Kastamonu Uni., Orman Fakültesi Dergisi, 2020, 20(2): 143-157 Research Article
Kastamonu Univ., Journal of Forestry Faculty
Doi:10.17475/kastorman.801835

An Investigation of Heavy Metal Accumulation in Macrofungi Around the Seydisehir District

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Received Date: 31.12.2019 Accepted Date: 19.07.2020

Abstract

Aim of study: In this study, heavy metal accumulation, around aluminum plants in the Seydişehir district and in the areas close to them were investigated.

Area of study: Macrofungi samples were collected in the field studies carried out between 2015-2017 in the forest areas in Konya province Seydişehir district and its surrounding. In the study areas, twenty-two different species were identified in seven different localities.

Material and methods: Macrofungi grown in the area were identified and heavy metals were analyzed by the ICP-MS in the macrofungi.

Main results: According to the obtained data, the amounts of Fe and Al in Seydişehir soils were found to be excessive compared to the other heavy metals examined. According to the obtained data, the fungi species with the highest content of heavy metals detected was *Pleurotus eryngii,* (DC.) Quél. collected from Upper site of Toki, and the smallest content of heavy metals in total were found in *Suillus collinitus* (Fr.) Kuntze collected from the Madenli 2 locality, *Gymnopus dryophilus* (Bull.) Murrill collected from the Kuğulu Park locality, and *Russula queletii* collected from the Pond locality.

Research highlights: Caution should be exercised in the consumption of macrofungi grown in soil rich in heavy metals. Excessive consumption can have a negative effect on human health.

Keywords: Macrofungi, Heavy Metals, Pollution, Seydişehir, Konya, Turkey

Seydişehir İlçesinin (Konya-Türkiye) Çevresindeki Makromantarlarda Ağır Metal Birikimlerinin Araştırılması

Öz

Çalışmanın amacı: Bu çalışmada Seydişehir ilçesinde bulunan Alüminyum tesislerin çevresinde ve ilçeye yakın alanlarda yetişen özellikle yenen makromantarlardaki ağır metal birikimleri araştırılmıştır.

Çalışma alanı: Konya İli Seydişehir İlçesi ve çevresindeki ormanlık alanlarda 2015-2017 yılları arasında yapılan arazi çalışmalarında makromantar örnekleri toplanmıştır. Arazi çalışmalarında 7 farklı lokaliteden 22 farklı tür tespit edilmiştir.

Materyal ve yöntem: Yörede yetişen makromantarlar tespit edilmiş ve elde edilenler makromantarlarda ICP-MS ile ağır metal analizleri yapılmıştır.

Temel sonuçlar: Elde edilen verilere göre Seydişehir topraklarında Fe ve Al miktarları incelenen diğer ağır metallere göre çok fazla miktarda bulunmuştur. Elde edilen verilere göre toplamda ağır metal içeriği en fazla olan mantar türü Toki Üzerinden toplanan *Pleurotus eryngii,* (DC.) Quél.'de, toplamda en az ağır metal içeriği ise Madenli 2 lokalitesinden toplanan *Suillus collinitus* (Fr.) Kuntze, Kuğulu Park lokalitesinden toplanan *Gymnopus dryophilus* (Bull.) Murrill ve Gölet lokalitesinden toplanan *Russula queletii* türlerinde tespit edilmiştir.

Araştırma vurguları: Ağır metaller açısından zengin topraklarda yetişen makromantarların besin olarak tüketilmesine dikkat edilmelidir. Aşırı tüketim insan sağlığı açısından sakıncalı durumlar oluşturabilir.

Anahtar kelimeler: Makrofunguslar, Ağır metal, Kirlilik, Seydişehir, Konya, Türkiye

Introduction

The vegetative structures of the macrofungi are generally made of cylindrical, tubular cells. The fungi cell is composed of micelle and hyphae. Micelles come together and make up mycelium tissues. The main structure of the wall is chitin in macrofungi. In addition,

Citation (Atıf): Alkan, S., Kasik, G. & Ozturk, C. (2020). An Investigation of Heavy Metal Accumulation in Macrofungi Around the Seydisehir District . *Kastamonu University Journal of Forestry Faculty*, 20 (2), 143-157.

different polysaccharides are involved in the cell structure (Campbell & Reece, 2008; Kaşık, 2010). Depending on the main wall materials and the species and hyphae structure, lignin, callose, and some organic materials can be added (Campbell & Reece, 2008).

Both of fungi groups that are harvested from nature and that are cultivated are important for nutrition and commercial uses. However, research during the past three decades on nutritive aspects of wild macrofungi has exposed their negative facet too (Lalotra et al., 2016). Macrofungi are classified as edible, inedible, and poisonous fungi when evaluated in terms of human nutrition. Since Turkey's fungi species is very wide variety, edible and poisonous mushroom species are frequently encountered in the same regions, and because local people do not distinguish the different types of fungi, there are reports every year in the media of dozens of cases mushroom poisoning. However, studies of macrofungi of Turkey are increasing rapidly. In this way, the spread of macrofungi and how many fungi types are available and while people's familiarity with mushrooms will be determined and also observed and revealed in Turkey. Heavy metals are elements that exhibit metallic properties such as ductility, malleability, conductivity, cation stability, and ligand specificity. They are characterized by relatively high density and high relative atomic weight with an atomic number greater than 20 (Raskin et al., 1994). Heavy metals are defined as minerals with a density of 5g/cm^3. Heavy metals occupy an important place in terms of human health and environmental pollutants. It is known that these minerals in the soil are absorbed by plants and mushrooms and other living organisms.

The ability of plants to accumulate essential metals as the same of fungi equally allows of them to obtain other nonessential metals. Because metals cannot be broken down, when concentrations within the plant exceed optimal levels, they adversely affect the plant both directly and indirectly. Some of the straight toxic effects caused by high metal concentration include inhibition of cytoplasmic enzymes and damage to cell structures due to oxidative stress (Assche & Clijsters, 1990). In addition, the increase in the rate of heavy metals in the soil has a negative effect on the growth and activities of soil microorganisms and can also indirectly affect the growth of plants, fungi, lichens and algae. For example, a decrease in the number of beneficial soil microorganisms due to high metal concentration can lead to a decrease in organic matter decomposition and a decrease in soil nutrients, causing direct or indirect damage to other living things.

