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An Investigation of The Use of Mushrooms in The Research on Environmental Pollution

Muhammed Kamil ODEN[1]

[1] Selcuk University, Sarayönü Vocational High School, Department of Environmental Technology, Konya, Turkey
Orcid ID:0000-0002-0573-5634/ muhammedkoden@selcuk.edu.tr

Abstract: Efforts to eliminate environmental pollution are becoming more and more important. Because, with the rapidly increasing world population and technological developments, natural resources are rapidly being destroyed. In this respect, it is widely believed that 100 years later, human beings will find it difficult to find water and nutrients and environmental pollution will reach serious levels. These environmental impurities are known to be of organic, inorganic and biological origin. In terms of toxic effects, heavy metal group is more prominent. These pollutants can interfere with soil, air and water resources and threaten living things. The most important part of the studies in the prevention of environmental pollution is the cost of plant or application investment, additional consumables and chemical needs, operating costs and toxic effects of the outputs (such as a waste sludge) after treatment. Therefore, the use and investigation of the easier and economical application of natural products in environmental studies is gaining importance. In this study, the usability of fungi growing naturally in environmental pollution prevention studies were investigated. In the literature, some studies have been identified that remove pollutants with mushrooms and their process, fungus and optimization criteria were compared. The achievements were shared with the values and what kind of pollutants were removed. In the light of the information presented in this study, it was observed that parameter "*Pleurotus* mushroom" species were more preferred in these studies and high pollutant parameter removal was obtained.

Key words: Mushroom, Environment, Biosorption, *Pleurotus*, Pollution, Removal

Çevre Kirliliği Araştırmalarında Mantarların Kullanımının İncelenmesi

Öz: Çevresel kirliklerin ortadan kaldırmaya yönelik çalışmalar günden güne önem kazanmaktadır. Çünkü hızla artan dünya nüfusu ve teknolojik gelişmeler ile birlikte doğal kaynaklar hızla yok edilmektedir. Bu bakımdan bundan 100 yıl sonra insanoğlunun su ve besin bulmakta zorlanacağı ve çevre kirliliklerinin ciddi boyutlara ulaşacağı yönünde yaygın bir kanı bulunmaktadır. Bu çevre kirliliklerinin organik, inorganik ve biyolojik kökenli olabildikleri bilinmektedir. Toksik etkileri bakımından ise ağır metal grubu daha ön plana çıkmaktadır. Bu kirleticiler toprağa, havaya ve su kaynaklarına karışabilmekte ve canlıları tehdit edebilmektedir. Mevcut çevre kirliliklerin önlenmesi çalışmalarında dikkat edilen kısımların başında, tesis veya uygulama yatırım maliyeti, ilave sarf malzeme ve kimyasal ihtiyacı, işletme maliyetleri ve arıtım sonrası oluşan çıktıların (çamur gibi) toksik etkisidir. Bu yüzden çevre çalışmalarında uygulaması daha kolay, ekonomik ve doğal ürünlerin kullanımı ve araştırılması günden güne önem kazanmaktadır. Bu araştırma çalışması ile doğal olarak yetişen mantarların çevre kirliliği önleme çalışmalarında kullanılabilirliği incelenmiştir. Literatürde mantar ile kirletici gideren bazı çalışmalar tespit edilmiş ve bunların proses, mantar ve optimizasyon kriterleri kıyaslanmıştır. Elde edilen başarı değerleri ile birlikte ne tür kirleticileri giderdiği paylaşılmıştır. Bu çalışma içerisinde sunulan bilgiler ışığında "*Pleurotus*" mantar türlerinin bu çalışmalarda daha fazla tercih edildiği ve yüksek kirletici parametre giderimi elde ettiği görülmüştür.

Anahtar kelimeler: Mantar, Çevre, Biyosorpsiyon, *Pleurotus*, Kirlilik, Giderim

Introduction

In today's world, the most important problems encountered in all geographies are water, food, energy need and rapidly consumed natural resources and generated environmental pollution due to rapid population growth. The resulting environmental pollution has adverse effects on the aquatic environment, soil and air. Different Environmental Engineering treatment methods and pathways are being tried to prevent these impurities and great successes are achieved in the removal of pollutants. The main advantages of all the works that are planned and to be done are, they need to be easy to be applied, they need to fewer energy needs, they shouldn't need extra chemical, and material (such as coagulant and adsorbent. In order to achieve these advantages in full, it is necessary to apply to nature, biotic and abiotic components.

