Fungal treatment of industrial effluents: a mini-review

Ashutosh Kumar Tripathi[1], Nirmal Sudhir Kumar Harsh[2], Nutan Gupta[1,*]

[1]*Ecology and Environment Division, Forest Research Institute, Dehradun, India;* [2]*Forest Pathology Division, Forest Research Institute, Dehradun, India*

Received January 2, 2007

Abstract

Water pollution through industrial discharges, which is mainly in the form of effluent or wastewater, is one of the biggest problems. These effluents have strong concentrations of chemical oxygen demand (COD), phenol and its derivatives and often contain metals, inorganic nutrients, organic compounds, proteins, cyanides, chlorinated lignin and dyes. Bioremediation of toxic industrial effluents by microorganisms serves as an effective method to substitute the conventional recovery and removal processes. Fungal biomasses have huge capability of treating effluents discharged from various industries. White rot fungi are ubiquitous in nature and their adaptability to extreme conditions makes them good biodegraders. Their enzyme producing activity makes them effective decolorizers; they remove toxic metals by biosorbtion ultimately rendering the effluents more ecofriendly. [Life Science Journal. 2007; 4(2): 78 – 81] (ISSN: 1097 – 8135).

Keywords: industrial effluents; fungi; degradation; white rot fungi; enzymes; decolorization; biosorption

Pollution has been defined in various ways. It is considered as the release of unwanted substances to the environment by man in quantities that damage either the health or the resources itself. Water pollution involves the release of small amounts of substances directly through point sources or indirectly through non point sources. Industrial effluents from various industries like textile, dyestuffs, paper and pulp, distillery, olive oil mill and metal industries etc. are the major contributors to water pollution as they create more subtle effects on behavior, reproduction or even survival of biotic communities.

The physical and chemical methods of industrial effluent treatment processes remove organic pollutants at low level; they are highly selective to the range of pollutants removed and prohibitively expensive. Control of pollution is one of the prime concerns of society today with economic constraints on pollution control processes, affordable and effective methods have become a necessity. Untreated or partially treated wastewaters and industrial effluent discharges into natural ecosystems pose a serious problem to the ecosystem and the life forms. Microbial treatment systems have advantage of being simple in design and low in cost (Banat *et al*, 1996).

Fungi, their biology, economic value and pathogenic capabilities are not new to human society. They have been used from fermentation of foods to production of pharmaceuticals. Fungi thrive well in inhospitable habitats with environmental extremes because of their enzyme system (Cooke, 1979). Fungi are involved in the biodegradation of undesirable materials or compounds and convert them into harmless, tolerable or useful products. Many organisms are involved in the biodegradation of organic waste, which has resulted in the production of novel substances of biotechnological importance.

Fungi are recognized for their superior aptitudes to produce a large variety of extracellular proteins, organic acids and other metabolites, and for their capacities to adapt to severe environmental constraints (Lilly and Barnett, 1951; Cochrane, 1958). Fungal systems appear to be most appropriate in the treatment of colored and metallic effluents (Ezeronye and Okerentugba, 1999).

Fungi not only produce various metabolites like citric acid, homogeneous proteins, heterogeneous proteins, peroxidases but have shown their effectiveness for removal, reduction and detoxification of industrial effluents ingre-

*Corresponding author. Email: nutangupta100@rediffmail.com

dients. Therefore in this review paper an attempt has been made to bring out the capabilities of fungi for bioremediation of industrial effluents. Bioremediation refers to the productive use of microorganisms to remove or detoxify pollutants, usually as contaminants of soil, water or sediments that otherwise threaten public health. Microorganisms have been used to remove organic matter and toxic chemicals from domestic and industrial waste discharged for many years (Gupta and Mukerji, 2001).

Fungi especially the white-rot fungi produce enzymes laccase, Mn peroxidase and lignin peroxidase (LiP), which are involved in degradation of lignin in their natural lignocellulosic substrates. This ligninolytic system of white rot fungi is directly involved in the degradation of various xenobiotic compounds and dyes. The ability of the white rot fungi to degrade dye can be directly correlated with its ability to degrade lignin; the dye molecules are degraded along with lignin. Use of white rot fungi is the most unique technology of bioremediation as their ability to degrade structurally diverse xenobiotic organo pollutants is more (Christian *et al*, 2005).

Industries of olive oil, distillery (molasses), cotton bleaching, pulp and paper processing produce billion liters of colored, often toxic and harmful effluents all over the world. These effluents have strong concentrations of Chemical Oxygen Demand (COD), phenol and its derivatives and often contain proteins, cyanides, chlorinated lignin compounds and dyes (Borja *et al*, 1992; Nieto *et al*, 1992; Bengtsson and Triet, 1994; Yesilada *et al*, 1998; Kahmark and Unwin, 1999).

