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Development of Cetyl Trimethyl Ammonium Bromide (CTAB)-Modified Magnetic Biochar-Based Sand Filter for Microplastics Removal from Wastewater Systems

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Microplastics (MPs), plastic particles <5 mm, are recognized as an emerging environmental micropollutant. Around 80% of ocean MPs are known to come from land-based sources, primarily associated with sewage or wastewater discharge from wastewater systems. Although sewage treatment plants (STPs) remove most MPs efficiently, the daily volume of treated sewage remains a major concern for MPs release, emphasizing the need for reliable and efficient treatment methods. In this context, the present study sought to provide insights into how effective the use of cetyl trimethyl ammonium bromide (CTAB)-modified magnetic biochar as an adsorbent for MPs removal and the potential integration of this technology in STPs to control environmental MPs pollution. Biochars from different agricultural waste residues, i.e., sugarcane bagasse, rice husk, and coconut shell were synthesized, surface modified, and compared for their MPs removal efficacy from aqueous matrices. Physico-chemical and morphological properties of different biochars were characterized and compared. Effects of various factors like contact time, adsorbent dosage, MPs concentration, pH, dissolved organic matter, and competitive ions were analyzed from synthetic water spiked with 1 µm sized polystyrene (PS) MPs during batch studies. The maximum MPs removal of about 98% was achieved at the favorable conditions: initial MPs concentration: 10 mg/L, CTAB-modified magnetic biochar dose: 7 mg/50 mL, pH 4, mixing speed: 180 rpm, and contact time: 3 minutes. Electrostatic and hydrophobic interactions, hydrogen bonding, and pore-filling were the key MPs removal mechanisms. The adsorption kinetics of MPs showed the best fit with the pseudo-second-order model (R^2=0.91), and the adsorption isotherm followed the Langmuir model (R^2=0.94), with a maximum adsorption capacity of 247.52 mg/g. Additionally, the present work also investigated the stability and immobilization of MPs in fixed-bed column experiments using locally available River sand (**Fig. 1**). Column studies removed ~99% MPs in real-time secondary sewage effluents using an MBC-CTAB-integrated sand filter at a flow rate: of 5 mL/min, bed height: of 4 cm, and MPs concentration: of 7 mg/L. The application of the developed technique efficiently removes MPs thereby highlighting its practical relevance as a sustainable approach for removing MPs from real-time wastewater, which is a shared global concern.

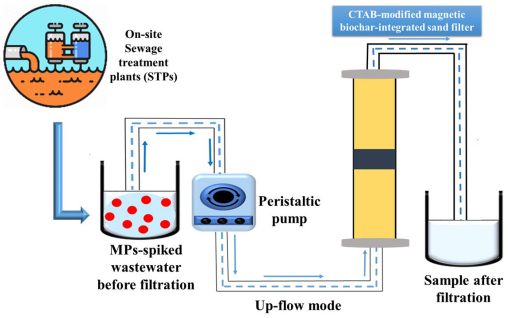

Fig. 1. Schematic showing fixed-bed column experimental setup for MPs removal from treated wastewater using CTAB-modified magnetic biochar-integrated sand filter.