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Earth Repair: Mycoremediation Phenomena

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Received: 8 March 2021 **Accepted: 3 May 2021**

DOI: https://dx.doi.org/10.24237/djps.17.03.554B

Abstract

Pollution has been increased recently due to the activities of industries and agriculture, especially pesticides, heavy metals, and other toxic compounds that are usually considered as carcinogenic and mutagenic, materials need a long time to be degraded into simple forms. Therefore, it is a crucial to eradicate such pollutants from environments in different mechanisms from which the possibility of using microorganisms such as fungi. This mechanism then would be called mycoremediation. Such process should be known and practice to achieve clean and healthy environments. In this review article, we shed light on the definition, applications, advantages, and disadvantages of mycoremediation.

Keywords: Mycoremediation, Mycofilteration, petrochemical, biodegradiation

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أصلاح الأرض: ظاهرة المعالجة الفطرية

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الخلاصة

من المعروف أن التلوث قد ازداد في العقود الماضية بسبب نشاط الصناعي والزراعي، وخاصة مبيدات الآفات والمعادن الثقيلة والمركبات السامة الأخرى التي عادة ما تكون معقدة، ومسببة للسرطان، ومطفرة، وتحتاج إلى وقت طويل حتى يتم تقسيمها إلى أشكال بسيطة. لذلك من الضروري القضاء على مثل هذه الملوثات من البيئة بآليات مختلفة يمكن من خلالها استخدام الكائنات الحية الدقيقة مثل الفطريات تسمى هذه الآلية بالمعالجة الفطرية. يجب أن تكون هذه العملية معروفة وممارسة من قبل العاملين لتحقيق بيئات نظيفة وصحية، في هذه المقالة سوف نلقي الضوء على تعريف وتطبيقات ومزايا وعيوب المعالجة الفطرية.

الكلمات المفتاحية: المعالجة الفطرية، التصفية الفطرية، البتروكيماويات، التحلل البيولوجي.

Introduction

Waste of agriculture and industries such as coal gasification, batteries, refinery, petrochemical industries is randomly extracted to our environment [53]. Chlorophenols, ethyl-benzene, nitro-phenols, polycyclic aromatic hydrocarbons, toluene, xylene, polychlorinated biphenyls, and organic solvents [18,19] are the main pollutants, which need a long time to be eradicated [54]. Many mechanisms can be taken into account to eradicate such pollutant; one of them is called bioremediation that use microorganisms to degrade these complexes [27]. Bacteria can degrade many of these pollutants; however fungi can be used to degrade or sequester recalcitrant contaminants using their enzymes in process called mycoremediation [55] that is safe and economic compared to physicochemical mechanisms [20] as some of these fungi can be hyperaccumulators of heavy metals [28]. Additionally, fungi' has a vital role in our ecosystem is decomposition [29]; therefore, mode of fungi's action in degrading pollutants is secreting enzymes from mycelium that can degrade lignin and cellulose which are the building blocks of plant fiber which resemble most organic pollutant structures [30]. It is essential to determine the appropriate fungi to metabolize specific pollutant. Many factors are taken into account in degradation such as pollutant nature, temperature, pH, and Oxygen [65]. Consequently, knowledge and practice are essential to apply mycoremediation in the field to get healthy environments [66]. In this review, we will talk about the mycoremediation concept and its beneficial applications in the biodegradiation of many pollutants that are considered to be toxic to human and animals, and finally, we will present the advantage and disadvantages of myco-remediation.

Mycoremediation

Mycologist Paul Stamets in 2005 [45] poses the statement of mycoremediation technology and its applications to the pollution of oil spills. This technology relates to the functionality of fungal mycelia [25] like in white rot fungi, brown rot fungi, and others [16]. It is however a new branch of bioremediation that has been practiced earlier of 20th century. Knowledge of this branch is weak and need to be applied in the field which considered as slow advancement [56, 31]. It has been revealed that there are 50 thousands of fungi species known, and they can live on different materials [32]. The exciting and dynamic approaches of Mycoremediation get a benefit of this variation in species and ability to breakdown and metabolize various compounds [61] White rot fungi, zygomycetes, ascomycetes and the brown-rot basidiomycetes have been used in this field widely [41] as they produce enzymes can break down lignin which resembles polycyclic aromatic hydrocarbons (PAHs) [6].

