Plant Archives Vol. 20 Supplement 1, 2020 pp. 788-792 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

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

Raghad J. Fayyad*, Sahira Nsayef Muslim and Alaa Naseer Mohammed Ali

Biology Department, Collage of Science, Mustansiriyah University, Iraq.

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 leaded 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 (Wasilkowskid *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). 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, the ability of microorganisms to metabolize and degrade the environmental contaminants provides a safe and economic alternative methodology compared to other physicochemical technologies (Perpetuo *et al*., 2011). As reported in previous lectures that the use of bacteria in bioremediation is useful to remove some pollutant, but not the obstinate contaminants that is difficult to be break down. Bioremediation using fungi (mycoremediation) and algae (phycoremediation) is commonly used to degrade the recalcitrant pollutants.

Therefore, this review considers an attempt to summarize the possible applications which use fungi or algae as bioremediation agents as well as displaying the advantages and drawbacks of using these organisms in this ecologically important process.

****Author for correspondence :*** E-mail: raghadjasim@uomustansiriyah.edu.iq

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

Table 1: Factors that affect the rate and fungal ability for decompose contaminants.

Factor	Effect on pollutant degradation rate of fungi
Physical nature of pollutant	Simple molecular contaminants are easier to degrade than more complicated ones
Temperature	This factor also controls the rate of contaminants break down (high temperatures speed the process whereas the lower temperatures slow it up).
pH of fugal environment	Fungi usually prefer a pH between 4 to 5
Oxygen	Oxygen is required to fungal metabolism pathways.
Fungal strain	There is large diversity between strains of fungi, with different strains able to degrade and metabolize different polluted substances.

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 a 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 CO_2. In addition, the produced algal biomass has immense potential as feedstock for biofuel generation (Huang *et al*., 2010). The heavy metals

Table 2: Factors that affect the rate and ability for algae to break down contaminants.

Factor	Effect on pollutant degradation rate of algae
Algal strain	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).
Algae physiological state	As reported by (Mehta and Gaur, 2005), that the biomass of lifeless algae adsorbs more pollutants than living algae.
Seasons of the year	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)

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 micro algae, (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 microalga, 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

Al-Shwafi, N.A. and A.I. Rushdi (2008). Heavy metal concentrations in marine green brown and red seaweeds from coastal waters of Yemen, the Gulf of Aden. *Environ. Geol*., **55:** 653-660.

Anon, I. (2014). The pros and cons of Mycoremediation. Radical Mycology Convergence.

Asiriuwa, O.D., J.U. Ikhuoria and E.G. Ilori (2013). Remediation Potential of Heavy Metals from Contaminated Soil. ll. *Env. Pharmacol. Life Sci*., **2(5):** 16-22.

Bwapwa, J.K., A.T. Jaiyeola and R. Chetty (2017). Bioremediation of acid mine drainage using algae strains: A review, *south african journal of chemical engineering*., **24:** 62-70.

Chekroun, K.B., E. Sánchez and M. Baghour (2014). The role of algae in bioremediation of organic pollutants. *International Research Journal of Public and Environmental Health*., **1(2):** 19-32.

Christenson , L. and R. Sims (2011). "Production and harvesting of microalgae for wastewater treatment, biofuels and bioproducts," *Biotechnology Advances.,* **29(6):** 686-702.

Fragoeiro, S. (2005). Use of fungi in bioremediation of pesticides. Applied Mycology Group Institute of Bioscience and Technology., 1-241.

Huang, G., F. Chen, D. Wei, X. Zhang and G. Chen (2010). Biodiesel production by microalgal biotechnology. *Appl. Energ*., **87:** 38-46.

Jin, Z.P., K. Luo, S. Zhang, Q. Zheng and H. Yang (2012). Bioaccumulation and catabolism of prometryne in green algae. *Chemosphere*., **87:** 278-84.

Kim, J., B.P. Lingaraju, R. Rheaume, J. Lee and K.F. Siddiqui (2010). Removal of ammonia from wastewater effluent by Chlorella vulgaris. *Tsinghua Sci Technol*., **4:** 391-396.

Lavrinoviès, A. and T. Juhna (2017). Review on Challenges and Limitations for Algae-Based Wastewater Treatment. *Construction Science*., **20:** 17-25.

