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# Comparative analysis of efficiency of various Immobilized systems used in biodegradation of dyes: A Review

Abstract

The biodegradation of synthetic dyes represents a major challenge due to their chemical recalcitrance and toxicity. Immobilization of microbial cells and enzymes has emerged as an effective strategy to enhance the stability, reusability, and efficiency of biodegradation processes. Various immobilization systems, including adsorption, entrapment, covalent binding, and encapsulation, have been investigated for their comparative efficiency in dye degradation. Entrapment in alginate and polyacrylamide matrices provides high microbial viability and protection, whereas adsorption on natural carriers like biochar and activated carbon offers cost-effectiveness and enhanced surface interaction. Encapsulation in nanomaterials and covalent binding to synthetic polymers exhibit improved durability and operational stability, making them suitable for repeated use in continuous systems. Studies reveal that immobilized systems generally outperform free microbial cells by providing resistance to environmental stress, higher degradation rates, and extended activity. For example, bacteria such as Pseudomonas fluorescens and Bacillus cereus have shown enhanced azo dye degradation when immobilized, while fungi like Trametes versicolor and Aspergillus oryzae demonstrate efficient decolorization due to their robust ligninolytic enzymes. Comparative evaluation highlights that the choice of immobilization method depends on dye type, microbial strain, and application scale. Overall, immobilized systems hold significant promise for developing sustainable, scalable bioremediation strategies for industrial dye effluents.

Key words: Immobilization, Biodegradation, Dyes

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