The toxic effect of heavy metals on the environment is still among the biggest concerns of human life. Because the human son, who is with the big predators at the top of the food chain, takes the heavy metals accumulated in living tissues along this chain as food (Ihab et al., 2013). Also, for heavy metals absorbed into the body, there is a very narrow concentration range between beneficial and toxic effects, and when present above the threshold, it can pose a serious threat to human health. As a result, it can lead to morphological abnormalities, decreased growth and increased mortality (Olumuyiwa et al., 2007; Elekes et al., 2010; Radulescu et al., 2010; Lalotra et al., 2016).

The heavy metals eaten cause poisoning, cancer and brain damage (Al-Garni, 2005). It is very difficult to treat nutrients, soil, water and wastewater containing heavy metals. Purification methods for water and wastewater sedimentation, flotation, biosorption, electrolytic recovery, membrane separation, adsorption on minerals and activated carbon adsorption can be listed as methods (Esalah et al., 2000; Ho et al., 2001; Canet et al., 2002). However, most of these methods are expensive methods. Due to industrial and technological developments, heavy metals are constantly released into the environment, and contamination of agricultural land with heavy metals is an important problem in industry and defense related areas around the world (Amini et al., 2008). This problem is not only limited to the soil of agriculture but also affects forest areas and nature.

The concentration of heavy metals in the fruiting bodies of macrofungi is thought to depend on the type of fungus. But at the same time, other factors such as soil pH, organic matter and clay content also play an important role in the accumulation and displacement of these heavy metals in fungi (Kalac & Svoboda,

2000; Gürsoy et al., 2009; Frankowska et al., 2010). In this study, heavy metal accumulations in the macrofungi of Seydişehir (Konya) district were examined. In this way, the situation in the fungus in terms of pollutants will be revealed.

Data on the absorption and accumulator properties of macrofungi are available in various publications, and there are also studies in different regions in Turkey (Tüzen et al., 1998; Sesli & Tüzen, 1999; Demirbaş, 2000; Demirbaş, 2001a; Demirbaş, 2001b; Demirbaş, 2001c; Demirbaş, 2002; Yılmaz et al., 2003; Tüzen, 2003; Işıldak et al., 2004; Türkekul et al., 2004; Doğan et al., 2006; Yamaç et al., 2007; Gençcelep et al., 2009; Kaya & Bağ, 2010; Uzun et al., 2011; Sarıkürkçü et al., 2012; Altıntığ et al., 2017; Akgül et al., 2016; Karapınar et al., 2017: Akın et al., 2019). Also, worldwide several researchers have investigated the heavy metal concentration in many wild growing fungi (Laaksovirta & Alakuijala, 1978; Vetter, 1987; Lepsova & Mejstrik, 1988; Lepsova & Kral, 1988; Kalač et al., 1989; Vetter, 1990; Thomas, 1992; Vetter, 1993; Vetter, 1994; Jorhem & Sundström, 1995; Cibulka et al., 1996; Michelot et al., 1998; Svoboda et al., 2000; Kalač et al., 2004; Elekes et al., 2010; Magdziak et al., 2013; Mazurkiewicz & Podlasinska, 2014; Wang et al., 2014; Dulay et al., 2015; Lalotra et al., 2016; Proskura et al., 2017). However, there is no study in the literature of the heavy metal content of the fungi in the study area.

In this study, it was aimed to investigate the heavy metal content of macrofungi in Seydişehir region and the effects of these heavy metals on soil.

Field studies in the town of Seydisehir were carried out between 2015 and 2017 in the autumn and spring months when the macrofungi were most active. In the preliminary study, the geographic structure of the research area and the suitable environments for fungi were determined (Figure 1).

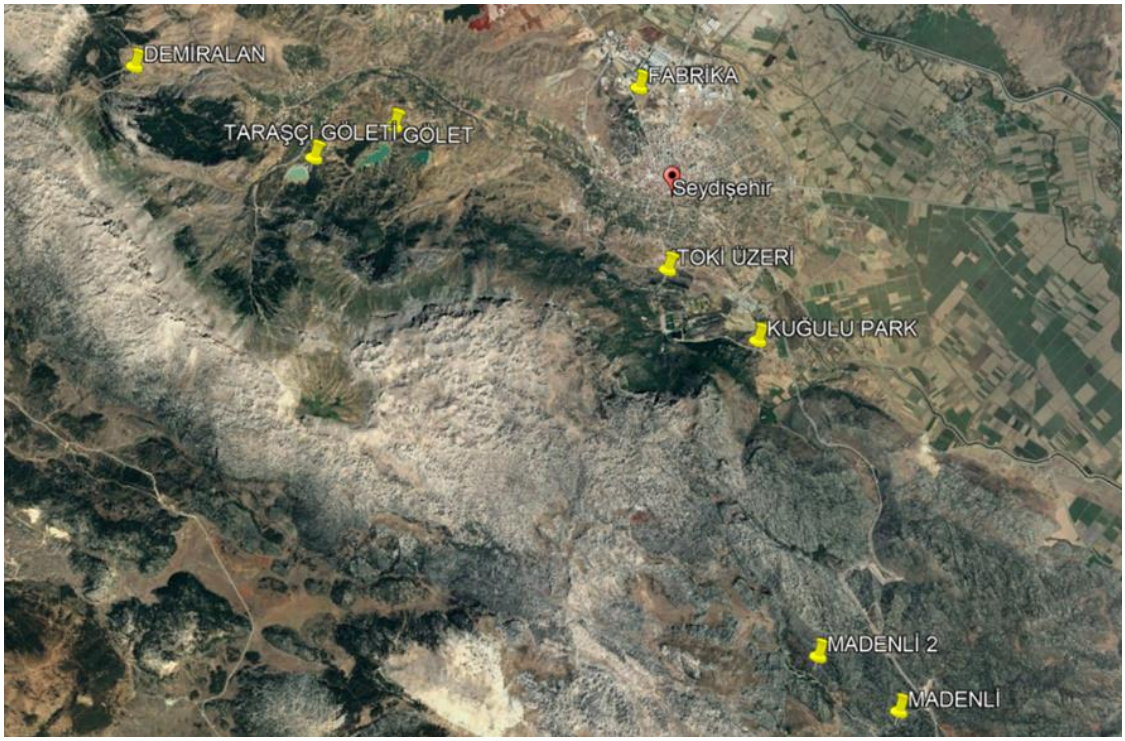

Figure 1. Research area

Materials and Methods

Photographs of the macrofungi detected in the field studies were taken, the samples were numbered, and their ecological and morphological characteristics were noted. Fungal samples were placed in aluminum foil, and the fungi was easily identified and

