APPLICATION STRATEGIES FOR USING FUNGI AND ALGAE AS BIOREMEDIATORS: A REVIEW

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Abstract
Bioremediation is a process by which microorganisms or their enzymes have uses to enhance break down of contaminants in order to remove them from the environment, these contaminants are derived from industrial or agricultural sources and contaminates the environments, these pollutants are possessing potential health impacts like carcinogenic and mutagenic, since these pollutants characterized with slow degradation and long period environmental persistence. For previous reasons, the removal of such toxic substances from polluted areas is persistently of great importance, some of organic pollutants are difficult to degrade by bacteria, so that algae and fungi reported as potential bioremediation agents for theses hard contaminants.

In this review, authors displayed many application strategies for both mycoremediation and phycoremediation, explaining the major factors affect the ability and rate of both previous processes and attempt to summarize the possible advantages and drawbacks of use fungi or algae as bioremediation agents from the current review, we concluded that using of algae and fungi to sequester or degrade the contaminants from an ecosystem is considering a biological strategy with many advantages such as eco-friendly, low cost and efficient to get rid of pollutants which difficult to degrade, in spite of high efficiency of both algae and fungi in bioremediation, genetic engineering techniques are needed to improve algal and fungal strains efficiency and further studies are needed to understand the optimum environmental conditions for these organisms and to discover new strategies to clean up most difficult contaminants.

Key words: phycoremediation, heavy metals, mycoremediation, decomposition.

Introduction
The increasing of agricultural and industrial activities, particularly in the last decades, have led to the significant increase in the concentration of toxic compounds that contaminate the environments. Among manufactured substances the most hazardous are nitrophenols, chlorophenols, benzene compounds, xylene, toluene, polycyclic aromatic hydrocarbons (PAHs) and organic solvents (Wasilkowski et al., 2012).

The major sources of these pollutants in wastewaters, soil, petrochemical and batteries processing plants, as well as synthetic chemicals i.e. pesticides and herbicides. Many of these chemicals are possessing potential health impacts like carcinogenic and mutagenic, since these pollutants characterized with slow degradation and long period environmental persistence. For previous reasons, the removal of such toxic substances from polluted areas is persistently of great importance (Menn et al., 2012).

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**Mycoremediation**

According to (Wasilkowskid et al., 2012), mycoremediation known as a process by which fungi brake down or sequester pollutants in certain ecosystem. Stimulating fungal enzymatic activity, mycelium reduction of toxins by fungal mycelium in-situ. Some fungi have capability of absorbing and concentrating heavy metals within the fruit bodies of mushroom, these fungi known as hyperaccumulators (Menn et al., 2012). Decomposition is one of the important roles of fungi in the environment, which is achieved by fungal mycelium. The mycelium produce secretion of http://en.wikipedia.org/wiki/Acid compounds and extracellular enzymes that degrade cellulose and lignin, the two major building units of plant fiber. These are organic substances consisting of long hydrogen and carbon chains, their structures are similar to many organic contaminants. The key to remediation using fungi is determining the suitable fungal species to target a certain contaminant.

As mentioned in (Thomas et al., 2009), Mycoremediation is an novel biotechnology that uses specific living fungal species for both ex-situ and in-situ management as well as cleanup of contaminated locations. This technology is an environmentally and economically sound complementary conventional management for toxic waste (extracting and transporting). Mycelia can degrade these potential toxins in the soil before they enter our dietary supply (Singh, 2006).

There are many factors that affect the rate and fungal ability for decompose contaminants as displayed in (Table 1). (Sasek, 2003).

White rot fungi’ is group of fungi that concerned with the most developed branch of mycoremediation. This type of fungi are taxonomically and more physiologically similar fungal group that secrete enzymes which decompose lignin and other similar multi-chained substances like PAHs (polycyclic aromatic hydrocarbons) that chemically similar to lignin, for this reason white rot fungi produce enzymes are also able to decompose hydro carbonic pollutants (Sasek, 2003). Another groups of fungi have been identified as potential decomposers of polycyclic aromatic hydrocarbons are ascomycetes, zygomycetes and the brown-rot basidiomycetes (Thomas et al., 2009).

