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*Editorial*

# Application of Biochar, Adsorbent and Nanomaterials in Wastewater Treatment

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With rapid industrial and economic development, the problem of water pollution poses a great threat to the environment and human health. It is essential to find eco-friendly adsorbents for the remediation of wastewater. Biochar is a carbon-rich product obtained from the thermochemical conversion of biomass under oxygen-limited conditions. Biochar has received increasing attention in the treatment of environmental pollution due to its advantages such as large specific surface area, low cost, and abundant functional groups. Additionally, other adsorbents and nanomaterials were also employed in the treatment of wastewater.

This Special Issue mainly focused on three points: (1) processing and preparation methods and modification of biochar; (2) adsorbent and nanomaterial preparation from biochar and other bio-based materials; and (3) application and mechanism studies of biochar and nanomaterial in wastewater treatment for the effective degradation or removal of heavy metals, toxic and harmful pollutants, etc. Ten research articles and one review are published in this Special Issue, covering the treatment of different types of water, such as polluted groundwater, printing and dyeing wastewater, and eutrophic water.

Biochar is mainly produced from biomass at medium temperatures (300–600 °C) [1]. The physical and chemical characterization of biochar indicate that it has good performance in the adsorption of pollutants in wastewater [2]. To further increase the adsorption capacity and reuse efficiency of biochar, it has been modified using different solvents and magnetized. Among the research articles in this Special Issue, Phuong et al. [3] reported the physicochemical properties of rice straw biochar (RSB) and magnetic biochar (MRSB). The adsorption capacity of MRSB for Safranin O was around 1.4 times larger than RSB. The adsorption mechanism of MRSB was mainly porous diffusion, π-π interaction, and H-bonding. The adsorption capacity of magnetic biochar was greater than pristine biochar. In addition, the magnetic biochar was easily separated by the magnet. Biochar/magnetic biochar adsorbents showed great potential for the treatment of actual textile wastewater. In another study by Carolina et al. [4], the biochar and advanced oxidation processes (AOPs) were combined for the elimination of dye wastewater. The author reviewed the removal of dye using biochar and AOPs, and provided insight into the coupling of biochar with AOPs for the removal of dyes, biochar modification, reusability, and final disposal. The union of biochar and AOPs not only improves the removal rate of dyes, but also degrades the dyes to harmless substances. Kirmizakis et al. [5] applied a spectral induced polarization (SIP) method to monitor the adsorption of arsenic on Fe-modified biochar derived from date-palm leaves. The SIP method is sensitive to the interfacial conductivity and adsorption properties of biochar, offering a new way of monitoring cost-effective wastewater treatment. Gaga et al. [6] prepared biochar originating from the mixture of dehydrated digested sludge from sewage treatment plants and margins. The obtained biochar was employed to remove hydrogen sulfide ($H_2S$) from biogas. The minerals in biochar act as adsorption and catalytic oxidation sites for $H_2S$, converting up to 98% of $H_2S$ to monomeric sulfur and sulfate. Kalsoom et al. [7] studied the application of wood-derived biochar in the fixed-bed column system. Both granular activated carbon and wood-derived biochar showed a high adsorption capacity for selected pesticides.

The review by Sun et al. [8] overviewed the changes in the physicochemical properties of biochar before and after modification using SEM, XRD, XPS, TG, and other characterization techniques. The author analyzed various factors influencing the removal of arsenic from water using modified biochar. The results show that the main mechanisms of arsenic removal using modified biochar are complexation, precipitation, and electrostatic interactions. The paper of Gao et al. [9] proposes a novel modified activated alumina (AA) as the fluorine adsorbent for groundwater. Gao et al. [9] synthesized manganese-modified activated alumina (MAA) using the impregnation method. MAA has an excellent adsorption capacity, with a nearly 30% increase in fluoride removal efficiency compared to the control. The enhanced fluorine adsorption capacity was due to the doping of $MnO_2$ and $\gamma$-MnOOH on the AA surface. The electrostatic attraction and ion exchange effect played an important role in the removal of fluorine.

Guo et al. [10] synthesized two novel biodegradable and eco-friendly adsorbents for the remediation of ${PO_4}^{3-}$ in eutrophic water. The author prepared agar-La and sponge-La by doping lanthanum oxide nanoparticles into agar and cellulose sponges. Sponge-La showed a removal rate of 80–100% at pH values of 4–8. Although the adsorption process was slower for agar-La, the adsorption capacity (156 mg/g) was higher than sponge-La. Importantly, both adsorbents can be easily separated from the matrix after adsorption. Sun et al. [11] reported a novel polyethyleneimine-modified nanocellulose/magnetic bentonite composite (PNMBC) as the functional biosorbent for the efficient removal of Cu(II). The PNMBC exhibited the ultrafast adsorption of Cu(II) at 10 min, and an ultrahigh equilibrium absorption capacity of 757.45 mg/g. Han et al. [12] prepared environmentally friendly lignosulfonate/chitosan-graphene oxide hydrogel (LCGH) composites through a simple and green method. In the composite, the lignosulfonate, chitosan, and graphene oxide provided strong repulsion, multilayer backbone, and cross-linker, respectively. The strong adsorption capacity of LCGH for Cr(VI) (564.2 mg/g) was related to the three-dimensional porous structure and functional groups of LCGH. In addition, LCGH showed good cycle regeneration performance in practical applications, maintaining 85.4% of the adsorption capacity after five cycles.

Finally, the article by Li et al. [13] provided new insights into controlled-release fertilizer. The author applied the novel material of chlorella as a bio-based filler and used the physical cross-linking method to prepare chitosan-chlorella hydrogel beads. The introduction of chlorella improved the mechanical stability and swelling properties of chitosan-chlorella hydrogel beads, which showed better water retention and controlled release of humic acid.

In summary, this Special Issue contains ten research papers and one review dealing with the problems of contamination with heavy metals, nutrients, pesticides, dyes, and other pollutants. The papers in this Special Issue provide novel and timely information on various approaches to the utilization of biochar, biosorbents, and nanomaterials for the treatment of wastewater pollution. The selected papers are of great importance for improving the knowledge of the preparation and modification of biochar, adsorbents, and nanomaterials, and provide insights into the study of their practical application potential. We believe that the collation of these papers has contributed to further interest in sorbent preparation and water pollution management.

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