examined in the laboratory. The soil samples were taken from the points where the mushroom samples were detected, they were placed in the polyethylene zipped bags, and a label number was placed in the bag. While taking soil samples, it was tried to be taken from a depth of approximately 20-25 cm by using anchors, knives and similar tools. Soil samples taken with sterile gloves were collected in locked nylon bags, 25-30 gr each. In addition, in order for the soil samples not to interfere with each other, a note with the locality, date, collection number, GPS coordinate and soil feature were written into the bags.

The macroscopic and microscopic features of the fungi were used as data in the diagnosis. While the dried samples were examined under the microscope (DM 1000 imaging system), their diagnosis was made with the help of appropriate literature (Phillips, 1981; Breitenbach & Kränzlin, 1986; 1991; 1995; 2005; Grünert & Grünert, 1984; 1991; Ellis & Ellis, 1990; Dähncke, 1993; Smith & Smith, 1996).

The fungi were first dried in the drying cabinet, and fungaryum samples were prepared from the samples that were dried. The fungi samples are stored in the fungarium at Selcuk University Fungal Research and Application Center.

Dried and diagnosed mushrooms samples were washed with ultrapure water for heavy metal determination. It was dried at 45-50°C for one day and pulverized using blender. Soil samples, on the other hand, were cleaned of dry vegetal wastes and stone fragments, and made into fine powder using blender and the powdered samples were numbered. The samples were submitted to Selçuk University's ILTEK laboratory for analysis which was carried out in a ILTEK laboratory with ICP-MS. Both types of dried samples were weighed using an analytical balance of approximately 0.1 grams, four decimal places, and transferred to a screw-capped teflon incinerator. A mixture of 7 mL nitric acid and 3 mL hydrogenperoxide was added at room temperature. The containers were then burned in the microwave oven for 1 hour. The analysis of samples were performed using an Inductively Coupled Plasma Mass Spectrometry (ICP-MS).

Results

Macrofungi List

Table 1 shows the distribution of the mushroom species determined for analysis in the localities as a result of the field and laboratory studies.

Table 1. Macrofungi list and localities

Localitie	Coordinate	Altitude	Examples/Edibility
1-Madenli	37°18’31K, 031°52’44D	1450m	M1-*Volvopluteus gloiocephalus* /Edible M2-*Agaricus bisporus* /Edible M3-*Inocybe erubescens* /Poisonous
2-Madenli 2	37°19’18K, 031°51’43D	1597m	M1-*Lycoperdon molle* /Edible M2-*Suillus collinitus* /Edible M3-*Agaricus bitorquis* /Edible
3-Kuğulu Park	37°23’01K, 031°51’38D	1138m	M1-*Lycoperdon mammiforme* /Edible M2-*Gymnopus dryophilus* /Edible M3-*Cortinarius venetus* /Poisonous M4- *Agaricus bisporus* /Edible
4- Upper site of Toki	37°24’00K, 031°50’45D	1125m	M1-*Neoboletus erythropus* /Edible M2-*Russula delica* /Edible M3- *Pleurotus eryngii* /Edible
5-Pond	37°26’14K, 031°46’56D	1181m	M1-*Boletus reticulatus* /Edible M2-*Russula queletii* /Poisonous M3-*Tricholomopsis rutilans* /Non-Edible M4-*Amanita excelsa* /Non-Edible M5-*Cantharellus cibarius* /Edible
6- The Taraşçı Pond	37°25’58K, 031°45’43D	1239m	M1-*Clitocybe costata* /Non-Edible M2-*Clitocybe foetens* /Non-Edible M3-*Chroogomphus rutilus* /Edible

(Table 1. Continued)

7-Demiralan	37°27'21K, 031°43'21D	1583m	M1-*Chroogomphus rutilus* /Edible M2-*Suillus grevillei* /Edible M3-*Hebeloma sinapizans* /Poisonous
8- Factory	37°25'18K, 031°50'55D	1186m	

Analysis Results

As a result of the study, the heavy metal content was obtained from the mushroom samples and the soil samples. When the determined mineral content from the Madenli locality was examined (Table 2), it was found that the highest aluminum and the lowest lead was in M1, the highest aluminum and the lowest cobalt was in the M2, and the highest aluminum and the lowest cobalt is in the M3. When the soil taken from Madenli locality was examined in terms of minerals, it was observed that it was rich in aluminum and iron. Then, zinc, magnesium, chromium, and nickel density were also observed. In the fungi samples, copper and cadmium ratios were found to be higher in the soil and in terms of chromium, cobalt, nickel, lead, iron and aluminum, the soil ratios were higher. In terms of zinc and magnesium, the mineral density in the soil and mushroom samples was relatively equal.

