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Bioremediation of Industrial Effluents using Arbuscular Mycorrhizal Fungi

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Mother Nature can feed us but human appetite is uncontrollable. The rapid expansion and sophistication of industries over the last thirty years in increasing amount has contributed to enormous waste effluents and their untreated escape in environmental bodies is causing pollution and imbalance in ecosystem. To reduce impurities and prevention from ill effects in nature scientists have developed eco friendly techniques and bioremediation has emerged as a clean and green technology as it employs use of microorganisms like fungi and bacteria to restore environment from contaminants like petroleum products, heavy metals, weedicides, sludge waste, textiles, fly ash, paper and pulp effluents. Technologies like Phytoremediation, Phytostabilization, Bioaugmentation, Phytoextraction, Rhizofiltration, Biosorption, Biostimulation, and Hyperaccumulation have substantiated effects in amelioration of environment. The promising technique is Mycoremediation incorporating the removal or requisition of toxic compounds employing fungi, an efficient tool as it shows tolerance to extreme physical and chemical conditions, easy large scale fermentation, and most important its symbiotic association with plants and contribution in nutrient increase in biogeochemical cycles. Arbuscular Mycorrhizal Fungi are vital soil microbes proven benefits in increased yields, crops quality, stress tolerance and capturing of heavy metals.

Key words: Bioremediation, Arbuscular Mycorrhizal Fungi, Industrial Effluents, Heavy Metals.

Bioremediation technology has emerged as a potent tool because of its ability to remove or reduce pollutants but also for abolition of unwanted substances from soil, air, water and from industrial effluents using bacteria, fungi and other biological agents (EPA 2012)[1]. The technique work by digesting the contaminants into its reduced or simplest form called biodegradation which are not degradable on its own example dyes. The basic characterization involves *in-situ* and *ex-situ* bioremediation where the former calls treatment on the site and latter away from the site which can be anywhere (EPA 2012)[1]. The factors required for bioremediation includes existence of microbial populations capable of degrading the pollutants, the availability of contaminants to microbes and optimized environmental constraints like pH, temperature, acidity, alkalinity and oxygen[2]. Since bioremediation seems to be a good alternative to conventional clean-up technologies; substantial research in this field is rapidly increasing[3]. The pollution from emancipation of industrial process like paper and sugar mills, engineering industries, pharmaceuticals industries, leather and tanning

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industries, cement industry, electroplating industry, agrochemical based products solid and hazardous wastes containing Copper, Nickel, Lead, Zinc, Iron, Chromium and their retention in water and soil is troublesome to humans and environment[4]. Successful treatments using bioremediation has been carried on Industrial Wastewater[4], Polycyclic aromatic hydrocarbons[5], Pesticides[6], Dyes[7], Paper and pulp effluents[8]. Mushrooms have also proven as effective machinery for mycoremediation of waste and other pollutants namely *Pleurotus, Agaricus, Ganoderma and Schizophyllan* commune[9, 10, 11.] Also there is crucial role of AMF in soil amendment especially in moderation of heavy metals and AMF express pure soil and plants roots and shoots associations and also encourage nutrient and biomass augmentation[12].

Use of Bioremediation for industrial effluents

Biostimulation incites the production of enzymes by microbes already available in soil and environmental factors motivate the above process by supply of carbon, nitrogen and phosporus[2]. Also metals removal is seen from the food chain by being bound to the secretions produced by many algae and bacteria which attract metals that are toxic in high levels [13]. Genetically modified microbes like Mercury resistant bacteria use *mer* operon for waste water treatment [14]. A fresh strain of *Psuedomonas putida* SP-1 has been isolated for marine area clean-up which can volatilize mercury up to 100 % [15]. Bioremediation of steel effluents by *Bacillus*, *Pseudomonas*, *and Arthrobacter* and *Micrococcus* species; when employed; biochemical tests showed 95% reduction in Chemical Oxygen Demand and Biochemical Oxygen Demand level. Thus, bacterial species can be utilized for bioremediation of steel effluents [17]. Phycoremediation using microalgae; *Chlorella minutissima, Scendesmus spp.* & BGA *(Nostoc)* grows well in polluted habitats of sewage water and causes gradual decrease in BOD, COD, and Total Dissolved Solids and also work as antileachates for nitrogen compounds and used for algal manure [4]. Textile industry effluents treatment by *Aeromonas hydrophila* can decolorize three triarylmethane dyes; Basic violet 14, Basic violet 3, and Acid blue 90 up to 96%[7]. The classification of fungi as in relation to the remediation process involved are Lignolytic fungal degradation, Soil fungal Biosorption and Mycorrizal fungal degradation are as follows-

Lignolytic fungal degradation

Lignin degradation is important for Carbon sequestration, useful in paper-pulp industries and crude oil deposits. The fungi are *Basidiomycets*[18] and produces a series of enzymes laccases, peroxidases, Hydrogen Peroxide, Reactive oxygen species to catalyze oxidation of xenobiotics by cleavage of carbon-carbon and oxygen-oxygen bonds[19]. Some examples are *Phanerochaete chrysoporium*[19], the brown rot fungi *Agaricomycetes* related with conifers and causes partial oxidation, demethylation but considered in preferential biodegradation[20].