Mycoremediation vs. Mycofilteration

It is noteworthy to understand the other concept of mycoremediation that is called Mycofiltration [4]. It used to describe how to capture the pollutants in the mushroom forming fungi before reaching water [4]. This process resembles mycoremediation; however, it filters the pollutant water from dangerous waste by using fungal mycelia [5]. First using was to control *Escherichia coli* in the water outflow, leading to eliminate the presence of coliforms in water. The mode of action here is that mushroom producing fungi excrete crystalline entities during the mycelium growth which can sense the presence of *E. coli*, leading to signal back to fungi which in turn produce macro crystals that attract these bacteria and let them be consumed [10]. Another example of microfilteration is the control of *Plasmodium falciparum* by *Polyporus umbellatus* [28]. Also, it can be used to filter gold particles from electronic waste by underground parts of specific fungi [33]. Mycofiltration is known to be economic, low impact, and small installation space [43].

Advantages of Mycofiltration

They are a) sediment containment, b) moisture and habitat recovery enhancement, c) reduction of hydrocarbon, some pathogens, and temperature, d) minimal disturbance of pollutants, e) subsurface penetration by mycelium, and f) aesthetic enhancement [1, 34]

Types of Mycoremediators

Fungi used as mycoremediators are presented in table 1 [53, 27, 29; 16].

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Table 1: Fungi used as mycoremediators

Fungi Species	Contaminants
Shaggy Mane	arsenic, cadmium, and mercury
Elm Oyster	Dioxins, wood preservatives
Phoenix Oyster	TNT, cadmium, mercury, copper
Pearl Oyster	PCB's, PAH's, cadmium, mercury, dioxins
King Oyster	Toxins, Agent Orange
Shitake	PAH's, PCB's, PCP's
Turkey Tail	PAH's, TNT, organophosphates, mercury
Button Mushrooms	Cadmium
King Stropharia	*E-coli* and other biological contaminant
Lentinula edodes	2,4- dichlorophenol
Pleurotus pulmonarius	Radioactive cellulose-based waste
Jelly sp., *Schizophyllum commune* and *Polyporous* sp.	malachite green
Pleurotus pulmonarius	Crude oil
Pleurotus ostreatus	Oxo-biodegradable plastic
Coriolus versicolor	PAH
Phanerochaete flavido-alba	olive oil mill wastewater

Applications of mycoremediation

Temperature, pH, water content, macro and micromolecule, and redox potential of soil effect on microbial growth hence on bioremediation [21]; however, mycoremediation has a wide range of applications [*48*, 24] like: 1) Industrial wastewaters, 2) Distillery and brewery wastes, 3) Petroleum hydrocarbons, 4) Pesticides, 5) Dyes, 6) Pulp and paper mill effluent, 7) Munitions wastes including TNT, 8) Bleach plant effluent, 9) Wood preservatives, 10) Organochlorins, 11) Biological treatment of soil and water: Killing pathogens

Some examples of mycoremediation applications are:

1- Dye containing effluents remediation

Many factors affect this type of remediation, for example agitators, pH, temperature, and concentration [33]. It has been known that enzymes extracted by fungi (white rot) can decolorize xenobiotic compounds including dyes by bio-sorption, bio-degradation, different designs of reactor, and immobilization of cells [43]. It is revealed that these enzymes are grouped into peroxidase and laccase. Dye removal by biosorption has been depending on dye molecule function group and on the structure. Decolorization by living cells depends on the adsorption and fungal catabolism [39]. Immobilized fungal cells have several advantages like reusable biomass, easy separation, and no aggregation in continuous-flow systems, tolerating pH and highly toxic compounds exposure [34]. Besides, *Aspergillus niger* also can be used as adsorbent of dye pollutant [39].

