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Biochars and hydrochars for the adsorption of organic contaminants from wastewater

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Academic dissertation

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Abstract

The continuous release of pharmaceuticals, pesticides, polyphenols, and other organic contaminants into aquatic environments threatens water quality, public health, and ecosystem stability. The problem is especially severe in low-resource regions, where limited treatment infrastructure can lead to the direct discharge of untreated wastewater. This thesis focuses on the potential of biochars and hydrochars produced from locally available biomass residues as sustainable, low-cost adsorbents for reducing organic contaminants in various wastewaters. Through four interconnected studies, it examines the occurrence of organic contaminants in wastewaters and rivers in Rwanda, the performance of different chars, and the production factors that govern adsorption behaviour. High-resolution LC-MS/MS was used to analyse samples. In a study focused on hotspots, hospital effluent was shown to contain elevated concentrations of pharmaceuticals; one of the 28 pharmaceuticals investigated had a concentration up to 24000 ng/L. In the Nyabugogo River in Rwanda, 57 pharmaceuticals, five pesticides, and four polyphenols were detected, with average concentrations ranging from 960 ng/L for pharmaceuticals to 70 ng/L and 49 ng/L for pesticides and polyphenols, respectively. Spatial patterns showed that pharmaceuticals were most prevalent in urban areas, while pesticides and polyphenols were most abundant in the rural and agricultural regions of the Nyabugogo River. Temporal patterns revealed permanent pollution sources. To address these pollution challenges, adsorption experiments were performed using biochars and hydrochars produced from coffee pulp and husk, bagasse, softwood and bark under different thermochemical conditions. Cookstove biochars showed moderate pharmaceutical removal (14–66%). Hydrochars from coffee waste effectively removed polyphenols from coffee processing wastewater, achieving 100% removal, while higher-temperature biochars removed pesticides with 75% average removal. A systematic investigation of gasification conditions showed that increasing char conversion from 0% to 10% under a gasification atmosphere produced the greatest improvement in surface area and removal efficiency, which plateaued at near-complete removal beyond this threshold; biochars produced under a nitrogen atmosphere were comparatively less effective. Bark-derived biochars consistently achieved high removal (>90%), while husk-derived materials mainly improved from 10% of char conversion. These findings indicate that biochars and hydrochars derived from locally available agro-industrial residues can act as adsorbents for organic contaminants adsorption with potential relevance for sustainable water treatment in resource-limited regions.

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Biochars, hydrochars, adsorption, organic contaminants, wastewater

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