Thousands of mushrooms (fungi) grow spontaneously in nature due to many microbiological and microbiological constituents in our world. It is known that there are quite a few species (about 10,000) of mushroom groups and about 60 - 70% of them are non-toxic, edible mushrooms. But not all of the desired flavor and quality. The number of mushrooms that can be cultured is close to 50 and the number of fungi produced commercially in the economic area is about 20-25. In our country in the 1970s only a few mushrooms can be grown in the plant, today, the number of enterprises and facilities of different sizes is close to 1000 and annual mushroom production amount is close to 30,000 tons (Aksu et al., 1996; Aksu, 2006; Deniz et al., 2016).

Edible fungi are considered as a healthy nutrient with high protein value for humans. 100 g of mushrooms; 4 g of protein, 0.26 g of fat, 3.75 g of non-dilute substances, 0.92 g of cellulose, 0.97 g of mineral matter are present. Mushrooms with these values have an important place among other vegetable species and they are more valuable than most of the vegetables in terms of their nutritional value (Chang and Buswell, 1996; Aşkun ve Işıloğlu, 1997; Polat ve Selvi, 2011; Ulziijargal and Mau, 2011). 22% of the common mushroom samples are protein (mostly composed of basic amino acids), 5% fat (essential fatty acids in the human body), 63% fiber-containing carbohydrates, 10% as minerals in ash and many other such as thiamine, riboflavin, niacin, and biotin. It is known to contain vitamin (Matilla et al., 2000). Basic fatty acids and calorie-rich mushroom species are rich in plant proteins, minerals, and vitamins. In terms of healthy eating, consumption is increasing. In our country, due to the favorable environment and climate conditions in terms of mushroom cultivation, the potential for edible mushrooms is quite high (Demirci, 2010). Mushrooms are living things that reproduce with their spores. The spores are dispersed in the wind and can live in the soil for years. The climatic conditions, that is, the temperature and humidity of the soil and air, when appropriate, these spores germinate and give a fractionation. These mushrooms, which have a million species in our world and are generally referred to as cork mushrooms as shown in Figure 1, are mostly encountered as a foodstuff (Royse and Schisler, 1980; Pilz and Molina, 2002; Wasser, 2011).

In this review, different mushroom studies used in pollutant removal from the receiving environment of the Environmental Engineering were investigated. Along with the success yields, the optimization criteria of fungal varieties and processes were presented in the article and the success of the applications was compared.

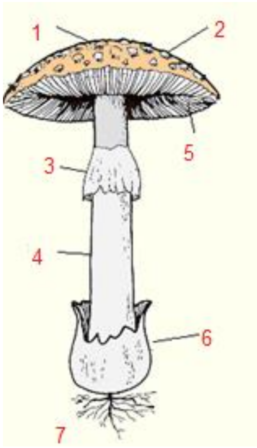

Figure 1. General view and parts of mushrooms (1: Cap (Pileus), 2:Scales, 3:Annulus, 4: Stipe, 5:Lamellae, 6:Volva, 7:Base) (Coşkun, 2019)

General characteristics of mushrooms

Mushrooms are eukaryotic organisms that are commonly found in nature and are not photosynthetic, which can grow in different environmental conditions with sexual and non-sexual reproductive characteristics. They show 3 different structures according to their morphological structure; 1. Mayans (Without Flamenco), 2.Molars (Flamenco), 3.Macrofungi (Miles and Chang, 1997). Mushrooms are usually divided into four sub-classes *called Ascomycota, Basidiomycota, Chytridiomycota and Zygomycota*. Some edible mushrooms and macrofungi are all included in *Ascomycota* and *Basidiomycota*. Mushrooms are heterotrophic organisms because they do not carry chlorophyll differently from autotrophic plants and are unable to synthesize their own carbohydrates through photosynthesis. They supply carbohydrate requirements and some organic substances from their environment (Elmastaş et al., 2007).