Table 2. Heavy metal contents in fungi samples detected at the Madenli locality (ppm)

	T1-Madenli	M1-*V. volvacea*	M2-*A. bisporus*	M3-*I. erubescens*
Cr	83217.722	10576.94	1983.422	6041.463
Fe	**37184030.24**	954126.176	494813.211	2007690.72
Co	25956.669	740.784	**385.492**	**1275.419**
Ni	82598.173	2756.448	1246.997	4814.196
Cu	33654.812	155752.426	73094.695	71441.173
Cd	**4522.193**	16215.705	1095.791	12065.65
Pb	34830.167	**377.847**	684.299	4266.42
Al	2750185.232	**1171665.236**	**1501307.056**	**1153990.451**
Zn	127915.439	115113.59	115958.737	142951.951
Mg	99090.018	77249.843	22829.401	98968.125

When the mineral content of the fungi detected at Madenli locality 2 was examined (Table 3), in M1 aluminum was found to be at the highest amount and cadmium at the lowest; in M3, cobalt found to be at its lowest and aluminum at its highest. In addition, lead was not detected in the M2 and M3 samples. Al and Fe were the most common minerals in the soil samples of Madenli 2 locality. Following these, amounts of Ni, Cr, Ni, Zn were also detected. More Cu and Zn were found in the fungi than in the soil. Although Pb was not detected in two of the fungi samples, it was found that one fungi sample contained more Pb than soil did.

Table 3. Heavy metal contents in fungi samples detected at Madenli 2 locality (ppm)

	T2 Madenli 2	M1-*L. molle*	M2-*S. collinitus*	M3-*A. bitorquis*
Cr	129426.436	8210.661	1041.095	2908.631
Fe	**27473213.63**	866241.054	173137.657	234111.147
Co	26178.954	**2360.545**	506.477	**445.707**
Ni	329905.67	19040.726	761.257	3549.894
Cu	32231.589	62976.332	7686.134	58649.853
Cd	**137.803**	3924.711	**38.691**	869.39
Pb	9149.192	39849.958	**none**	**none**
Al	10165838.99	**1820719.197**	**827977.517**	**1839959.385**
Zn	69938.837	131506.38	39995.646	88333.076
Mg	127395.762	78265.486	19821.611	51172.225

In all of the fungi from the Kuğulu Park locality, aluminum was found to be at the highest level (Table 4). Lead was not detected in M2 and M3. Minerals found to be at their lowest amount in the fungi samples were lead in M1, Chromium in M2, Cobalt in M3 and M4. In the Kuğulu Park locality, the highest amount of Fe was observed in soil samples. Subsequently, the amounts of Al, Mg, Zn, Ni were identified. More Cu, Zn was found in fungi samples than in the soil. Although Pb was not detected in two of the fungi samples, it was found that two other fungi sample contained more Pb than soil did.

Table 4. *Heavy metal contents in fungi samples detected at Kuğulupark locality (ppm)*

	T3 Kuğulu Park	M1-*L. mammaeforme*	M2-*G. dryophilus*	M3-*C. venetus*	M4-*A. bisporus*
Cr	29072.504	8210.661	1041.095	2908.631	8210.661
Fe	**25670226.940**	866241.054	173137.657	234111.147	866241.054
Co	11907.879	**2360.545**	506.477	**445.707**	**2360.545**
Ni	42666.119	19040.726	761.257	3549.894	19040.726
Cu	24027.744	62976.332	7686.134	58649.853	62976.332
Cd	**1045.973**	3924.711	**38.691**	869.390	3924.711
Pb	16032.553	39849.958	**none**	**none**	39849.958
Al	1990880.346	**1820719.197**	**827977.517**	**1839959.385**	**1820719.197**
Zn	92884.818	131506.38	39995.646	88333.076	131506.380
Mg	126033.101	78265.486	19821.611	51172.225	78265.486

When the mineral content of the fungi determined from Upper site of Toki locality was examined (Table 5), the highest iron levels were found in all mushroom samples. The lowest levels were Cadmium in M1, cobalt in M2, and cadmium in M3. On the other hand, the highest amount of Fe was observed in the soil samples of the Upper site of Toki locality. The amounts of Al and Zn followed. The fungal samples contained more Cu, Zn, and Mg than the amounts detected in the soil.

Table 5. Heavy metal contents in fungi samples detected in Upper site of Toki locality (ppm)

	T4 Upper site of Toki	M1-*B. erythropus*	M2-*P. delica*	M3-*P. eryngii*
Cr	28146.368	1472.399	2957.909	8910.256
Fe	**24117347.69**	**909838.494**	**1365274.514**	**5637602.950**
Co	11556.847	490.445	**627.063**	2881.817
Ni	42204.671	1480.944	2680.658	10397.806
Cu	42365.505	13432.778	47318.883	117559.403
Cd	**1412.006**	**151.913**	12962.513	**733.694**
Pb	17580.387	337.662	835.496	12925.527
Al	1484868.413	622952.500	1053847.412	1370860.723
Zn	88091.452	37093.049	52210.436	133798.535
Mg	60607.686	847233.053	13462.605	327349.463

The mushrooms detected from the pond locality were found to have the highest level of all except M5 (Table 6). Iron was found to be at its highest in M5. In M1, lead was at the lowest level, cobalt was lowest in M2, M3, and M4; and, in M5, the lowest was cadmium. No lead was detected in M2 and M3. At the pond locality, Fe was the mineral with the highest level in the soil samples followed by Al, Zn, Mg, Cr, and Ni . The fungus samples contained more Cu, Zn, and Mg in than the soil.

In the fungi samples identified from the Taraşçı locality, aluminum was found to be the highest in M1 and M3 and iron in M2 (Table 7). The lowest is found to be cobalt in M1 and M2, and lead was lowest in M3. At the Taraşçı locality, the highest amount of Fe

was observed in the soil samples followed by Al, Zn, Cu, Mg, and Cr. More Mg was found in the fungi samples than in the soil. Depending on the amount detected in the soil, more Cu and Zn was found in the fungi samples.

