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From Biochar to iron-modified-biochar: Ecofriendly composites for the remediation of nanoplastics and metal ions from contaminated waters

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Agricultural waste to resource" and "nanoplastics- novel emerging contaminants" are currently at the scientific frontiers and require novel solutions. This study aims to use sugarcane bagasse-derived biochar to remove nanoplastics (NPs) from an aqueous environment and further modify the biochar with iron nanoparticles to remove NPs and plastic additive metal ions simultaneously. In this work, biochar composites were synthesised at three different pyrolysis temperatures, i.e. 350, 550 and 750^{0}C (BC-350, BC-550 and BC-750, respectively) and evaluated for their potential in removing NPs. Results showed that attributing to decreased carbonyl functional groups, increased surface area and pore abundance, BC-750 showed drastically higher NPs removal than other composites. Further sorption studies confirmed rapid NPs removal with equilibrium attainment within 5 minutes of interaction and efficient NPs sorption capacity, i.e. 44.9 mg/g for BC-750. Non-linear-kinetic modelling suggested pseudo 1st order removal kinetics while isotherm and thermodynamic modelling confirmed- sorption spontaneity and monolayer nature of NPs sorption. The effect of various environmental parameters, i.e. competing ions, pH, humic acid and complex aqueous matrices on NPs sorption, was also studied. Enhanced electrostatic repulsion decreased NPs sorption at alkaline conditions, whereas steric hindrance caused limited removal at higher humic acid concentrations. BC-750 also showed the minimal impact of competing ions on NPs sorption with complete removal in synthetic groundwater. Further, the biochar used was modified into redox-sensitive iron biochar and utilised for the simultaneous removal of NPs of different sizes and functionality along with the metal ions used as plastic additives in both batch and column modes. Our study suggested that 1 kg of the designed material may purify a maximum of 39,890 liters of water contaminated with 1 ppm metal concentrations and 90,300 liters of water contaminated with 1 mg/L Nanoplastic concentrations in a continuous mode.