühner & Maire	Along forest edges, in forest meadows, on bare soil	Edible
Melanoleuca stridula (Fr.) Singer	Along grassy path sides	Edible
Mycena amicta (Fr.) Quél.	In conifer forests or mixed conifer-hardwood forests, on dead wood	Unknown
Mycena galopus var. *candida* J.E.Lange	Among leaf litter in woods, hedgerows, and on path sides	Unknown
Mycena pura (Pers.) P. Kumm.	In beech litter	Poisonous
Mycena strobilicola J. Favre & Kühner	On spruce cones embedded or buried in the ground	Not edible
Mycetinis alliaceus (Jacq.) Earle ex A.W. Wilson & Desjardin	On leaf litter, buried twigs, and other debris, usually beech; especially on chalk	Not edible
Myxomphalia maura (Fr.) Hora	On burnt ground in conifer woods	Not edible
Phellinus torulosus (Pers.) Bourdot & Galzin	Parasitic on conifer and dead trees	Not edible
Pisolithus arhizus (Scop.) Rauschert	In sandy or well-drained gravelly soil in fields or on roadsides	Not edible
Russula cyanoxantha (Schaeff.) Fr.	In broad-leaved trees	Edible
Stereum hirsutum (Willd.) Pers.	On stumps, logs, and fallen branches of deciduous trees	Not edible
Suillus collinitus (Fr.) Kuntze	In coniferous woodland	Edible
Tapinella panuoides (Batsch) E.-J.Gilbert	On conifer debris; causes infected wood to become soft and discolour bright yellow	Not edible
Tricholoma fracticum (Britzelm.) Kreisel	In coniferous forests, primarily under *Pinus sylvestris*, in calcareous soils	Not edible
Tricholoma terreum (Schaeff.) P.Kumm.	In woods, especially in conifers	Edible

Table 2. Heavy metal contents of mushroom samples (mg kg^{-1}, dry weight).

Taxa	Cd	Cr	Cu	Mn	Zn
Agaricus aestivalis var. *veneris*	0.54	6.88	72.44	28.11	84.47
Agaricus altipes	0.37	15.53	57.78	27.93	50.19
Amanita ovoidea	0.26	4.59	5.00	9.23	29.78
Chroogomphus rutilus	0.48	5.71	8.20	10.81	22.83
Clavulina cinerea	0.18	9.26	8.13	5.21	37.03
Clitocybe costata	0.62	2.88	32.09	14.35	24.70
Cystodermella cinnabarina	1.41	7.21	12.69	14.63	20.32
Flavoscypha cantharella	0.25	6.75	17.55	6.70	---
Geastrum fimbriatum	0.56	3.02	43.17	---	47.27
Geopora arenosa	0.77	12.98	29.27	---	84.32
Gloeophyllum trabeum	0.36	4.00	8.68	10.88	20.00
Hohenbuehelia petaloides	0.11	1.01	2.61	1.38	5.75
Hygrophorus discoxanthus	1.84	7.66	56.28	7.10	49.87
Inocybe ayeri	0.69	17.13	6.91	21.47	44.28
Inocybe corydalina	2.02	6.06	7.93	8.63	80.19
Inocybe geophylla	1.54	6.44	16.47	3.57	63.96
Lactarius sp.	0.18	3.63	3.37	1.68	13.99
Lepiota cristata	0.66	5.98	41.67	5.92	45.58
Lepista nuda	1.15	6.29	67.42	13.87	76.07
Leucocoprinus lanzonii	2.58	10.11	60.16	11.93	44.09
Lycoperdon lividum	1.74	6.13	71.08	18.58	---
Lycoperdon perlatum	0.72	3.47	61.78	6.81	97.06
Melanoleuca paedida	1.21	3.76	61.37	45.21	54.61
Melanoleuca stridula	0.60	3.92	37.97	17.51	35.73
Mycena amicta	1.10	---	29.09	31.00	67.30
Mycena galopus var. *candida*	1.65	---	19.76	14.62	97.55
Mycena pura	2.01	6.11	71.82	18.30	54.90
Mycena strobilicola	0.34	12.81	11.35	12.31	49.57
Mycetinis alliaceus	0.55	3.65	29.59	47.52	55.42
Myxomphalia maura	1.35	6.64	11.10	31.53	34.67
Phellinus torulosus	0.22	8.16	19.52	10.29	7.84
Pisolithus arhizus	0.12	2.44	12.20	6.86	9.68
Russula cyanoxantha	0.27	15.65	17.76	9.17	49.65
Stereum hirsutum	0.18	8.18	8.33	20.42	17.97
Suillus collinitus	0.21	9.46	7.64	8.53	34.02
Tapinella panuoides	0.25	3.62	7.67	2.54	15.78
Tricholoma fracticum	1.39	19.55	3.54	17.14	19.84
Tricholoma terreum	1.47	7.07	28.90	43.15	68.07