Table 6. Heavy metal contents in fungi samples detected at the pond locality (ppm)

	T5 Pond	M1- *B. reticulatus*	M2- *R. queletii*	M3- *T. rutilans*	M4- *A. excelsa*	M5- *C. cibarius*
Cr	31178.190	2853.495	2198.089	486.568	5792.021	10399
Fe	**19582411.31**	455993.833	350412.425	115970.738	1017452.263	**1849949.019**
Co	11289.413	370.753	**276.858**	**139.469**	**666.163**	1036.299
Ni	26954.817	2042.675	949.112	373.072	2405.33	3527.656
Cu	27638.305	17514.321	25599.304	18638.373	56319.596	24679.859
Cd	**402.692**	1338.907	543.685	3810.002	1819.101	**390.524**
Pb	16343.625	**138.337**	**none**	**none**	1969.168	1138.908
Al	1880385.583	**796234.517**	**608948.354**	**1149810.35**	**1084941.235**	1019937.313
Zn	62798.279	76837.784	58453.251	33508.774	130803.06	54495.367
Mg	42022.419	15459.952	22701.091	104721.084	37878.347	11894.543

Table 7. Heavy metal contents in fungi samples detected at The Taraşçı Pond locality (ppm)

	T6 The Taraşçı Pond	M1- *C. costata*	M2- *C. foetens*	M3- *C. rutilus*
Cr	28651.941	3197.869	2075.242	2576.917
Fe	**25457455.310**	1198878.27	**1040427.919**	918864.936
Co	13871.601	**1430.623**	**602.647**	495.883
Ni	22880.592	3120.931	3167.340	2866.249
Cu	75106.306	45779.473	13860.521	11008.770
Cd	**96.705**	1781.898	1666.364	**252.272**
Pb	22370.229	1633.336	777.429	108.957
Al	1798887.612	**1304396.248**	944049.848	**1258335.843**
Zn	101458.916	69557.614	41156.918	32604.789
Mg	41628.887	178232.106	67933.710	275107.263

Iron was found to be at the highest level in all of the fungi samples from the Demiralan locality (Table 8). The lowest level of lead was seen in M1, of cadmium in M2, and of cobalt in M3. The highest amount of Fe in the soil samples was observed in the Demiralan locality followed by Al, Zn, Mg, Cr, and Ni. The fungi samples contained more Mg than the soil. Depending on the amount of soil, the fungi samples still contained more Zn (Table 8). The distribution of minerals in soil samples is given in Table 9.

Table 8. Heavy metal contents in fungi samples detected at the Demiralan locality (ppm)

	T7 Demiralan	M1- *C. rutilus*	M2- *S. grevillei*	M3- *H. sinapizans*
Cr	43840.567	1302.144	3293.871	3583.244
Fe	**28040055.73**	434882.741	1523078.247	**1101523.519**
Co	13652.114	339.097	739.927	**574.804**
Ni	43701.854	1072.255	3036.071	2599.885
Cu	30797.234	5125.301	5814.112	22236.064
Cd	**858.359**	294.250	**220.604**	2740.581
Pb	24641.466	**77.409**	1242.654	1604.243
Al	3688657.174	**795798.145**	**1055020.891**	994395.611
Zn	102068.52	17954.607	41183.402	107683.340
Mg	64872.337	111306.657	18140.375	272228.957

Table 9. Heavy metal contents detected in soil samples (ppm)

	Madenli T1	Madenli 2 T2	Kuğulu Park T3	Upper site of Toki T4	Pond T5	The Taraşçı Pond T6	Demiralan T7	Fabrika T8
Cr	83217.722	129426.436	29072.504	28146.368	31178.19	28651.941	43840.567	28877.512
Fe	**37184030.24**	**27473213.63**	**25670226.94**	**24117347.69**	**19582411.31**	**25457455.31**	**28040055.73**	**27978604.75**
Co	25956.669	26178.954	11907.879	11556.847	11289.413	13871.601	13652.114	12039.85
Ni	82598.173	329905.67	42666.119	42204.671	26954.817	22880.592	43701.854	30541.133
Cu	33654.812	32231.589	24027.744	42365.505	27638.305	75106.306	30797.234	21964.456
Cd	4522.193	137.803	1045.973	1412.006	402.692	96.705	858.359	180.729
Pb	34830.167	9149.192	16032.553	17580.387	16343.625	22370.229	24641.466	16463.377
Al	**2750185.232**	**10165838.99**	**1990880.346**	**1484868.413**	**1880385.583**	**1798887.612**	**3688657.174**	**2530496.067**
Zn	127915.439	69938.837	92884.818	88091.452	62798.279	101458.916	102068.52	63966.81
Mg	99090.018	127395.762	126033.101	60607.686	42022.419	41628.887	64872.337	78292.502

The soil samples were compared with the samples taken from the factory localities. When the soil samples were examined, there was not much difference between the mineral quantities in the factory locality coded as T8, and the mineral amounts in the samples taken from other regions. Only Maden and Maden 2 localities were found to be rich in Fe and Al.

When the fungi were examined in terms of absorbing the percentage of heavy metals in the soil, the results were interesting. In the fungi detected in locality 1, especially in the fungi taken from the Cu and Zn localities, the heavy metals content was over 50%. Again, the Cd and Mg in two fungi and the Al in one fungus increased to over 50% in terms of content (Table 10).

When the heavy metal content in the fungi detected in locality 2 was examined, it was over 50%, especially in all fungi taken from Zn localities. Again, the Cu and Cd levels were higher than 50% in two fungi and Mg was higher than 50% in one fungus (Table 10).

Table 10. Percentage of heavy metals in terms of the soil in fungi at the Maden and Maden 2 localities

	L1-M1	L1-M2	L1-M3	L2-M1	L2-M2	L2-M3
Cr	12.70996	2.383413	7.259827	6.343882	0.804391	2.247324
Fe	2.565957	1.330714	5.399336	3.153039	0.630205	0.852143
Co	2.853926	1.485137	4.913647	9.016957	1.934672	1.702539
Ni	3.337178	1.509715	5.828453	5.771567	0.23075	1.076033
Cu	462.7939	217.1894	212.2763	195.387	23.84659	181.9639
Cd	358.5806	24.23141	266.8097	2848.059	28.07704	630.8934
Pb	1.084827	1.964673	12.24921	435.5571	none	none
Al	42.60314	54.58931	41.96046	17.91017	8.144704	18.09943
Zn	89.99194	90.65265	111.755	188.0306	57.1866	126.3005
Mg	77.95926	23.03905	99.87699	61.43492	15.55908	40.16792

When the heavy metal content of the fungi detected in locality 3 were examined, it was seen that there was over 50% content in all mushrooms taken from Cu, Cd, and Zn localities. Al and Mg were at more than a 50% level in two fungal species (Table 11).