**Application of mycoremediation**

It is known that mycoremediation biotechnology has a varieties applications as presented bellow:

**Mycofiltration:** Mycofiltration is defined as uses of fungal mycelia to filter toxic contaminants and microorganisms from water bodies, in this technique mushroom-forming fungi produce a web-like tissue, this tissue capable to capture and break down environmental contaminants before they can reach sensitive water bodies. (Lovy et al., 1999).

**Treatment of effluents containing colorants:** In this process lignin-degrading enzymes that produces by fungi decolourize different textile stains, White rot fungi like Aspergillus niger are the most deeply examined as decolorizing fungal group to uptake or adsorb dye by their mycelia without true degradation. Several physical factors affects decolourization rate such as temperature, pH concentration of dye and agitators. (Ramachandran and Gnanadoss, 2013).

**Pesticides treatment:** Surface water and groundwater may contaminated with pesticides when there is excessive concentration of a pesticide or its metabolic wastes or by-products in this case remediation is necessary to prevent migration to a more sensitive locations of the ecosystem Phanerochaete Chrysosporium was the first fungal strain to be concerned with organo pollutants degradation and it has been deeply studied as a model organism for lignin degradation mechanism.

**Lentinusedodes** mushroom has been authenticated to remove up to 60% of pentachlorophenol from soil. Penicillium steckii, also isolated from samples of soil where the Simazine herbicide had been spread. (Fragoeiro, 2005).

**Pathogens treatment:** Mycoremedation also considering one of the cleanup strategy to remove different pathogens from an ecosystems. Fungi have long been identified as antibiotics producers that possess bactericidal activity. Various fungal species, especially the wood-degrading Basidiomycetes, are predates

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<tr>
<th>Factor</th>
<th>Effect on pollutant degradation rate of fungi</th>
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<tr>
<td>Physical nature of pollutant</td>
<td>Simple molecular contaminants are easier to degrade than more complicated ones</td>
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<tr>
<td>Temperature</td>
<td>This factor also controls the rate of contaminants break down (high temperatures speed the process whereas the lower temperatures slow it up).</td>
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<tr>
<td>pH of fungal environment</td>
<td>Fungi usually prefer a pH between 4 to 5</td>
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<tr>
<td>Oxygen</td>
<td>Oxygen is required to fungal metabolism pathways.</td>
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<tr>
<td>Fungal strain</td>
<td>There is large diversity between strains of fungi, with different strains able to degrade and metabolize different polluted substances.</td>
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*Table 1*: Factors that affect the rate and fungal ability for decompose contaminants.
nematodes and bacteria, another example, the oyster mushroom (*P. leurotusostreatus*), typically predator of fecal coliform bacteria as a nitrogen source. (Thomas et al., 2009).

Heavy metals treatment: Many researches have dealt with of mushrooms metal contents, particularly edible types. It has been shown that concentrations of heavy metal in mushroom are significantly higher than those in other plants, this led to suggestion that mushrooms possess a potential mechanism that enables them to take up some heavy metals from the environment (Okparanma et al., 2011).

Because macrofungi are fundamental part of the forest environment, sometimes the metals have transferred from soil-to mycelium through the relationship between symbiotic plants and mycelium (Asiriuwa et al., 2013).

The advantages and limitations of mycoremediation

There are several advantages of using this biotechnology over commercialized strategies, including Safety, communal acceptance, unobtrusive technology, Low maintenance, recyclable end products and not expensive cleanup technology nevertheless, like any technology, there are limitations as well: Still in testing and as with any Biological systems its efficiency level are never 100% (Anon, 2014).

**Phycoremedation**

Phycoremediation is another environmental biological cleanup technology involving in use of micro- or macro-algae for the diminution or biologically transformation of contaminants, including nutrients such as inorganic and organic carbon, Phosphorous, Nitrogen, sulfates, heavy metals etc.

The idea of Phycoremediation is that during this strategy, micro algae utilize nitrogen, phosphorus, carbon, dangerous chemicals and other salts from the waste water as source of nutrients for these organisms. (Verma et al., 2018). algal blooms has usually shown in untreated wastewater, this phenomenon is as results of the presence of excess nitrogen or phosphorus in water (eutrophication), uncontrolled spread of these aquatic algae leads to oxygen depletion and loss of essential flora and fauna within water bodies, leading to the gradual loss of water bodies (Khan and Ansari, 2005). So that, there is a serious need to find rapid, cost-effective, eco-friendly strategies and easy achieved by the common population or less learned man.