These substances taken from the mushrooms are divided into three groups as parasitic, saprophytic and symbiotic. When fed with dead tissues, called saprophytic fed mushrooms, parasitic mushrooms and animal tissues or those living dependent on plants are called symbiotic fungi (Chang, 1999).

Fungi are considered as plants with their inability to act in terms of their properties, their cell walls in their cells, their proliferation ability. They do not contain chlorophyll and do not contain the organs that are common in the plants because they have a very different structure than high plants. Biologically it breaks down the substrates and therefore the fungi play an important role in the ecosystem. Mushrooms are defined as food and as a source that contains many bioactive components in their medically valuable content (Sarıkürkçü et al., 2004; Bonfante and Genre, 2008; Guillamón et al., 2010). There are many studies investigating the contents of fungi in Turkey (Işıldak et al., 2004; Akgül et al., 2016; Akın et al., 2019). Some of the data obtained from the study on the minerals of wild edible mushrooms made by Kaya et al. (2017) are given in Table 1. As can be seen from this point, the mushrooms are rich in minerals. Reproduction in mushrooms, according to the environmental conditions and species, non-sexual and sexual takes place. In most of the fungi, although both reproductive types are seen, non-sexual reproduction is more common and is carried out asexually spores (Sümer, 2000).

Table 1. The mineral content of some wild edible mushrooms (Kaya et al., 2017)

Mushroom Name	Habitat	Amount of mineral (mg/kg dry weight)			
		Ca	Fe	Mg	Mn
Coprinus comatus (O.F. Müll.) Pers.	Meadow	2627	306.4	62.39	31.08
Leucoagaricus leucothites (Vittad.) Wasser	Meadow	590.5	59.42	61.03	9.95
Lycoperdon molle Pers	Forest clearings	584.2	585.3	67.23	68.53
Volvopluteus gloiocephalus (DC.) Justo	Among grasses	2404	585	65.22	138.2
Coprinellus micaceus (Bull.) Vilgalys, Hopple & Jacq. Johnson	Around Populus sp. remains	1794	148.4	62.34	12.91
Psathyrella candolleana (Fr.) Maire	Around Populus sp. remains	2397	382.8	63.54	45.57
Lepista nuda (Bull.) Cooke	Forest and shruby areas	1361	156	62.29	19.88
Melanoleuca cognata (Fr.) Konrad & Maubl.	Mixed forest	562.9	84.47	61.91	53.19
Tricholoma terreum (Schaeff.) P. Kumm	Pine forest	2487	217.4	62.07	12.54

Therapeutic and anti-oxidant/microbial characteristics of mushrooms

As a result of scientific researches, it has been determined that some macrofungi species have various chemical compounds showing antibacterial, antifungal, antiviral and antiprotozoal properties. The organism needs such chemicals in order to survive in the environment where it lives and to give an advantage to the competitive species around it. The antimicrobial effects of macrofungi are caused by certain phenolic compounds, purines, pyrimidines, quinones, terpenoids, and phenyl proponoid derivative antagonistic substances, which are synthesized in the fungal structure and are usually organism-specific (Benedict et al., 1983; Aly and Bafiel, 2008; Bokhari, 2009; Amini et al, 2012). Significant pharmacological and physiological features of fungi are to increase immunity, to preserve homeostasis and to regulate biorhythm, to prevent and improve various diseases, to cure life-threatening diseases such as cancer, stroke and heart diseases (Rathee et al., 2012). Edible fungi are considered as therapeutic foods in the treatment of diseases such as cancer, hypocholesterolemia, hypertension (Manzi et al., 2001).

In the studies, various therapeutic effects of fungi such as antimicrobial, anti-inflammatory and antibiotic effects have been shown. In terms of their antioxidant properties, mushrooms can accumulate various secondary metabolic products, including steroids, phenolic compounds, terpenes, and polyketides. There are also a variety of molecules, such as polysaccharides and polyphenols, which are particularly effective in clearing free radicals known to be harmful to cells. It has been determined that phenolic compounds have an antioxidant effect on the inhibition of LDL (low-density lipoprotein) oxidation (Yu and Keller, 2005; Frisvad et al., 2008; Schneideret al., 2011 Kozarski et al., 2012). In addition to their protective effects on biological systems, phenolic compounds exhibit antioxidant activity. Antioxidant capacity of plant tissues; It is mainly related to the amount of antioxidants such as phenolic compounds, tocopherols, carotenoids and ascorbic acid and the activity of free radical scavenging enzymes (superoxide dismutase, catalase, peroxidase, etc.) (Yagi, 1970; Bartosz, 1997; Watanabe vd., 2008).