---: Not determined.

The levels of Cd in samples ranged from 0.11 to 2.58 mg kg^{-1}, and the highest Cd levels were detected in *Leucocoprinus lanzonii*. In the literature, Cd contents of wild-growing mushrooms collected from different parts of Turkey were reported to be within the range of 0.10-3.48 mg kg^{-1}. Cd contents of the mushrooms in Balıkesir are in agreement with these published values (Demirbaş, 2001; Isildak et al., 2004; Doğan et al., 2006; Yamaç et al., 2007; Yagiz et al., 2008).

Cr concentrations ranged from 1.01 to 19.55 mg kg^{-1}, and *Hohenbuehelia petaloides* and *Tricholoma fracticum* had the minimum and maximum Cr concentrations, respectively. Cr contents of mushroom samples collected from the Black Sea region in Turkey were reported to range from 1.1 to 9 mg kg^{-1} (Mendil et al., 2004; Yagiz et al., 2008); however, Cr was found in the range of 3.05-84.5 mg kg^{-1} in samples collected from Konya, Turkey (Doğan et al., 2006). Therefore, the Cr contents of mushrooms seem to differ with respect to sampling areas. Similarly, Cr contents of wild-growing mushrooms were reported to be 1.3-24.3 mg kg^{-1} by Isildak et al. (2004). The findings reported in this study are in agreement with previously reported values.

Cu levels ranged from 2.61 to 72.44 mg kg^{-1}, and the highest Cu levels were seen in *Agaricus aestivalis* var. *veneris*. Cu levels in mushrooms were generally reported to be 100-300 mg kg^{-1} in Europe, which is not considered a health risk (Kalač & Svoboda, 2000). Based on these results, the Cu levels in mushrooms reported in this study were within acceptable levels.

The minimum and maximum concentrations of Mn were 1.38 mg kg^{-1} in *Hohenbuehelia petaloides* and 47.52 mg kg^{-1} in *Mycetinis alliaceus*, respectively. In the literature, Mn levels in some mushroom species were reported to range from 3 to 81.3 mg kg^{-1}; however, the majority of these values were lower than 30 mg kg^{-1} (Demirbaş, 2001; Isildak et al., 2004). Kalač & Svoboda (2000) reviewed the usual trace element composition of mushroom species and reported that Mn levels ranged from 5 to 60 mg kg^{-1}, and *Agaricus* spp. can be considered as accumulators of Mn. In this study, Mn levels in *Agaricus altipes* and *Agaricus aestivalis* var. *veneris* were 27.93 and 28.11 mg kg^{-1}, respectively.

Hohenbuehelia petaloides and *Mycena galopus* var. *candida* had the minimum and maximum Zn concentrations at 5.75 and 97.55 mg kg^{-1}, respectively. The Zn contents of some mushrooms in Turkey were reported to range from 32 to 162 mg kg^{-1} (Mendil et al., 2004; Yagiz et al., 2008). The current results are in agreement with values reported in the literature; however, Zn concentrations in *Lycoperdon perlatum* (97.06 mg kg^{-1}) and *Tricholoma terreum* (68.07 mg kg^{-1}) were higher than the values reported by several researchers (Demirbaş, 2001; Gençcelep et al., 2009). Similarly, Zn contents of mushrooms collected from Europe were reported to range from 30 to 150 mg kg^{-1} (Kalač & Svoboda, 2000), and it was emphasized that *Lycoperdon perlatum* may be considered an accumulator of Zn. In addition, the Zn content of *Lycoperdon perlatum* collected from the vicinity of metal smelters in Romania was 127-136 mg kg^{-1} (Radulescu et al., 2010), and these values were higher than the values reported in this study.