When the heavy metal contents of the fungi detected in the locality 4 were examined, especially in all mushrooms taken from the Zn localities, heavy metals were present at a level of over 50%. Cu, Cd, Al, and Mg levels were higher than 50% in two fungal species (Table 11).

Table 11. Percentage of heavy metals in fungi found in soil at the Kugulu Park (L3) and Toki (L4) localities

	L3-M1	L3-M2	L3-M3	L3-M4	L4-M1	L4-M2	L4-M3
Cr	6.758321	1.747335	2.698416	3.031025	5.231222	10.50903	31.65686
Fe	3.964942	0.429712	0.668584	0.434886	3.772548	5.660965	23.37572
Co	6.386276	19.13719	3.151871	1.683264	4.243761	5.4259	24.93601
Ni	5.082279	2.749437	2.460693	1.776445	3.508958	6.351567	24.63662
Cu	298.3362	142.5864	93.0502	265.3747	31.70688	111.692	277.4885
Cd	84.37713	312.6796	485.3633	100.1742	10.75867	918.0211	51.96111
Pb	2.791789	none	none	2.342765	1.920674	4.752432	73.52243
Al	88.90193	40.21762	45.14622	79.63397	41.95338	70.97244	92.32203
Zn	152.2185	85.85241	59.90935	146.8256	42.10743	59.26845	151.8859
Mg	72.40387	47.42799	71.01442	26.39437	1397.897	22.2127	540.1121

When the heavy metal contents in the fungi detected in locality 5 were examined, especially the fungi from the Cu, Cd and Zn localities, they contained heavy metal levels of more than 50%. Al and Mg was found at a higher than 50% level in three of the fungus types (Table 12).

When the heavy metal contents in the fungi detected in locality 6 were examined, it was seen that there are heavy metals at an over 50% content level in all fungi taken from the Cd, Al, and Mg localities. Again, Zn increased to over 50% in one of the fungus species (Table 12).

Table 12. Percentage of heavy metals in fungi in Pond (L5) and the Taraşçı Reservoir (L6) localities

	L5-M1	L5-M2	L5-M3	L5-M4	L5-M5	L6-M1	L6-M2	L6-M3
Cr	9.152215	7.050085	1.560604	18.57716	33.35344	11.16109	7.242937	8.993865
Fe	2.328589	1.789424	0.592219	5.195746	9.446993	4.709341	4.086928	3.609414
Co	3.284077	2.452368	1.235396	5.900776	9.179388	10.31332	4.344466	3.574807
Ni	7.578145	3.521122	1.384064	8.923563	13.08729	13.64008	13.84291	12.52699
Cu	63.36974	92.62255	67.43674	203.7737	89.29585	60.9529	18.45454	14.65758
Cd	332.4891	135.0126	946.133	451.7351	96.97834	1842.612	1723.142	260.8676
Pb	0.846428	none	none	12.04854	6.968515	7.301383	3.475284	0.487063
Al	42.34422	32.38423	61.14758	57.69781	54.24086	72.51127	52.47965	69.95078
Zn	122.3565	93.08098	53.35938	208.2908	86.77844	68.55742	40.56511	32.13595
Mg	36.78977	54.02138	249.2029	90.13843	28.30523	428.1453	163.1889	660.8566

When the heavy metal contents in the fungi detected in locality 7 was examined, there was a content of more than 50% in the fungus type taken from the localities of Cu, Cd, and Zn. Again, the Mg level increased more than 50% in two of the fungi species (Table 13).

Table 13. Percentage of heavy metals in fungi located in the Demiralan locality

	L7-M1	L7-M2	L7-M3
Cr	2.970181	7.513295	8.173352
Fe	1.550934	5.431795	3.928393
Co	2.483842	5.419871	4.210366
Ni	2.453569	6.947236	5.949141
Cu	16.64208	18.87868	72.2015
Cd	34.28053	25.70067	319.2814
Pb	0.314141	5.042939	6.510339
Al	21.5742	28.60176	26.9582
Zn	17.59074	40.34878	105.501
Mg	171.578	27.96319	419.638

The lowest and highest heavy metals specified in the fungi may be seen in Table 14; the fungi containing the most heavy metals were found in the Madenli, Madenli 2, and Upper site of Toki localities while the fungi containing the lowest levels of heavy metals in were in the Pond and Demiralan localities.

Table 14. Heavy metals detected in fungi at the highest and lowest amounts

	En fazla	En az
Cr	L1-M1	L5-M5
Fe	L4-M3	L3-M2
Co	L4-M3	L5-M3
Ni	L2-M1	L5-M3
Cu	L1-M1	L7-M1
Cd	L1-M1	L2-M2
Pb	L2-M1	(L2-M2,M3/L3-M2,M3/L5-M2,M3=0)L7-M1
Al	L2-M3	L5-M2
Zn	L1-M3	L7-M1
Mg	L2-M1	L5-M5

In terms of the sum of all heavy metals, the amount contained in the fungi is given in Figure 2.