2- Pesticides remediation

Different kinds of pesticides could be used worldwide in agriculture to improve crop productivity and quality [62]. It is known that the wide spread and different structures of pesticides would be found in soil, water, and even air; leading to concern of their potential environmental hazard [8]. The effect of these chemicals on environment is predicted to be dangerous since they can affect denitrifying bacteria, fungi, biodiversity reduction, and surface and ground water pollution [1]. There is globe concern of ground water pollution with these chemicals and byproducts in areas depending on them for drinking [49]. The main source of pesticide contamination is the poor pesticide management on farm [49], leading to increase the concentration of these hazardous chemicals within environment, and this would need fast remediation before contaminating other sensitive area. It is revealed that if a concentration of pesticide be more than (1 mg kg soil^{-1}) [15], remediation would be necessary as this concentration is considered as a trigger concern of pesticide pollution [22]. It is agreed that the concentration of pesticides 0.1 µg kg soil^{-1} and 0.5µg kg soil^{-1} in water and other materials is allowed for human consumption and prohibited if this range exceeds [50]. It has been studied that *Penicillium chrysosporium*, *Lentinus edodes*, and *P. steckii* are good examples of degrading organopollutants, pentachlorophenol, and Simazine in high rates reach to more than 60%, especially when carbon added to the media [44].

3- Chemicals remediation

As mentioned earlier, highly recalcitrant compounds are thrown by industries [2] from which polycyclic aromatic hydro-carbons are considered a challenge to eliminate since behaving as a potent teratogen, mutagen and carcinogen, and also their low solubility would reduce the bioavailability of them [26]. Different strategies are used to remediate environment from such pollutant, including microorganisms' usage such as *Phanerochaete chrysosporium, Irpex lacteus, Stropharia coronilla* [3], *Pleurotus ostreatus* and others [44] which produce enzymes like Manganese-Peroxidase, lignin-Peroxidase, and Laccase could degrade high molecular weight such as polycyclic aromatic hydrocarbons PAHs [2, 26].

4- Pathogens removal

Generally, fungi can kill bacteria via producing antibiotics as Fleming discovery [45]. Therefore, it is worthy to remediate pathogen contaminated environments by fungi such as Basidiomycota that live on nematodes, bacteria [3]. The genus *Pleurotus ostreatus* decomposes fecal coliform bacteria as a source of nitrogen [12]. Also, *Agaricus bisporus* that can be used for human consumption produces extracellular enzymes killing gram positive and gram negative bacteria [14]. Different fungi exhibit ability to sense the presence of bacteria in the pollutant areas, and then secrete compounds to digest the bacterial colonies [57]. Other strategy is to aggregate motile bacteria around crystals produced by fungal species in order to immobilize and digest [21]. It is found that there is 50% reduction of fecal coliform concentration waste of horse runoff before reaching water stream [58, 23; 63]. This could be achieved by passing the waste through fungal enhanced wood chips in a process called mycoremediation [36, 37].

5- Heavy metals remediation

It is well studied that fungal mushrooms have the ability to accumulate heavy metals in their fruit body, even the edible kinds [2, 26]. Also, high concentrations of heavy metals could be found in mashrooms rather than vegetables and fruit [52]. Therefore, this property led to be an advantage of eradicate such carcogenic metals from our ecosystem. The process includes cultivation of mushroom containing fungi on pollutant area with heavy metals to use them as substrate and ending with clean area [59, 13]. Also, mushrooms are used to estimate pollution level in a specific area and the possibility danger to mankind health [38, 46]. It is demonstrated that heavy metals can aggregate in the spore forming cap but not the rest of it [17, 7], and the rate of accumulation is depending on the long of mycelium with soil and soil factors like organic matter content redox potential, pH, clay mineralogy, and even competition with other metal ions found in soil [47, 42, 11].

Advantages and disadvantages of mycoremediation

It is revealed that this process is safe, accepted, inartificial, not noisy, end products can be used, and does not need high maintenance, not expensive, and no time consumption [64]. However, as with any technology, there are drawbacks as well: Still in testing, Applicability, Efficiency level, environment [60].

Conclusion

We shed light in this review on mycoremediation as a new branch of bioremediation and its applications in treating environments, and also, we presented some of fungi's mechanisms of remediation. The advantages and disadvantages were also mentioned. Indeed, this process appears to be useful to be applied to get clean environments.

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