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Combined Biological and Advanced Oxidation Process (AOP) for Bioremediation of Congo Red by *Penicillium* sp.

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Structured Abstract

Background: Toxic dyes widely used in the textile industry pose serious environmental and health risks due to their carcinogenic, mutagenic, and persistent nature. Biological treatment uses microorganisms, such as fungi, to enzymatically degrade dyes. Other conventional methods, such as physical and chemical methods, are often inadequate when applied alone, highlighting the need for more efficient approaches. This study investigates a combined biological and Advanced Oxidation Process (AOP) approach for degrading the toxic dye Congo red.

Methods: *Penicillium sp.* was prepared as the biological agent, while AOP utilised H_2O_2 under visible light. Three treatment setups consisting of biological, AOP, and combined Biological-AOP have been evaluated. Decolourisation efficiency will be monitored using UV–Vis spectrophotometry, followed by FTIR analysis to confirm structural degradation. The phytotoxicity tests will assess the detoxification potential of the treated samples using *Vigna radiata*.

Results: This research is expected to generate quantitative data on treatment performance, with the combined method anticipated to yield superior dye degradation. The findings show that the decolourisation efficiency (DE%) achieved by Biological-AOP treatment is 85.6%, the highest among the treatments. The UV–Vis results show lower absorbance than the others, indicating chromophore breakdown of the Congo red structure. This is also supported by FTIR analysis, which shows the disappearance or shifting of key functional groups, such as the aromatic C=C functional group. The toxicity level of Congo red showed higher toxicity after being treated with the Biological-AOP treatment. This was determined by the shorter length of the shoot and root of *Vigna radiata*.

Conclusion: The findings of this study show that Congo red can be effectively degraded using a combined Biological-AOP treatment, as confirmed by several analytical methods, including UV-Vis spectrophotometry and FTIR analysis. This has been confirmed by lower absorbance, breakdown of the dye chromophore group and shifting of the dye's functional group.

Keywords: Congo red, Biological-AOP, Degradation, Toxic Dye, Breakdown

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