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MICROBIAL BIOREMEDIATION OF INDUSTRIAL POLLUTANTS: A COMPREHENSIVE REVIEW

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Abstract:

Industries play a crucial role in the production of a diverse array of products beneficial to humanity. However, industrial activities have led to significant environmental pollution, with waste materials being discharged into water bodies, soil, and the atmosphere. Various methods are employed by industries to treat effluents, and bioremediation stands out as a highly effective technique for decontaminating polluted environments. This review critically assesses the bioremediation potential of microorganisms in addressing major industrial pollutants.

Key words: Industrial effluents, Microbes in bioremediation, Biodegradation, Microbial consortium

Background

Environmental pollution poses a global challenge with significant implications for human health. Primarily driven by unsustainable human activities, pollution leads to numerous public health issues (Khan, 2004). Industrial pollution, in particular, is a critical contributor to these environmental problems, affecting both emerging and established industrial nations.

Different industries have different pollution intensity. Khan M and Tarique (2015) analysed the pollution load showing that there are few industries which contribute to more than 90 percent of the pollution in the country during 1990-2010. So, there is an urgent need on the part of policymakers to give top most priority for controlling pollution in these industries which will help in reducing industrial pollution to a great extent.

The pollution from these industries can therefore be significantly reduced by the use of bioremediation technique.

1. Introduction

Environmental pollution is a critical issue being extensively researched to identify contaminants in natural resources. In India, industrial activities significantly contribute to overall pollution, impacting soil, air, and water- the core components of the environment. These activities cause substantial harm to local biotic communities. Toxic wastes from industrial effluents can bio accumulate in animal tissues, posing risks to living organisms along the food chain, thereby directly affecting human health and the environment.

Industries have significantly contributed to India's economic growth and development. However, their impact on pollution is relatively high. Estimates of pollution load, based on the Central Pollution Control Board (CPCB) notified 17 categories of polluting industries (Pandey R, 2000), indicate a substantial increase in pollution from the manufacturing sector in India during the post-reform period. Between 1990 and 2000, the total pollution load nearly doubled, and in the following decade, it tripled. Overall, from 1990 to 2010, the total pollution load increased nearly six fold, mirroring the growth in output value, which also increased six times and tripled between 2000 and 2010 (Khan M and Tarique, 2015).

Industries generate industrial wastes, which contain harmful chemicals, particulates, and toxic heavy metals. Plastic, dyes, chlorinated aliphatic hydrocarbons, aromatic hydrocarbons and heavy metals are important groups of these pollutants. These pollutants entered the environment due to leakage, improper disposal or accidents. Since more than 90 percent of the pollution is caused by selected industries, there is a need for making special cost-efficient eco-friendly technique that can be used to remove or lessen the effect. Bioremediation will aid in reducing pollution significantly.

Bioremediation is the one of the methods that uses microbial biomass to remove the pollutants. Bioremediation is process that is used to transform toxic heavy metals into a less harmful state using microorganisms. At present, bioremediation approach is applied to contaminants in soil, groundwater, surface water, sediments and air. This know-how has become attractive alternatives to conventional clean-up technologies due to relatively low capital costs. A successful bioremediation system requires efficient bacterial strains to reduce largest pollutant to a minimum level in shortest time. Microbial consortia aids as a powerful biodegradative agent as the genetic information of more than one organism is required to reduce most of the pollutants. Genetic potential and environmental factors such as temperature, pH, availability of oxygen and nutrients determine the rate and extent of biodegradation.

2. Review of the literature

Rajdeo Kumar et al. (2015) investigated the degradation efficiency of the fungus *Phanerochaete chrysosporium* and the bacterium *Pseudomonas fluorescens* in breaking down PCP in soil microcosms under natural conditions. Their experiments focused on the release of chloride and the cleavage of PCP rings at varying concentrations over time. The results offer valuable insights into the potential of these microorganisms to biodegrade pentachlorophenol.