For all elements, *Hohenbuehelia petaloides* has the lowest elemental composition. There is no information about the elemental composition of *Hohenbuehelia petaloides* in the literature. This species grows on stumps or decaying woods of deciduous trees, which may explain this outcome.

In Table 1, it is shown that 27 of the mushroom taxa grow on the ground; the others grow on wood, litter, in pastures, or on tree cones. As expected, the mushrooms growing on wood and stumps (*G. trabeum*, *H. petaloides*, *M. amicta*, *P. torulosus*, *S. hirsutum*, and *T. panuoides*) have relatively lower elemental compositions (Table 2). In addition, mushroom samples found on the leaf litter or litter (*M. galopus* var. *candida*, *M. strobilicola*, and *M. alliaceus*) have relatively higher metal contents than the other samples; however, the highest Mn and Zn contents were found in *Mycetinis alliaceus* (47.52 mg kg^{-1}) and *Mycena galopus* var. *candida* (97.55 mg kg^{-1}), respectively. All of these findings suggest that substrates have an important impact on the elemental composition of mushrooms.

The background levels of some trace element contents in the European species of wild-growing mushrooms were reviewed by Kalač (2010) for the period of 2000-2009. According to Kalač (2010), the values (mg kg^{-1}, dry weight) obtained for most of the species grown in unpolluted sites were 1-5 for Cd, 20-100 for Cu, 0.5-5 for Cr, 10-60 for Mn, and 25-200 for Zn. The metal contents of mushrooms collected from Balıkesir are in an agreement with the results indicated by Kalač (2010).

Knowledge of the heavy metal contents of wild-growing mushrooms is important for public health due the fact that some mushrooms are widely consumed for food in many countries. The proposed maximum levels of Cd and Cu set by the Food and Agricultural Organization and the World Health Organization (FAO/WHO) are 0.5 and 2 mg kg^{-1} (1987), respectively. In the current study area, 15 taxa were identified as edible (Table 1), and the Cd and Cu contents of these species were 0.11-1.84 and 2.61-72.44 mg kg^{-1}, respectively (Table 2). Therefore, Cd and Cu contents in the edible mushrooms were higher than the acceptable values set by the FAO/WHO (1987). Nevertheless, in the specific study area, the authors see no immediate toxicological risk, because the local community consumes only *Lactarius* sp.

Heavy metal contents of the soil samples and comparison of heavy metal contents of mushrooms and soil samples

Nine soil samples were collected in this study from beneath randomly selected mushroom samples. Some properties of the soil samples (pH, electric conductivity (EC), and organic matter (OM)) are given in Table 3, and comparison of heavy metal contents of soil and mushroom samples are given in Figures 2-6.

Table 3. Some properties of the soil samples.

Soil samples	pH	EC	OM
Soil 1	7.88	217.00	15.46
Soil 2	8.02	166.40	19.71
Soil 3	8.14	146.30	9.28
Soil 4	8.08	173.20	12.81
Soil 5	8.14	232.00	9.51
Soil 6	6.98	283.00	19.34
Soil 7	8.24	137.40	8.43
Soil 8	7.78	213.00	27.23
Soil 9	7.49	403.00	41.56