There are many factors that affect the rate and ability for algae to break down contaminants as displayed in (Table 2).

**Applications of phycoremedation**

Municipal wastewater treatment by using microalgae: This cleanup strategy has been a research subject for many decades (Oswald, 1988). Several species of microalgae are effective in the nutrients removal especially nitrogen and phosphorous from wastewater, as well as several species flourish in wastewaters due to C, N and P abundance that act as essential elements for their growth. Although, the microalgae ability of wastewater treatment differs between genera and between different points of wastewater treatment plant, (Renuka et al., 2015).

The previous author estimated the efficiency of nutrient removal of *Chlorella* sp. in wastewater specimens collected at different locations of wastewater treatment plant. It was shown that maximum removal of NH4-N(82.4%) was calculated in wastewater collected before primary settling, while maximum removal of PO4-P(90.6%) was calculated in wastewater after primary settling.

Li et al., (2011) observed a potential growth of *Chlorella kessleri* and *Chlorella protothecoides* in municipal wastewater.

Heavy metal removal by microalgae in wastewater: The algae demonstrated to be active in heavy metals accumulation also in xenobiotics degradation (Suresh and Ravishankar, 2004).

In recent years, the phycoremediation of colored wastewater has concerned great attention due to their essential role in fixation of CO₂. In addition, the produced algal biomass has immense potential as feedstock for biofuel generation (Huang et al., 2010). The heavy metals

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<td>Algal strain</td>
<td>Algae ability to remove pollutants i.e.,( heavy metals) varies with the various algal strains as a rule in the following descending order: green algae (Chlorophyta), brown algae (Phaeophyta) and red algae (Rhodophyta) (Al-Shwafi and Rushdi, 2008).</td>
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<tr>
<td>Algae physiological state</td>
<td>As reported by (Mehta and Gaur, 2005), that the biomass of lifeless algae adsorbs more pollutants than living algae.</td>
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<td>Seasons of the year</td>
<td>Seasons of the year can greatly influence the removal of contaminants, this may due to physical parameters like temperature and light intensity. Algae are so sensitive to change in these parameters with different seasons (Bwapwa et al., 2017)</td>
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presence in municipal wastewater in combined with the nutrients is a matter of concern, because microalgae can segregate these substances (Mani and Kumar 2014). So that these heavy metals interfere with the macronutrients uptake by microalgae, (Levy et al., 2005). However, if present in very small amounts, some of these metals (Cd, Cu, Pb etc.) may serve as micronutrients for enhancement of microalgae growth. (Renuka et al., 2014).

Phycoremediation of petroleum hydrocarbons: The bioremediation strategy offers a promising method to treat oil-contaminated shore lines, this is accomplished by bacteria, fungi and algae that produce several enzymes capable of degrading harmful organic substances (Chekroun et al., 2014).

(Yuste et al., 2000). Reported that since the use of bacteria to degrade hydrocarbon in oil contaminated areas does not guarantee to get rid of all compounds of crude oil because some compounds are difficult to break down, but some enzymes yielded from microalgae capable of degrading dangerous organic substances to convert the petroleum hydrocarbons into less toxic substance.

The green alga Scenedesmus obliquus is an example of alga that used to construct an artificial microalgal-bacterial association for degradation of crude-oil (Tang et al., 2010).

Phycoremediation of Pesticides: In this field green alga Chlamydomonas reinhardtii showed potential ability to accumulate and break down the herbicide (prometryne) within aquatic ecosystems (Jin et al., 2012).

The advantages and limitations of phycoremediation

Phytoremediation using algae, also termed as phycoremediation, has the many advantage especially when micro algae is used (Christenson and Sims, 2011).

These advantages summarized with rapid remediation because of the high growth rates of microalgae, environmental cleanup with lower energy and costs because of autotrophy and volume reduction of polluted area because of the simple structure and single cellular nature of microalgae.

Also there are several limitations to use microalgae as bioremediation agent. Such limitations, as difficulty of algae biomass separation and harvesting from water body, less efficiency of phycoremediation in cold climate and the ability of algae biomass to diminish micropollutant content (Lavrinoviès and Juhna, 2017).

References