High levels of lignin peroxidase have been correlated with high decolorization efficiency of olive mill effluents (Sayadi and Ellouz, 1995). Distillery wastewater causes many environmental problems and colored substances must be removed from it before discharge into the environment. Locally isolated *Aspergillus fumigatus* has been found to be effective for decolorization of anaerobically treated distillery wastewater (Mohammad *et al*, 2006). Benito *et al* (1997) studied the decolourization of molasses wastewater using *Trametes versicolor*. Dhamankar (2000) described the possibility of using dead yeast cells for decolourization of distillery effluents as dry yeast powder decolourized the effluents of biomethanation plant by more than 70%.

Eaton *et al*, (1980) used *Phanerochaete chyrosporium* and found it effective for color removal through microbial degradation of polymeric lignin molecules from pulp and paper industrial effluents.

The large amount of lignin derivatives in these effluents is responsible for their dark-brown colour (Calvo *et al*, 1995). The influence of *Ceriporiopsis subvermispora, P. chyrosporium, Trametes versicolor, Rhizopus oryzae* and *Rhizomucor pusillus* has been observed on paper and pulp effluents (Manzanares *et al*, 1995; van Driessel and Christov, 2002; Nagarathnamma and Bajpai, 1999; Nagarathnamma *et al*, 1999). *Trametes versicolor* is one of the white rot fungi known to decolourize kraft mill effluents from sulphate pulping (Livernoche *et al*, 1983). Another white rot fungus *Phanerochaete chyrosporium* produces isoenzymes, including lignin peroxidases and Mn-dependent peroxidases that are capable of degrading not only lignin, but also chlorinated lignins found in pulp bleaching effluents (Kirk *et al*, 1986; Lankinen *et al*, 1990).

The effluents of pharmaceutical industries, dyeing, printing, photographs, textile and cosmetic contain dyes (McMullan *et al*, 2001). Effluents from textile industries are a complex mixture of many polluting substances such as organochlorine-based pestcides, heavy metals, pigments and dyes, among the various types of organics present color is the most difficult to remove, color indicates an increased Biological Oxygen Demand (BOD) and COD. Azo dyes are used extensively in the textile and dyestuff industries, these dyes have a complex structure some of them are carcinogenic and mutagenic. *Phanerochaete chyrosporium* a major wood rotting fungus is capable enough to degrade a wide range of recalcitrant xenobiotic compound, including azo dyes (Aust 1990; Cripps *et al* 1990).

Phanerochaete chyrosporium degrades a wide variety of structurally diverse organopollutants (Bumpus *et al*, 1985) through its non-specific H_2O_2 dependent extracellular lignin degradation enzyme system (Cripps *et al,* 1990). Abadulla *et al*, (2000) have assessed the potential of *Trametes hirsuta* and a laccase from this organism to continuously degrade textile dyes and found that both water consumption and effluent toxicity in textile dyeing could be reduced by enzyme remediation with laccases.

Vyas *et al* (1995) have shown good results of *Pleurotus ostreatus* through its enzymatic activity to decolorize Remazol Brilliant Blue R dye. Mohorcic *et al* (2004) found *Bjerkandera adusta* to decolorize synthetic textile dye Reactive Black 5 from blue black to a yellow color.

The carpet dye effluent did not support the growth of *Trametes versicolor* but then too the fungus was found to be effective in decolorizing it (Ramsay and Goode, 2004). Dead biomass of *Aspergillus niger* has been found to be an effective biosorbent of dyes methyl violet and basic fuchsin (Bhole *et al*, 2004).

The tremendous increase in the use of heavy metals results in increased flux of metallic substances in aquatic environment. Heavy metals beyond permissible limits cause direct toxicity to all living beings. Metallic effluents can have ecological impacts on water bodies leading to increased nutrient load especially if they are essential metals. These metals in effluents may increase fertility of the sediment and water column and lead to eutrophication, which leads to oxygen deficiency, algal bloom and death of aquatic life.