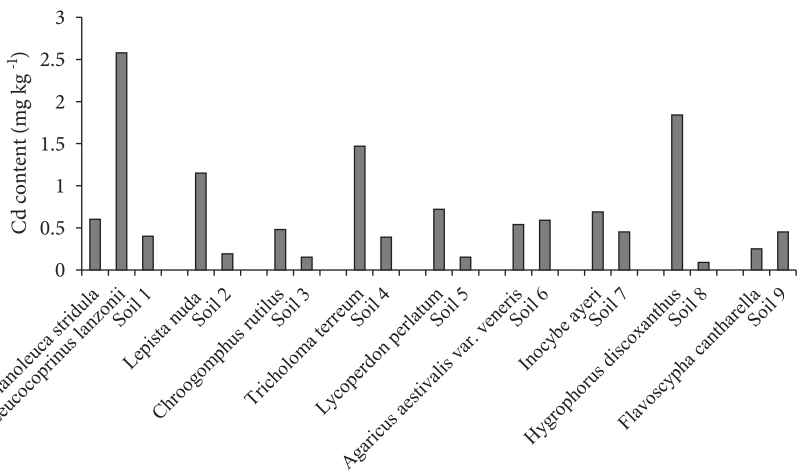

Figure 2. Cd contents of mushroom and soil samples.

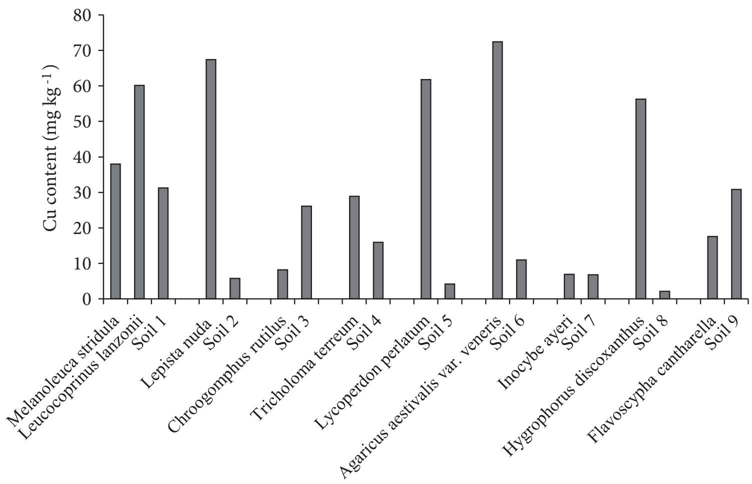

Figure 3. Cu contents of mushroom and soil samples.

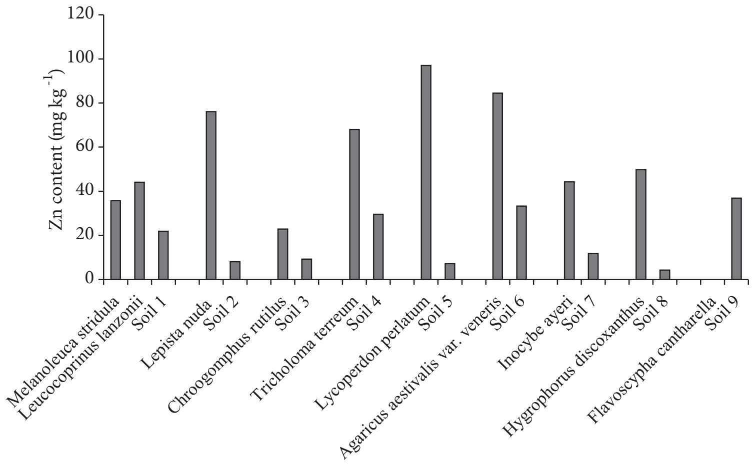

Figure 4. Zn contents of mushroom and soil samples.