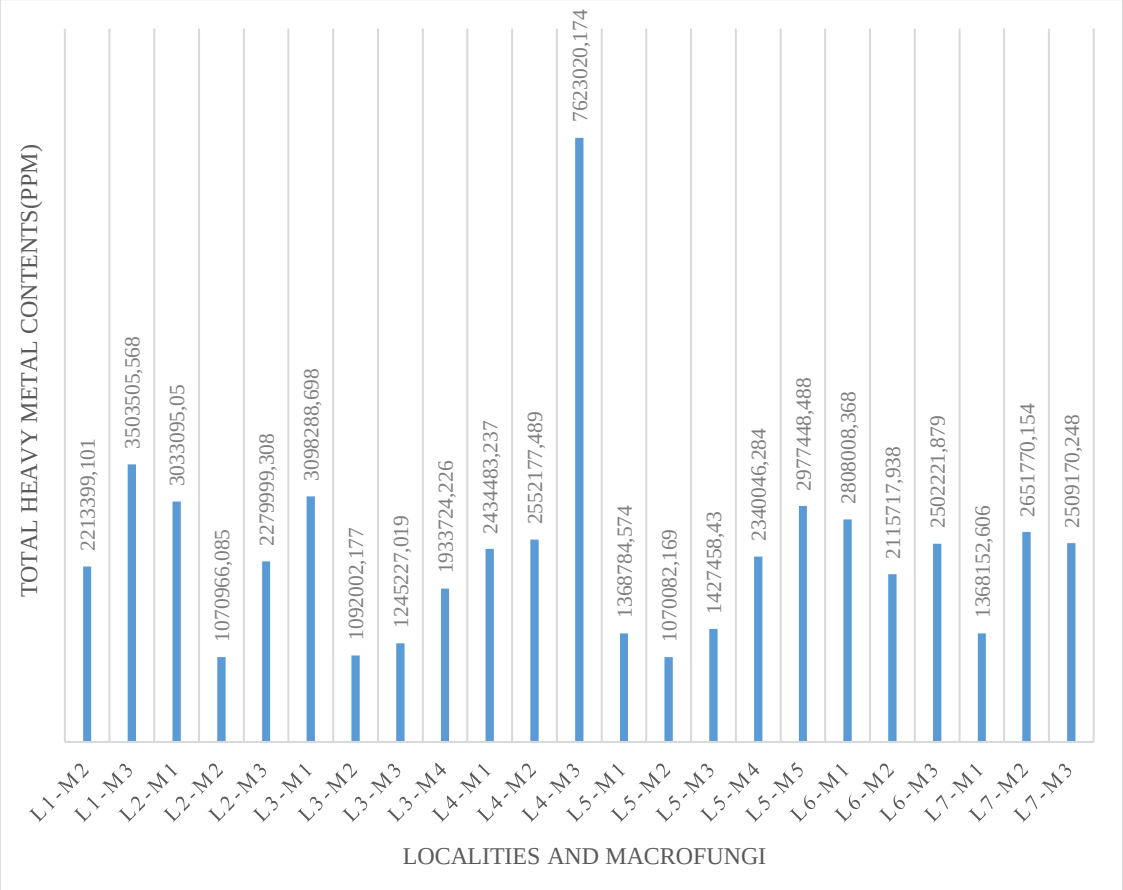

Figure 2. Total amount of heavy metals contained in fungi (ppm)

Figure 2 shows that while all the fungi contain similar proportions of heavy metal, in the L4-M3, the heavy metal content was observed to be denser by comparison. The lowest level of heavy metal content was found in the L5-M2, L2-M2, and L3-M2 samples.

The total heavy metal contents of the soil

samples are given in Figure 3 where it may be seen that the highest level of heavy metal content was found in the Madenli and Madenli 2 localities while the lowest level of heavy metal content was detected in the Pond locality.

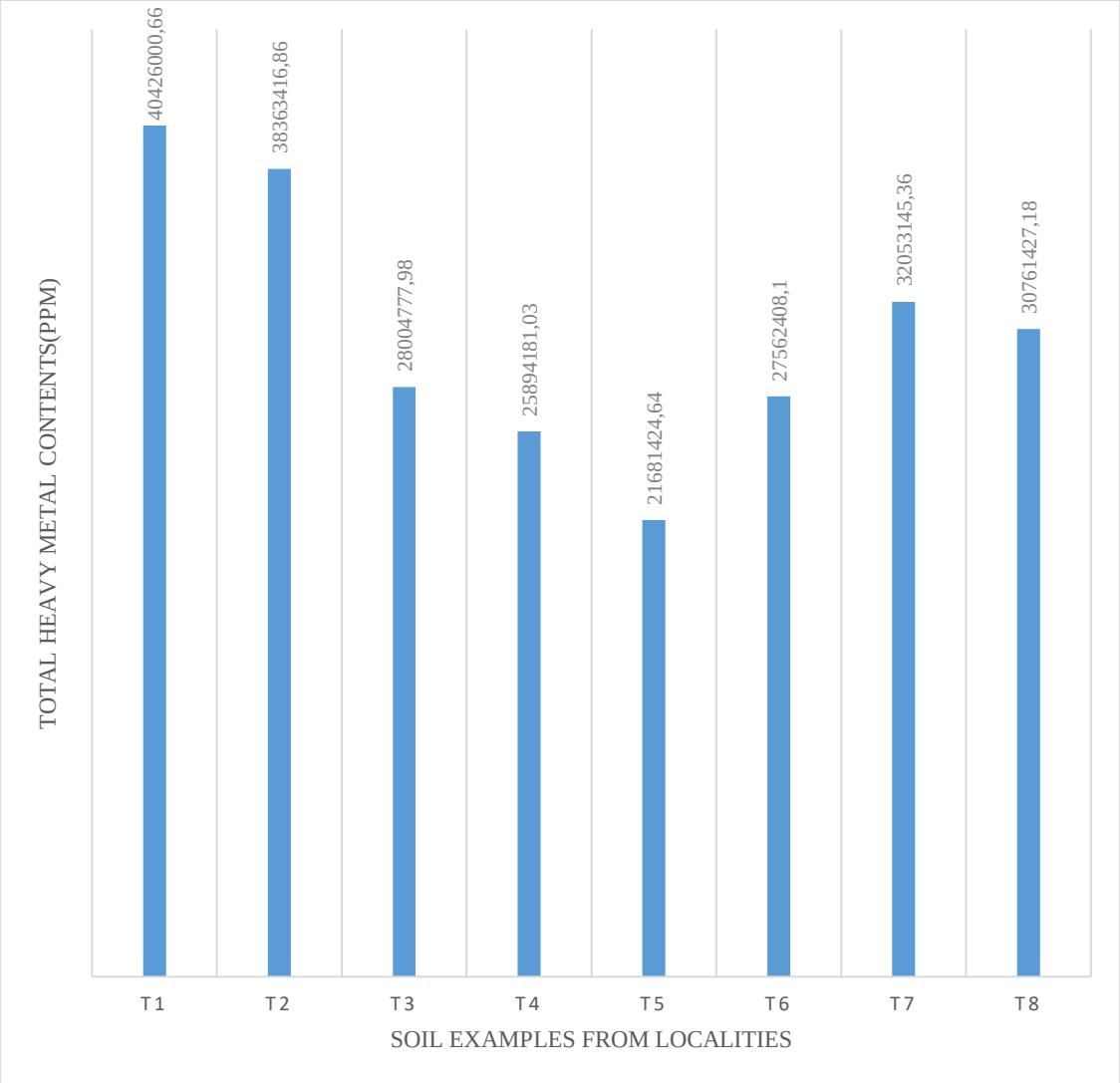

Figure 3. *Total amount of heavy metal in soil samples taken from localities (ppm)*