Heavy metals in water bodies cause several health problems. Heavy metals such as mercury, cadmium and chromium can accumulate, and they enter the food chain and biomagnifies to toxic levels. Several fungal species have developed a high resistance to heavy metals and developed a variety of mechanisms to remove ions, such as to cell surfaces. Akthar and Mohan (1995) used biomass of *Aspergillus niger* to remove Zn^{2+} and Cd^{2+} as the low affinity of the resident Ca^{2+} and Mg^{2+} ions of the biosorbent makes them excellent counter ions for the heavy metals that form more stable complexes. Massaccesi *et al* (2002) have used filamentous soil fungi like *Aspergillus terreus, Cadosporium cladosporioides, Fusarium oxysporum, Gliocladium roseum, Penicillium* spp. and *Trichoderma koningii* isolated from industrially polluted sediments for the removal of Cadmium. The fungus *Penicillium frequentans* has been found to effectively remove phenanthrene in soil (Amezcua-Allieri *et al*, 2005).

Thus, more technically advanced research efforts are required for searching, exploiting new fungal species and improvement of practical application to propagate the use of fungi for bioremediation of industrial effluents.

References

1. Abadulla E, Tzanov T, Costa S, Robra KH, Paulo AC, Gubitz GM. Decorization and deyoxification of textile dyes with a laccase from *Trametes hirsuta*. Applied & Environmental Microbiology 2000; 66(8): 3357 – 62.
2. Akthar MN, Mohan PM. Bioremediation of toxic metal ions from polluted lake waters and industrial effluents by fungal biosorbent. Curr Sci 1995; 69:1028 – 30.
3. Amezcua-Allieri MA, Lead JR, Rodriguez-Vazquez R. Changes in Cd and Cr fluxes during the bioremediation of phenanthrene. Soil Use and Management 2005; 21: 337 – 9.
4. Aust SD. Degradation of environmental pollutanys by *Phanerochaete chyrosporium*. Microbial Ecology 1990; 20: 197 – 209.
5. Banat IM, Nigam P, McMullan G, Marchant R, Singh D. The isolation of thermophilic bacterial cultures capable of textile dyes decolourization. Env Hlth 1996; 23(4): 547 – 51.
6. Bengtsson BE, Triet T. Tapioca starch wastewater toxicity characterized by Microtox and Duckweed tests. Ambio 1994; 23: 473 – 7.
7. Benito G, Pena M, Rodriguez D. Decolourization of wastewater from an alcoholic fermentation process with *Trametes versicolor*. Bioresource Technol 1997; 61: 33 – 7.
8. Bhole BD, Ganguly B, Madhuram A, Deshpande D, Joshi J. Biosorption of methyl violet, basic fuchsin and their mixture using dead fungal biomass. Curr Sci 2004; 86(12): 1641 – 5.
9. Borja R, Martin A, Maestro R, Alba J, Fiestas JA. Enhancement of the anaerobic digestion of olive mill wastewater by the removal of phenolic inhibitors. Process Biochem 1992; 27: 231 – 7.
10. Bumpus JA, Tien M, Wright D, Aust SD. Oxidation of persistent environmental pollutants by white rot fungus. Science 1985; 228: 1434 – 6.
11. Calvo AM, Terron MC, Fidalgo ML, Pelayo JM, Galletti GC, Gonzalez AE. Pyrolysis-gas chromatography-mass spectrometry characterization of wheat straw alkaline-cooking effluents after biological treatment with the fungi *Phanerochaete chyrosporium* and *Ganoderma australe*. Analutica Acta 1995; 309: 145 – 52.
12. Christian V, Shrivastava R, Shukla D, Modi HA, Vyas BRM. Degradation of xenobiotic compounds by lignin-degradibg white-rot fungi: enzymology and mechanisma involved. Indian Journal of Experimental Biology 2005; 43: 301 – 12.
13. Cochrane VW. Physiology of the Fungi. John Wiley and Sons Inc., New York. 1958.
14. Cooke WB. The Ecology of Fungi. CRE Press Inc. Boca Raton, Floida. 1979.
15. Cripps C, Bumpus JA, Aust SD. Biodegradation of azo and heterocyclic dyes by *Phanerochaete chyrosporium*. Applied and Environmental Microbiology 1990; 56: 1114 – 8.
16. Dhamankar VS. Towards developing a technology for the removal of caramel from sugar industry by-products. In: Proceedings of the 62 Annual convention of the Sugar Technologists association of India Agra. India August 19 – 20, 2000; C22 – 6.
17. Eaton D, Chang H, Kirk TK. Fungal decolorization of kraft bleach plant effluent. Tappi J 1980; 63: 103 – 6.
18. Ezeronye OU, Okerentugba PO. Performance and efficiency of a yeast biofilter for the treatment of a Nigerian fertilizer plant effluent. World J Microbiol Biotechnol 1999; 15: 515 – 6.
19. Gupta R, Mukerji KG. Bioremediation: Past, Present and Future. In: Role of microbes in the management of environmental pollution. Tewari R, Mukerji KG, Gupta JK, Gupta LK. (eds). A.P.H. Publishing Corp, New Delhi. 2001; 73 – 81.
20. Kahmark KA, Unwin JP. Pulp and paper effluent management. Water Environ Res 1999; 71: 836 – 52.
21. Kirk TK, Tien M, Johnstud SC, Eriksson KE. Lignin degrading activity of *Phanerochaete chyrosporium* Burds: comparison of cellulase negative and other strains. Enzyme and Microbial Technology 1986; 8: 75 – 80.
22. Lankinen VP, Inkeroinen MM, Pellien J, Hatakka AI. The onset of lignin modifying enzyme, decrease of AOX and colour removal by white rot fungi: growth on bleach plant effluent. Water Science and Technology 1990; 24: 189 – 98.
23. Lilly VM, Barnett HL. Physiology of the Fungi. McGraw-Hill Book Co., 1st ed. New York, New York. 1951.
24. Livernoche D, Jurasek L, Desrochers M, Dorica J. Removal of colour from kraft mill wastewater with cultures of white rot fungi ad with immobilized mycelium of *Coriolus versicolor*. Biotechnology and Bioengineering 1983; 25: 2055 – 65.
25. Livernoche D, Jurasek L, Desrochers M, Veliky IA. Decolorization of a kraft mill effluent with fungal mycelium immobilizatio in calcium alginte gel. Biotechnology Letters 1983; 3: 701 – 6.
26. Manzanares P, Fajardo S, Martin C. Production of ligninolytic activities when treating paper pulp effluents by *Trametes versicolor*. J Biotechnol 1995; 43: 125 – 32.
27. Massaccesi G, Romero MC, Cazau MC, Bucsinszky AM. Cadmium removal capacities of filamentous soil fungi isolated from industrially polluted sediments, in La Plata (Argentina). World Journal of Microbiology & Biotechnology 2002; 18: 817 – 20.