Soil fungi biosorption

Many soil residing fungi are useful for heavy metal absorption. Some examples are *Saccharomyces cerevisiae* that can absorb Pb (92%), Au (100%), Mo(68%), Co and Cu effectively[21], *Mucor spp., Aspergillus(A.niger* absorbs nickel at a very high concentration, Ar (75%), *A. carbonarius, Rhizopus spp., Botrytis cinerea, Neurospora crassa*[23], *Penicillium* strains *like P. simplicisimmum* to remove Pb (ii) ,Cd(II), Zn(ii), Cd(ii); are potent producers of cellulose, pectinase and mannase for removal of agricultural wastes in form of phenols and halogenated compounds[23].

Mycorrhizal fungi

The mycorrhizal fungi are a symbiotic association between a vascular plant roots and fungi forming unique structures called arbuscules which are site of exchange of Phosphorus, carbon, water and other nutrients. They are commonly divided into Ectomycorrhizas and Endomycorrhizas. The former hyphae do not penetrate cells in the root and in latter the hyphae penetrates cell wall and invaginates the cell membrane [24]. Endomycorrhizal fungi include Arbuscular, Ericoid, Orchid and Arbutoid as Ectoendomycorrhizas[24]. Monotropoid includes a special category. Ericoid mycorrhizas have noticeable saprophytic characteristics which helps plants to receive nutrients from unrecompensed matter [25]. Arbutoid Endomycorrhizal fungi found in plant order *Ericales* and genera *Arctostaphylos* and *Arbutus*. The fungal hyphae form a Hartig net into outer cortical cells, and allow transfer of nutrients from the fungi to plants and vice-versa

(Moore 2013). Monotropoid mycorrhizal fungi are a non-mutualistic parasitic interaction where plant orders *Ericaceae* and plants are hetrotrophic and mixotrophic to obtain carbon from fungi partner (Moore 2013). In orchids, the hyphae penetrate cells of embryo form hyphal coils within cells and obtain Phosphorus and Nitrogen (Moore 2013) http://microbewiki.kenyon.edu/index.php/Endomycorrhizal_fungi.

Role of Arbuscular Mycorrhizal Fungi in Bioremediation of Industrial effluents

Heavy Metals are accumulated by the fungal hyphae are transported to the plant, root-to-shoot transport (Phytoextraction) and Heavy metals seizing within the soil (Phytostabilization). Mycosorption of heavy metals in contaminated soils using AM plants show good accumulation in comparison to non-AM plants[26]. *Paspalum conjugatum L.* association with mycorrhiza in gold mining areas in Indonesia for Hg treatment was extensively studied [26]. Treatment of alkaline soil contaminated by petroleum effluents using AMF along with plant growth promoting bacteria in oat plants by reducing dangerous Hydrocarbons is also observed in recent investigations[27]. Another inference for treatment of crude oil contaminated soil on *Phaseolus vulgaris* with AMF when increased production of oxidative enzymes was seen [28]. Though White rot fungi *Coriolopsis rigida* strain LPSC no 232 degrades lignin, dyes, and aliphatic crude oil fractions but when supplemented with AMF, enhanced nutrient content and plant growth was observed[29]. Also, Copper and Cadmium uptake in heightened amounts in the roots of *Aster tripolium L.* with AMF came into notice in comparison to uninoculated plants of AMF[30].

Future Perspectives

As we have seen that continuous and intensive urbanization is causing harsh environmental effects, control and amendment of industrial effluents is inevitable using a biocontrol sustainable system. AMF has come into light as a gleam of anticipation due to its exclusive attributes in enhancing yields, crops quality, flowering, fruiting, increased chances of survival of seedlings, reduced percentage of disease occurrence, more tolerance to drought, salinity, temperature etc., increased use of Nitrogen, Phosphorus and Potassium fertilizers, and reduction in soil erosion, and maintenance of nutrient cycles. Thus, exploration and focus on it can lead us to a healthier and clean habitat to live in along with other complementary and supplementary methods of bioremediation.

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