Li, Y., Y. Chen, P. Chen, M. Min, W. Zhou, B. Martinez, J. Zhu and R. Ruan (2011). Characterization of a microalga Chlorella sp. Well adapted to highly concentrated municipal wastewater for nutrient removal and biodiesel production. *Bioresour Technol*., **102:** 5138-5144.

Lovy, A., B. Knowles, R. Labbe and L. Nolan (1999). "Activity of Edible Mushrooms Against the Growth of Human T4 Leukemic Cancer Cells, HeLa Cervical Cancer Cells and Plasmodium falciparum", *Journal of Herbs, Spices and Medicinal Plants*., **6(4):** 49-58.

Mani, D. and C. Kumar (2014). Biotechnological advances in bioremediation of heavy metals contaminated ecosystems: an overview with special reference to phytoremediation. *Int. J. Environ. Sci. Technol*., **11:** 843-872.

Mehta, S.K. and J.P. Gaur (2005). Use of algae for removing heavy metal ions from wastewater: progress and prospects. *Crit. Rev. Biotechnol*., **25:** 113-152.

Menn, F.M., J.P. Aster and G.S. Sayler (2012). Genetically Engineered Microorganisms and Bioremediation., 443-457.

Okparanma, R., J. Ayotamuno, D. Davis and M. Allagoa (2011). Mycoremediation of polycyclic aromatic hydrocarbons (PAH)-contaminated oil-based drill-cuttings. *African Journal of Biotechnology*., **10(26):** 5149-5156.

Oswald, W.J. (1988). The role of micro algae in liquid waste treatment and reclamation. In: Lembi CA, Waaland JR (eds) Algae and human affairs. Cambridge University Press, Cambridge., 225-281.

Perpetuo, E.A., C.B. Souza and C.A. Nascimento (2011). Engineering bacteria for Bioremediation. Progress in Molecular and Environmental Bioengineering-From Analysis and Modeling to Technology Applications., 605-632.

Ramachandran, R. and J. Gnanadoss (2013). Mycoremediation for the treatment of dye containing effluents. *International Journal of Computing Algorithm*., **(2):** 286-293.

Renuka, N., A. Sood, R. Prasanna and A.S. Ahluwalia (2014). Influence of seasonal variation in water quality on the microalgal diversity of sewage wastewater. *S. Afr. J. Bot*., **90:**137-145.

Renuka, N., A. Sood, R. Prasanna and A.S. Ahluwalia (2015). Phycoremediation of wastewaters: a synergistic approach using microalgae for bioremediation and biomass generation, *Int. J. Environ. Sci. Technol*., **12:**1443-1460.

Sasek, V. (2003).Why Mycoremediations Have Not Yet Come Into Practice in The Utilization of Bioremediation to Reduce Soil Contaminants: Problems and Solutions., eds. V. Sasek, J.A. and Baveye, P. 19th edn, Kluwer Academic, *The Netherlands.*, 247-263.

Singh, H. (2009). Mycoremediation: Fungal Bioremediation, 1st edn, Wiley-Interscience, New Jersey.

Suresh, B. and G.A. Ravishankar (2004). Phytoremediation-A Novel and Promising Approach for Environmental Clean-up. *Crit. Rev. Biotechnol*., **24:** 97-124.

Tang, X., L.Y. He, X.Q. Tao, Z. Dang, C.L. Guo, G.N. Lu and X.Y. Yi (2010). Construction of an artificial microalgal-bacterial consortium that efficiently degrades crude oil. *J. Hazard. Mater*., **181:** 1158-62.

Thomas, S.A., L.M. Aston, D.L. Woodruff and V.I. Cullinan (2009). Field Demonstrations of Mycoremediation for Removal of Fecal Coliform Bacteria and Nutrients in the Dungeness Watershed Washington. EPA Targeted Watershed Grant Program., 1-32.

Verma, K., K. Pooja, D. Bhagawan, V. Himabindu and S.V. Krishna (2018). Phycoremediation of sewage wastewater and industrialflue gases forbiomass generation from microalgae. *South African journal of chemical engineering.,* **25:** 133-146.

Wasilkowskid, D., Z. Swedziol and A. Mrozik (2012). The applicability of genetically modified microorganisms in bioremediation of contaminated environments. *Journal of Science*., **66(8):** 817-826.

Yuste, L., M.E. Corbella, M.J. Turiegano, U. Karlson, A. Puyet and F. Rojo (2000). Characterization of bacterial strains able to grow on high molecular mass residues from crude oil processing. *FEMS Microbiol. Ecol*., **32:** 69-75.