Discussion

This study examined the heavy metal quantities in the macrofungi growing in the Seydişehir (KONYA) district. In the study, the forest areas around the Seydişehir district were investigated. Two of the localities were chosen from the regions far from the city center, and the others were located in the city center where a point close to the factory was chosen. As a result of the field studies carried out in all localities, samples were taken from macrofungi that could be used in heavy metal accumulation. Soil samples were taken from the same localities and brought to the laboratory.

When the results of the analysis were evaluated, the presence of heavy metals was detected, and an analysis of 10 different heavy metals was conducted in soil samples taken from the research area. Although the amount of heavy metals varied among localities, it was determined that there was a strong presence of Fe and Al in the soil samples from Seydişehir. Fe ranged between 195822411 ppm and 37184030 ppm in localities. Al ranged between 1484868 ppm and 3688657 pmm.

In addition, the presence of Zn in almost all localities was determined, found at levels between 62798.279 ppm and 127915.439 ppm. Similarly, in all localities, the level of Mg, ranging between 41628.887 ppm and 127395.762 ppm, was found to be higher than other minerals. In addition, the level of Cu was determined to range between 75106.306 ppm and 21964.456 ppm.

When the heavy metal content of the fungi was considered, it was observed that the minerals with a high density in the locality have the same rate in the fungus structure. The amount of Fe and Al detected in the region was observed to be at a high level in the content of the fungi. In addition to Al and Fe, Cu, Zn, Cd, and Mg were found at higher levels than other minerals in the fungi samples.

Although some Pb was found in some fungi in the given localities, in some localities Pb could not be detected and identified. Depending on the density of heavy minerals in the environment, transition through the fungi bodies was also observed. However, percentages of some minerals from fungi to fungi differed based on other minerals. Cu, Cd, Zn, Al, and Mg, in particular, were inclined to make transition more substantial in terms of percentage.

When the heavy metal contents of the mushrooms are expressed in percentage depending on the heavy metal content in the soil, Fe and Al are very high in the soils. Although in the mushroom's tissue structure are also high, it seems low, when viewed in terms of the percentage of heavy metal in the soil.

When the soil samples were compared, there was no significant difference between soil samples taken from the factory localities and the soil samples taken from other regions. Fe and Al were high in all localities. In addition, Cr, Ni, Zn, and Mg were found in the localities of Kuğulu Park, Toki, and Pond; Demiralan showed a presence of Zn and Mg; and, in the The Taraşçı Pond localities where levels of Cu and Zn were higher than other heavy metals.

Emissions from rapidly expanding industrial areas can be contaminated by the accumulation of heavy metals and metalloids through the land application of fertilizers, coal combustion residues and pouring of petrochemicals. The presence of metals in the fruiting bodies of mushrooms directly reflects their amount in the soil, and bioaccumulation factors indicate the ability of mushrooms to accumulate these elements from the soil (Lalotra et al., 2016). It is seen that the data obtained in this study is high. There may be several reasons for this. The first is naturally the abundance of mines in the working area, the second may be the result of industrialization and modernization, and the result of industrial elements operating in the region. And the above reasons can be added to these.

According to the literature review, Lepsova ve Mejstrik (1988) stated that the fungus grown in mineral deposits are high in Pb and Cd content. Kalac et al. (1991) stated that similar minerals (Pb, Cd) accumulate in cork mushrooms/fungi and that the Pb, Cd, Cu and Hg levels were significant in fungi growing near lead deposits.

Işıldak et al. (2004), in a study of the heavy metal contents of edible macrofungi growing naturally in the Tokat region, reported that the Fe content is high in all fungi whereas Cr and Ni are high in some species.

According to Durukan (2006) it was determined that the Cu and Zn content in the macrofungi was higher than the heavy metal content in the soil. This result was also verified and similar in our study.

The study by Şen et al. (2012) that examined the heavy metal content specified for the natural fungi grown in Bigadiç (Balıkesir) in terms of Cd, Cr, Cu, and Zn showed similar results to our study. Some differences in the content should be evaluated in terms of habitat differences.

Altıntığ et al. (2017) conducted a study called detection of Cr, Cu, Fe, Ni, Pb and Zn with ICP-OES in mushroom samples collected from Sakarya. Considering the results of our study, the amount of Fe in the studied mushrooms, Altıntığ et al. (2017) when compared with his work, it is seen that it has come out too much. There are differences in other elements. This can be interpreted by the difference of the growing place of the mushroom.

Although the mineral content of the macrofungi was in line with mineral richness up to a certain level, it is not possible to talk about this linearity in terms of an excess amount of minerals in the environment. Mineral absorption is thought to be related to the structure of the fructification organ of the fungus. Macrofungi have been found to have the ability to strongly absorb minerals in the environment. Compared with green plants, macrofungi can accumulate high concentrations of heavy metals such as Cd, Pb and Hg (An & Zhou, 2007). Attention should be paid to the consumption of macrofungi grown in soils rich in heavy metals. Excessive consumption can pose a threat to human health.

Acknowledgments

Funding: This research was supported by Selçuk University Scientific Research Projects (BAP) Coordination Office (Project No: 15401109). Thank you for their financial support.

Conflict of interest: The authors declare that they have no conflict of interest.

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