Areas of usage of fungi

Fungi which are important parts of the ecosystem are important. They have an important place for people because of their roles. In addition to its harmful effects in human life, it also has beneficial effects. In addition, it plays a role in the decaying of plant and animal structures and causes the release of elements such as nitrogen, potassium, iron, phosphorus, sulfur, etc. in organic structures. They produce inorganic substances and thus help plants to make photosynthesis. Fungi have properties to break down cellulose. They cause deterioration of plant structures (Weimer, 1996; Gücin ve Tamer, 1997; Pérez et al., 2002).

In addition, in our country and in the world is a significant amount of cultural mushrooms. It is widely cultivated in Europe and has a high consumption of culture mushrooms (Chang and Miles, 1984; Demir, 2010; Eren et al., 2017).

Due to the flora and climatic conditions of Turkey, it is rich in natural fungi that can be grown in different environments. For this reason, edible varieties of macro mushrooms are collected in many regions of our country during the season they are grown and used as food and also trade is also done (Işıldak et al., 2004). When the distribution of culture mushroom production in Turkey is examined, *Agaricus* species is ranked first with 86%, *Pleurotus* species second with 10% and *Lentinula edodes* third with 3% (Eren ve Pekşen, 2016; Eliuz, 2019). There are also very different uses of fungi (Kaşık, 2010; Anonim a, 2019; Anonim b, 2019).

- They are used as yeast in bakery and fermentation industry.
- They are used in alcoholic beverages industry.
- They are used for industrial production of citric acid.
- They are used in bread making.
- They are used in the construction of some types of cheese.
- They are used in making many useful antibiotics such as penicillin.
- They are used in the preparation of some vitamins such as Thiamin, biotin and riboflavin.
- They are used in the production of some enzymes (amylase, pectolase) and hormones (such as gibberellin).
- They are used in genetic studies (Neurospora fungus).
- They are used in the construction of agricultural medicine.
- They are used in the construction of biological weapons.
- They are used as food.

In addition, different characteristics of the fungus are discovered and new areas of use can occur. A plastic-eating mushroom species found in a dump in Pakistan's capital Islamabad has been discovered and it is argued that the fungus may be a solution to the growing plastic pollution. According to the report published by the Royal Botanic Gardens in London, the fungus can dissolve the plastic, which has been dissolved in nature for centuries, in weeks (Çevre Aktüel, 2019).

Results for chemical resistance applications of mushrooms

During the developmental adventure on earth, the human being explores and explores new sources (such as mushrooms) that grow naturally to treat both the food source and the health problems they face. However, during this research adventure, he also develops new inventions and new techniques. The use of mushrooms, which have been known for centuries, to be used within the scope of Environmental Engineering activities are also innovations in this field. There are studies to reduce or remove impurities by taking advantage of the absorption, retention or shredding properties of mushroom groups. Table 2 shows that different mushrooms are used in pollutant removal in different processes. In the studies, it is seen that heavy metal removal and high removal efficiency are obtained. In the research articles, the most preferred treatment process is the adsorption mechanism.

Mushrooms are used to remove pollutants from different environments such as water system (Law et al.,2003), industrial soils (Chiu et al., 2009), solution (Kumar et al., 2013), aqueous solution (Kamarudzaman et al., 2015; Kariuki et al., 2017), synthetic wastewater (Yang et al., 2017), Piggery wastewater (Yang et al., 2018), aqueous mixtures (Bettin et al., 2019).

