

Investigating the Use of Biochar for Nitrate and Ammonium Removal from Aqueous Solutions

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ABSTRACT

The increasing generation of spent coffee grounds (SCG) from coffee shops and food-service activities represents a significant organic solid waste stream, creating opportunities for resource recovery within a circular economy framework. The conversion of SCG into biochar through thermochemical processes offers a sustainable waste valorization strategy while producing a functional material with potential environmental applications.

The present study investigated the potential of SCG-derived biochar for nitrate (NO_3^-) and ammonium (NH_4^+) removal from aqueous solutions, aiming to support sustainable nutrient management and waste valorization. Batch adsorption experiments were conducted using 2 g of biochar and 50 mL of nutrient solution. The influence of pH on adsorption performance was evaluated at pH 2, 3, 4, 6 and 9, followed by kinetic experiments at the optimum pH conditions identified for each ion.

The results demonstrated that nitrate adsorption was strongly influenced by solution pH, with maximum removal observed under acidic conditions ($\text{pH} \approx 2$), whereas ammonium removal was favored under alkaline conditions ($\text{pH} \approx 9$). Nitrate removal reached 68.8% after 3 h and increased to 81.4% after 73 h, while ammonium removal achieved approximately 20% after 3 h. The adsorption capacity of nitrate increased rapidly during the initial contact period and gradually approached equilibrium with increasing contact time.

Overall, SCG-derived biochar exhibited a significantly higher affinity for nitrate than for ammonium, likely due to favorable electrostatic interactions between protonated biochar surface functional groups and nitrate ions under acidic conditions. These findings highlight the potential of coffee-waste-derived biochar as a low-cost adsorbent for nutrient removal, contributing to water-quality protection, nutrient-loss mitigation, and the sustainable valorization of organic solid waste within a circular economy framework.