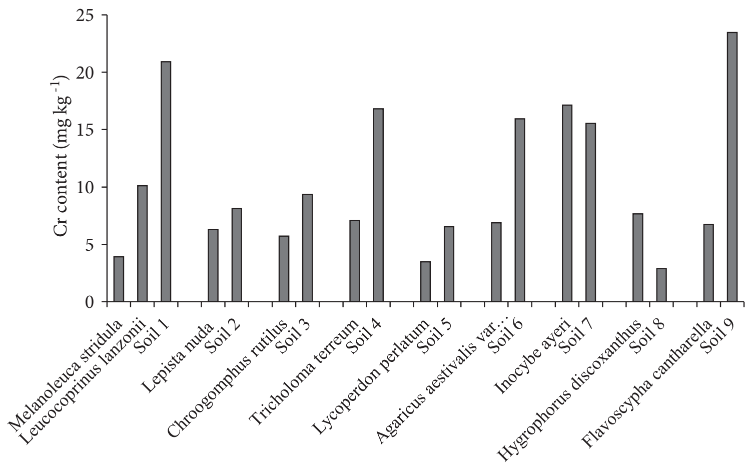

Figure 5. Cr contents of mushroom and soil samples.

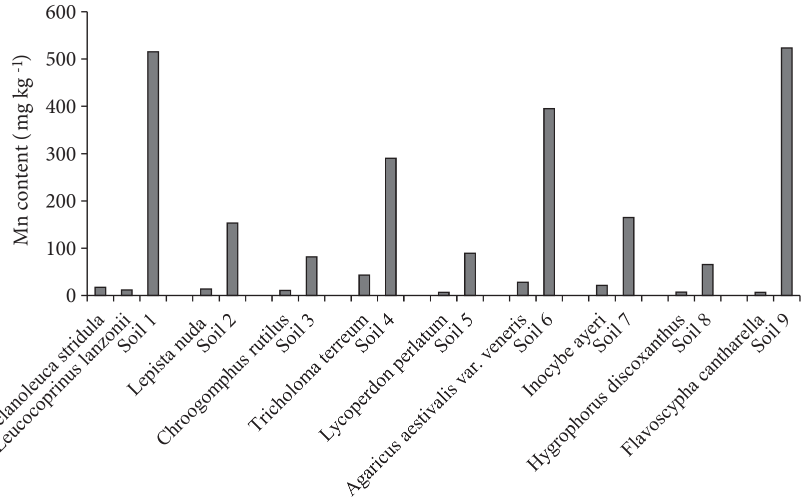

Figure 6. Mn contents of mushroom and soil samples.

Soil pH ranged from 6.98 to 8.26, and EC ranged from 137.40 to 403 µS cm^{-1}. OM content varied from 8.43% to 41.51%. Most soil samples were slightly alkaline, and there was no salinity problem.

Heavy metal contents of soil samples collected from agricultural areas in the United States ranged from 0.01 to 2 mg kg^{-1} for Cd, 0.3 to 495 mg kg^{-1} for Cu, and 1.5 to 264 mg kg^{-1} for Zn (Holmgren et al., 1993). Similarly, Kabata-Pendias (2001) reported that background levels of heavy metal contents in soil samples worldwide were 13-24 mg kg^{-1} for Cu, 270-525 mg kg^{-1} for Mn, and 17-125 mg kg^{-1} for Zn. The acceptable values of Cr in Europe were reported to range from 50 to 150 mg kg^{-1} (Lucho-Constantino et al., 2005). The heavy metal contents of soil samples collected from the study area in Balıkesir are in agreement with these values. Although the Mn contents of soil samples collected from Balıkesir were higher than the levels reported in the literature, Mn is not considered a pollutant in soils, and the maximum acceptable concentration of Mn is about 1500 mg kg^{-1} (Kabata-Pendias, 2001). Therefore, it was concluded that there was no pollution in the soil samples.

Cd, Cu, and Zn contents in the majority of mushroom samples were higher than those in the soils collected from beneath the samples (Figures 2-4). Cr concentrations in *Inocybe ayeri* and *Hygrophorus discoxanthus* were similar to the Cd, Cu, and Zn contents of the mushroom and soil samples (Figure 5). Mn contents in all soil samples were higher than the contents in mushroom samples (Figure 6).

