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# Preparation and evaluation of magnetic biochar thin films for the removal of crystal violet and ciprofloxacin from aqueous solutions

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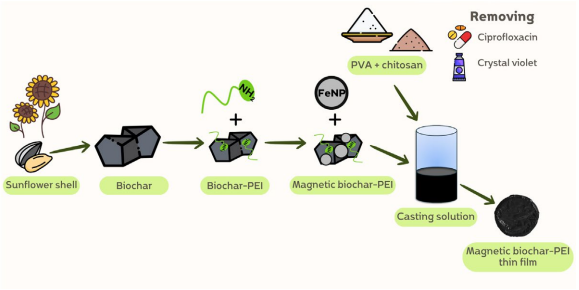


The removal of pharmaceutical compounds and organic dyes from aquatic environments remains a major challenge, particularly due to the limited applicability of conventional powdered adsorbents under practical conditions [1]. In this study, magnetic biochar-based thin films were developed as mechanically stable and efficient adsorbents for the removal of ciprofloxacin (CIP) and crystal violet (CV) from aqueous solutions. Biochar was produced via pyrolysis of sunflower shells and subsequently functionalized with polyethyleneimine (PEI) using ultrasonic assistance to enhance surface reactivity. Iron oxide nanoparticles ($Fe_3O_4$ NPs) were then introduced onto the biochar–PEI nanosheets through a co-precipitation process. The resulting composite was embedded within a polyvinyl alcohol (PVA)–chitosan matrix to form flexible and reusable B-PEI@FeNPs thin films. The schematic process of production is shown in Figure 1.

Material characterization and adsorption studies demonstrated high removal efficiencies for both target contaminants. Kinetic and isotherm analyses revealed that the adsorption process followed pseudo-second-order kinetics and was best described by the Freundlich isotherm model, indicating multilayer chemisorption on heterogeneous surfaces [2]. In the case of ciprofloxacin, the adsorption behavior also showed good agreement with the Langmuir model and intraparticle diffusion mechanisms, reflecting the complexity of its interactions with the adsorbent. The maximum Langmuir capacity was 34 and 16 mg/g for CV and CIP, respectively. Importantly, competitive adsorption experiments involving CIP and CV were performed, providing comparative insights that have been rarely addressed in previous studies. Overall, the results highlight the potential of magnetic biochar-based thin films as sustainable and effective materials for advanced water treatment applications.

[1] Loulidi, I. et al. Comparative study on adsorption of crystal violet and chromium (VI) by activated carbon derived from spent coffee grounds. Appl. Sci. 13, 2023.

[2] Sh, H. et al. Enhanced removal of crystal violet using raw fava bean peels, its chemically activated carbon compared with commercial activated carbon. Case Stud. Chem. Environ. Eng. 9, 100456 (2024).