28. McMullan G, Meehan C, Conneely A, Kirby N, Robinson T, Nigam P, Banat IM, Marchant R, Smyth WF. Microbial decolourisation abd degradation of textile dyes. Appl Microbiol Biotechnol. 2001; 56: 81 – 7.
29. Mohammad P, Azarmidokht H, Fatollah M, Mahboubeh B. Application of response surface methodology for optimization of important parameters in decolorizing treated distillery wastewater using *Aspergillus fumigatus* U_{B2} 60. International Biodeterioration & Biodegradation 2006; 57(4): 195 – 9.
30. Mohorcic M, Friedrich J, Pavko A. Decoloration of the diazo dye reactive black 5 by immobilized *Bjerkandera adusta* in a stirred tank bioreactor. Acta Chim Slov 2004; 51: 619 – 28.
31. Nagarathnamma R, Bajpai P. Decolorization and detoxification of xtraction stage effluent from chlorine bleaching of kraft pulp by *Rhizopus oryzae*. Appl Environ Microbiol 1999; 65: 1078 – 82.
32. Nagarathnamma R, Bajpai P, Bajpai PK. Studies on decolourizatin and detoxification of chlorinated lignin compounds in kraft bleaching effluents by *Ceriporiopsis subvermispora*. Process Biochem 1999; 34: 939 – 48.
33. Nieto LM, Cormenzana AR, Pareja PG, Hoyos SEG. Phenolic compounds biodegradatio of olive mill wastewater with *Aspergillus terreus*. Grasas y Aceites 1992; 43: 75 – 81.
34. Ramsay JA, Goode C. Decoloration of a carpet dye effluent using *Trametes versicolor*. Biotechnology Letters 2004; 26: 197 – 201.
35. Sayadi S, Ellouz R. Roles of lignin peroxidases and manganese peroxidases from *Phanerochaete chyrosporium* in the decolourization of olive mill wastewaters. Appl Environ Microbiol 1995; 61: 1098 – 103.
36. Van Driessel B, Christov L. Adsorption of colour from bleach plant effluent using biomass and cell wall fractions from *Rhizomucor pusillus*. J Chem Technol Biotechnol 2002; 77: 155 – 8.
37. Vyas BRM, Molitoris HP. Involvement of an extracellular H_2O_2-dependent ligninolutic activity of white rot fungus *Pleurotus ostreatus* in the decolorization of Remazol Brilliant Blue R. Applied and Environmental Microbiology 1995; 61(11): 3919 – 27.
38. Yesilada O, Sik S, Sam M. Biodegradation of olive oil mill wastewater by *Coriolus versicolor* and *Funalia trogii*: effects of agitation, initial COD cncentration, inoculum size and immobilization. World J Microbiol Biotechnol 1998; 14: 37 – 42.