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Maximizing biochar adsorption potential for pharmaceuticals removal: Impact of feedstock selection and pyrolysis temperature

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The concentration of pharmaceuticals in aquatic environments has been steadily increasing, parallel to their rising consumption. Alarmingly, pharmaceuticals have been detected even in the most pristine ecosystems, including polar regions. The limited understanding of the long-term effects these pollutants may have on aquatic ecosystems and human health is particularly concerning. The EU Urban Wastewater Treatment Directive (EU 2024/3019) now mandates the removal of pharmaceuticals, along with other micropollutants, from wastewater.

To align with new regulations, novel techniques must be implemented, as conventional wastewater treatment processes are insufficient for removing pharmaceuticals at the necessary levels. Among these contemporary treatment methods is adsorption, which has shown significant potential in pharmaceuticals removal. A wide variety of materials, including clay minerals, porous silica, iron oxides and metal-organic frameworks, were already tested as pharmaceuticals adsorbents. However, carbonaceous materials are particularly favored due to their high surface area and numerous adsorption sites.

Our study focuses on the use of biochars as pharmaceuticals adsorbents. Biochars are carbon-rich materials produced from various organic feedstock through pyrolysis - a thermal decomposition process carried out in the absence of oxygen. We synthesized biochars from six different feedstocks: straw, sawdust, horse manure, coffee grounds, wastewater sludge and spent mushroom soil, at three pyrolysis temperatures (350^{o}C, 550^{o}C and 750^{o}C). The materials were pyrolyzed for two hours in an inert, nitrogen atmosphere with a heating rate of 5^{o}C/min. To evaluate their adsorption properties, we conducted preliminary tests using diclofenac, a commonly used nonsteroidal anti-inflammatory drug often found in wastewater due to its widespread overuse.

The low-temperature biochars derived from horse manure and spent mushroom soil demonstrated significant potential as adsorbents, with their adsorption capacity for diclofenac exceeding 60 mg/g. Readily available feedstocks, combined with a straightforward synthesis process and high adsorption capacity, suggest that these biochars could be utilized as effective materials for pharmaceuticals removal from wastewater.

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