These findings show that metal contents of the mushroom species can be higher than those of the soil samples collected from beneath them. Similar results were reported by Nikkarinen and Mertanen (2004), and these authors emphasised that the correlations between mushrooms and soil samples were dependent upon the element involved. Jongmans et al. (1997) reported that fungal hyphae were found in the pores of mineral grains in the soil horizon of coniferous forests. Additionally, studies have shown that some of the fungal taxa were distributed in the deeper soil layers (Rosling et al., 2003; Tedersoo et al., 2003). In other words, mushrooms may take up the elements directly from the pores of mineral layers in soils (Nikkarinen & Mertanen, 2004). Studies should continue to address the uptake mechanisms of mushrooms because mushrooms are useful tools for distinguishing between polluted and unpolluted areas (Kalač & Svoboda, 2000). The findings of this study and others will be helpful in providing the wealth of information required to help reach this goal.

Acknowledgments

We would like to thank the Muğla University Scientific Research Project (BAP 09/27). Previous knowledge and experience regarding the sampling sites were obtained through a TÜBİTAK project (107T796).

References

Allı H (2011). Macrofungi of Kemaliye district (Erzurum). *Turkish Journal of Botany* 35: 299-308.

Allı H, Işıloğlu M & Solak MH (2011). New Ascomycete records for the macrofungi of Turkey. *Turkish Journal of Botany* 35: 315-318.

Breitenbach J & Kränzlin F (1984-2000). *Fungi of Switzerland*. Vols. 1-5. Lucerne: Verlag Mykologia.

Carvalho ML, Pimentel AC & Fernandes B (2005). Study of heavy metals in wild edible mushrooms under different pollution conditions by X-ray fluorescence spectrometry. *Analytical Sciences* 21: 747-750.

Chen XH, Zhou HB & Qiu GZ (2009). Analysis of several heavy metals in wild edible mushrooms from region of China. *Bulletin of Environmental Contamination and Toxicology* 83: 280-285.

Demirbaş A (2001). Concentrations of 21 metals in 18 species of mushrooms growing in the East Black Sea region. *Food Chemistry* 75: 453-457.

Doğan HH, Aktaş S, Öztürk C & Kaşık G (2012). Macrofungi distribution of Cocakdere valley (Arslanköy, Mersin). *Turkish Journal of Botany* 36: 83-94.

Doğan HH, Şanda MA, Uyanöz R, Öztürk C & Çetin Ü (2006). Contents of metals in some wild mushrooms: its impact in human health. *Biological Trace Element Research* 110: 79-94.

FAO/WHO (1987). *Codex Committee on Food Additives: Report of the Seventeenth Session of the Joint FAO/WHO*. Rome: Codex Alimentarius.

García MA, Alonso J, Fernandez MI & Melgar MJ (1998). Lead content in edible wild mushrooms in Northwest Spain as indicator of environmental contamination. *Archives of Environmental Contamination and Toxicology* 34: 330-335.

Gençcelep H, Uzun Y, Tunçtürk Y & Demirel K (2009). Determination of mineral contents of wild-grown edible mushrooms. *Food Chemistry* 113: 1033-1036.

Hansen L & Knudsen H (2000). *Nordic Macromycetes*. Vol. 1: *Ascomycetes*. Copenhagen: Nordsvamp.

Holmgren GGS, Meyer MW, Cahney RL & Daniels RB (1993). Cadmium, lead, zinc, copper and nickel in agricultural soils of the United States of America. *Journal of Environmental Quality* 22: 335-348.

Isildak Ö, Turkekul I, Elmastas M & Tuzen M (2004). Analysis of heavy metals in some wild-grown edible mushrooms from the middle black sea region, Turkey. *Food Chemistry* 86: 547-552.

Işiloğlu M, Merdivan M & Yilmaz F (2001). Heavy metal contents in some macrofungi collected in the northwestern part of Turkey. *Archives of Environmental Contamination and Toxicology* 41: 1-7.

Jongmans AG, van Breemen N, Lundström U, van Hees PAW, Finlay RD, Srinivasan M, Unestam T, Giesler R, Melkerud PA & Olsson M (1997). Rock-eating fungi. *Nature* 389: 682-683.

Kabata-Pendias A (2001). *Trace Elements in Soils and Plants*, 3rd edn. Boca Raton, Florida: CRC Press.