Table 2. Pollutant removal studies with different fungi in the literature

Mushroom Name	Process	Parameters	Result of Removal, % or q_e	Optimization Criteria	Reference
Pleurotus pulmonarius	Sorption	Pentachlorophenol (PCP)	89.0±0.4%	C_0: 100 mg/L PCP, Time: 2 days	Law et al.,2003
Penicillium lanosa-coeruleum	Biosorption with Pretreatment	Cu(II) Lead(II) Ni(II)	>95%, 27%, 72%	T (^{0}C): 25, pH 6.8-7.2, Time: 180 min	İlhan et al.,2004
Botrytis cinerea (B. cinerea)	Biosorption	Cd(II) and Cu(II)	17.03 mg/g 9.23 mg/g	C_0: 150 mg/L pH:5 T (^{0}C): 25 Dosage: 2 g/L	Akar and Tunalı, 2005
PEI-modified biomass of P. chrysogenum	Biosorption	Cr(VI)	279.2 mg/g (5.37 mmol/g)	T (^{0}C): 25, pH 4.6, Time: 6 h	Deng and Ting, 2005
Phanerochaete chrysosporium	Batch Reactor	Remazol Yellow RR Gran, Remazol Red RR Gran, Remazol Blue RR Gran, KOİ, Aramatik Grup, Cu (II)	53.49%, 34%, 20% 93.6%, 22.3%, 56%	C_0:50 mg/L,	Demir et al., 2006
Ganoderma carnosum	Biosorption	Lead(II)	22.79 mg/g	Time: 10 min, pH:5 Dosage: 4 g/L	Akar et al., 2006
Fungal biomass	Biosorption	Cr(VI) and Cu(II)	74.58 , 58	Time: 60 min, pH:2 and 4, T (^{0}C): 25 Dosage: 4 – 3 mg/L	Razmovski and Sciban, 2008
Pleurotus pulmonarius	Biodegradation	TPH, oil and grease, phthalate	56–64%, 31–33%and 51–54%	3% SMC amendment	Chiu et al., 2009
ZnO nano-mushrooms	Photocatalysts, Photo-degradation	Methyl orange	92%	Time: 210 min	Kumar et al., 2013
Agaricus bisporus)	Adsorption	Basic Red 18, Levafix Braun E-RN, Acid Red 111	400, 169.5, 140.9 mg/g	Time: 4 h, pH:3 and 8, Dosage: 0.2 g	Toptaş, 2014
Pleurotus mushroom compost	Biosorption	Mn(II)	successfully	C_0: 10 mg/L Exhaustion time: 26.7 h,	Kamarudzaman et al., 2015
Lepiota hystrix	Batch adsorption	Lead(II), Cu (II)	3.9 and 8.9 mg/g	C_0: 300 - 500 µg/g Time: 24-40 min, pH: 4.5 and 6, Dosage: 2.1- 1.5 g	Kariuki et al., 2017
Rhizopus delemar	Adsorption	tetrasiklin	1.117 mg/g	pH: 4, T (^{0}C): 25	Kip and Açıkel, 2018
Flammulina velutipes, Auricularia polytricha, Pleurotus eryngii and Pleurotus ostreatus	Ion exchange, Adsorption	Copper (II), Zinc (II), Mercury (II)	73.11%, 66.67%, 69.35%,	Time:120 min, pH: 6	Li et al., 2018
Acinetobacter sp. TX5	Fixed-bed reactor	NH_4^+-N, TN, COD	89% 95% 82%	Time:8 h, pH: 7, Subunit mass: 65 kDa, Max rate: 35 µmol /min.mg	Yang et al., 2018
Pleurotus sajor-caju PS-2001	Stirred-tank bioreactor	phenol	69–76%	C_0: 1 mmol/L pH 6.5 T (^{0}C): 28.	Bettin et al., 2019

Discussion and conclusion

Our country has different climate zones due to its half-sphere and it enables to grow different types of mushrooms. We have seen that the fungus we use for the treatment of nutrients and diseases until this time has found its place in different engineering disciplines. In this research, the studies on the removal of some parameters that cause environmental pollution with the help of different fungi were examined. The obtained information and results show that the fungi have found a significant use in this area. In addition, the results of the research articles examined showed a high rate of pollutant removal. In the light of the information presented in this study, it was observed that parametre *Pleurotus* mushroom species were more preferred in these studies and high pollutant parameter removal was obtained. In the research articles, the most preferred treatment process is the adsorption mechanism. With the rapid development of the researches of molecular biology, biotechnology and environmental engineering science, it is seen that many ecological components naturally growing in nature will increase the use of environmental pollution prevention studies. Therefore, the importance of studying the fungus and providing them with different scientific fields will be very important.

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