Basha S. and Rajaganesh K. (2014) identified four bacterial strains with heavy metal resistance, isolated from effluents of the textile industry, for bioremediation purposes. These strains, Escherichia coli, Salmonella typhi, Bacillus licheniformis, and Pseudomonas fluorescens, were effective in removing heavy metals from textile dye effluents, achieving reductions of up to 98.34% for cadmium, 94.83% for lead, and 96.14% for zinc.

Kumar et al. (2013) demonstrated the potential use of uranium-tolerant aerobic chemo-heterotrophic bacteria as indicators for assessing the environmental impact of mining. This study focused on natural isolates, including Firmicutes, Gammaproteobacteria, Actinobacteria, Bacteroidetes, and Betaproteobacteria (2%), from subsurface soils of uranium-rich deposits in Domiasiat. The bacterial community was identified at the molecular level using amplified ribosomal DNA restriction analysis (ARDRA) and 16S rRNA gene sequence analysis. The study evaluated representative bacteria for their uranium tolerance, uranium-binding capacity, presence of phosphatase enzymes, and metal-transporting genes. The findings provided a baseline for the bioremediation potential of these diverse indigenous bacteria.

Das et al. (2012) evaluated the efficacy of a bacterial consortium on raw effluents from the pharmaceutical industry. They observed a significant reduction in pollutants, with total suspended solids showing the highest decrease. The study reported a 70% reduction in total dissolved solids and an 80% reduction in sulphate levels. Additionally, there was a slight improvement in chemical oxygen demand across all effluent samples.

Kanekar P. and Kelkar P.S. (1998) described 14 alkaliphilic bacteria isolated from the alkaline Lonar Lake in India, which were used for phenol removal from industrial waste. These bacterial isolates, capable of growing on dye industry waste effluent and phenolic waste agar slants, were effectively utilized in the bioremediation of phenol.

Mandal A.K. et al. (2012) evaluated the efficiency of isolated bacterial strains in degrading total petroleum hydrocarbons (TPH) and various fractions of crude oil and oily sludge. They developed a microbial consortium consisting of five different strains, which was applied to biodegrade different TPH fractions in oily waste at Indian oil refineries. This consortium was also tested on a field scale along with nutrient formulation. The results indicated that using a microbial consortium is an effective approach for treating oil contamination through bioremediation.

Murugesan K (2003) demonstrated that white rot fungi such as *Phanerochaete chrysosporium* and *Corius versicolor* possess the ability to efficiently degrade stubborn chromophoric compounds found in effluents from the paper and pulp industry. However, practical implementation of fungal decolourization is hindered by the fungi's high oxygen demand and specific substrate requirements.

3. Conclusion

Industries are integral to modern civilization but also generate pollutants during manufacturing processes, adversely affecting soil, water, and air quality. This poses significant risks to both the environment and human health, necessitating immediate, pollutant-specific treatment methods. Bioremediation stands out as a promising approach for reducing or eliminating pollutants, offering a sustainable solution with minimal waste by-products. It provides an effective treatment for industrial pollutants, promoting the sustainable use of resources.

The microorganism for bioremediation could be isolated from the same polluted environment and their love for toxicant could be beneficial for the clean-up process. New bioremediation techniques could be developed by understanding the microbial communities and their response to the pollutants.

4. Research challenges

The isolation of chlorophenol-degrading bacteria has become challenging due to the toxic and recalcitrant nature of these compounds. The findings of the present study by Rajdeo Kumar et al. (2015) can be applied in industries that are major producers of pentachlorophenol (PCP). The proposed culture under optimized conditions could remediate contaminated soil and water where PCP is a prominent pollutant.

Further research is necessary to develop a rapid biodegradation process that offers economically feasible color removal in the paper and pulp industry. There is potential to clone genes encoding effective degradative enzymes, which could be transferred to suitable fungi for efficient decolorization of effluents.

Research on the biosorption potential and heavy metal resistance of microorganisms at the molecular level could lead to eco-friendly technologies for treating textile dye effluents before their release into the environment. Microbial bioremediation techniques hold promise for significant advancements, including field trials in polluted sites, thereby paving the way towards more sustainable practices.

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