

Chapter 13

Advances in Bioremediation for Removal of Toxic Dye from Different Streams of Wastewater

Priya Banerjee

University of Calcutta, India

Aniruddha Mukhopadhyay

University of Calcutta, India

Papita Das

Jadavpur University, India

ABSTRACT

Azo dyes are used in abundance in several industries like textile, printing, paper, plastic, cosmetics, paints, etc. Extensive discharge of such dyes in adjacent water bodies has raised much environmental concern. Azo dyes are toxic to living organisms and their genotoxic and carcinogenic potentials are intensified on being released as mixtures. In the recent years, various microorganisms have been isolated and reported to possess tremendous potential for efficient dye degradation. However, the process of bioremediation is highly controlled by experimental factors like effluent pH, temperature and concentration of dyes in solution. Therefore, appropriate optimization of these factors is to be determined in order to ensure maximum efficiency of this process. This review highlights application of immobilization techniques of bacterial cells for achievement of successful biodegradation. In this study, the existing problems of dye pollution and possible improvisations for obtaining enhanced bioremediation of dyes have also been discussed.

1. INTRODUCTION

Unplanned and unmonitored industrialization and urbanization in developing countries necessitate sustainable utilization of water via reclamation and recycling of industrial wastewater. Of different types of industries, those associated with textile processing and manufacturing reportedly consume a huge volume of water primarily for the dyeing and finishing procedures. This in turn is an area of prime concern for environmental audit. Besides, inept dyeing procedures often end up discharging large amounts of the potentially hazardous dyes as dispersion or true solution in wastewater to adjacent water bodies thereby

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severely contaminating the environment (Stolz, 2001). Owing to the quantity and constituents of the effluents produced, the textile industry has been considered as the most polluting industrial sector (Sen & Demirer, 2003). Anthroquinoid, indigoid, and azo aromatic compounds are the primary classes of dyes in application. Azo dyes are made up of conjugated structures comprised of double bonds and aromatic rings which participate in strong π - π interactions. These azo dyes are of immense environmental concern, especially in case of reactive dyeing of cellulosic fibres, as huge quantities of unbound dyes are released through the effluent (Khan & Banerjee, 2010). During the process of utilization, loss of dyes incurred may range from up to 2% (basic dyes) to 50% (reactive azo dyes) depending on the type of dye being used (Robinson *et al.*, 2001). Azo, nitro or sulfo groups present in the chemical structure of the dyes, often render them recalcitrant to microbial degradation thereby leading to accumulation of their residues in the biotic community (Pourbabae *et al.* 2006). Textile dyes present in effluents have been reported to exhibit mutagenic and genotoxic potentials as well (Sharma *et al.* 2007).

In recent years, significant attention is being allotted for preventing direct discharge of untreated textile effluents into neighboring water bodies. The conventional physical and chemical methods developed and implemented so far for the treatment of dye containing effluents are costly, involve operational glitches, and in nearly all cases result in CO₂ formation due to incomplete degradation of dyes (Karapinar *et al.* 2000). Complete degradation of textile effluents has been achieved only through biological oxidation (Karapinar *et al.*, 2000). Nevertheless, challenges encountered by the conventional activated sludge process (CASP) include maintenance of special nutritional requirements and survival conditions of the functional microorganisms. Due to an increasing global scarcity of potable water sources, laws regarding uses of water resources have become more stringent making it imperative to design new, efficient, cost effective and time saving methodologies for the treatment and reuse of wastewater. It stresses upon the application of biodegradation in combination with adsorption processes for ensuring faster effluent treatment and maintenance of better survival conditions for the participating microorganisms. Immobilized cells are also widely used for yielding important biological compounds, wastewater reclamation and soil bioremediation (Khan & Banerjee, 2010). Besides simplifying separation and enhancing the recovery of immobilized bacteria, other advantages of this process include reusability, cost reduction, comparatively longer effective lifetime and protection of immobilized strains from adverse experimental conditions. Immobilization also protects the bacterial cells from high concentrations of recalcitrant compounds and provides a longer contact time for better degradation of the same. Immobilized cells have been efficiently applied as biocatalysts for treating large amounts of liquid or soil samples in a simple and cost effective procedure.

This study summarizes the recent investigations in the removal of azo dyes (using both simulated and real textile effluents) using immobilized bacterial species which is an emerging procedure for the biological treatment of dye-rich industrial effluents. This review also analyses the process parameters of concern and their interaction that affect dye removal. It also describes two models for optimization namely Response Surface Methodology and Artificial Neural Network used to ensure maximum efficiency of the designed process.

2. BACKGROUND

Of all types of synthetic dyes being utilized for commercial applications, azo dyes are most extensively used. This type of dyes are aromatic compounds having one or more $-N=N-$ groups in their chemi-

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