Kacar B (1998). *Bitki ve Toprağın Kimyasal Analizleri: III, Toprak Analizleri*. Ankara: A.Ü. Ziraat Fakültesi Eğitim, Araştırma ve Geliştirme Vakfı Yayınları.

Kalač P (2010). Trace element contents in European species of wild growing edible mushrooms: a review for the period 2000-2009. *Food Chemistry* 122: 2-15.

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

Kalač P, Svoboda L & Havlickova B (2004). Contents of detrimental metals mercury, cadmium and lead in wild growing edible mushrooms: a review. *Energy Education Science and Technology* 13: 31-38.

Kaya A & Bag H (2010). Trace element contents of edible macrofungi growing in Adiyaman, Turkey. *Asian Journal of Chemistry* 22: 1515-1521.

Knudsen H & Vesterholt J (2008). *Funga Nordica, Agaricoid, Boletoid and Cyphelloid Genera*. Copenhagen: Nordsvamp.

Lucho-Constantino CA, Prieto-Garcia F, Del Razo LM, Rodriguez-Vazquez R & Poggi-Varaldo HM (2005). Chemical fractionation of boron and heavy metals in soils irrigated with wastewater in Central Mexico. *Agriculture Ecosystems & Environment* 108: 57-71.

Mendil D, Uluözlü OD, Tüzen M, Hasdemir E & Sarı H (2004). Trace metals levels in mushroom samples from Ordu, Turkey. *Food Chemistry* 91: 463-467.

Moser M (1983). *Keys to Agarics and Boleti*. London: Gustav Fischer Verlag.

Nikkarinen M & Mertanen E (2004). Impact of geological origin on trace element composition of edible mushrooms. *Journal of Food Composition and Analysis* 17: 301-310.

Phillips R (1981). *Mushrooms and Other Fungi of Great Britain and Europe*. London: Pan Books Ltd.

Radulescu C, Stihi C, Busuioc G, Gheboianu AI & Popescu IV (2010). Studies concerning heavy metals bioaccumulation of wild edible mushrooms from industrial area by using spectrometric techniques. *Bulletin of Environmental Contamination and Toxicology* 84: 641-646.

Radojevic M & Bashkin VN (1999). *Practical Environmental Analysis*. Cornwall: Royal Society of Chemistry, MPG Books Ltd.

Rosling A, Landeweert R, Lindahl BD, Larsson KH, Kuyper TW, Taylor AFS & Finlay RD (2003). Vertical distribution of ectomycorrhizal fungal taxa in a podzol soil profile. *New Phytologist* 159: 775-783.

Solak MH, Işıloğlu M, Kalmış E & Allı H (2007). *Macrofungi of Turkey, Checklist*. Vol. 1. İzmir: Genç Üniversiteliler Ofset (in Turkish).

Şen İ, Alli H & Çöl B (2012). Boron contents of some wild-growing mushrooms collected from the vicinity of boron mines in Balikesir, Turkey. *Biological Trace Element Research* 145: 233-239.

Tedersoo L, Koljalg U, Hallenberg N & Larsson KH (2003). Fine scale distribution of ectomycorrhizal fungi and roots across substrate layers including coarse woody debris in a mixed forest. *New Phytologist* 159: 153-165.

Turkekul I, Elmastas M & Tüzen M (2004). Determination of iron, copper, manganese, zinc, lead, and cadmium in mushroom samples from Tokat, Turkey. *Food Chemistry* 84: 389-392.

Yagiz D, Konuk M, Afyon A & Kök SM (2008). Minor element and heavy metal content of edible wild mushrooms native to Bolu, North-West Turkey. *Fresenius Environmental Bulletin* 17: 249-252.

Yamaç M, Yıldız D, Sarıkürkcü C, Çelikkollu M & Solak MH (2007). Heavy metals in some edible mushrooms from the Central Anatolia, Turkey. *Food Chemistry* 103: 263-267.

Yılmaz F, Işıloğlu M & Merdivan M (2003). Heavy metal levels in some macrofungi. *Turkish Journal of Botany* 27: 45-56.