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Perspective

Influence of sodium dodecyl sulfate coating on adsorption of methylene blue by biochar from aqueous solution

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ABSTRACT

Biochar is regarded as a promising new class of materials due to its multifunctional character and the possibility of effectively coupling different properties. With increasing introduction into the environment, environmental chemicals such as surfactants will load onto the released biochar and change its physicochemical characteristics and adsorption behavior toward pollutants. In this study, sodium dodecyl sulfate (SDS), as one type of anionic surfactant, was coated onto biochar with different loading amounts. The influence of SDS loading onto biochar's physicochemical properties were investigated by Fourier transform infrared (FT-IR) spectroscopy, elemental analysis, zeta potential and Brunauer–Emmett–Teller (BET) surface area and pore size distribution analysis. Results showed that the pore size of the biochar decreased gradually with the increase of SDS loading because of the surface-adsorption and pore-blocking processes; the pH of the point of zero charge (pH_{PZC}) decreased with increasing SDS loading. Although surface-coating with SDS decreased the pore size of the biochar, its adsorption capacity toward methylene blue (MB) significantly increased. The biochar-bound SDS introduced functional groups and negative charges to the biochar surface, which could thus enhance the adsorption of MB *via* hydrogen bonding and electrostatic interaction. The results can shed light on the underlying mechanism of the influence of anionic surfactants on the adsorption of MB by biochar.

Introduction

Biochar is a carbon-rich aromatic material produced by pyrolyzing biomass through various thermochemical processes (*i.e.*, pyrolysis, hydrothermal carbonization, flash carbonization, and gasification) under oxygen-limited conditions and at relatively low temperatures (<700°C) (Tan et al., 2017). The specific properties of biochar include high specific surface area, porous structure, and copious amounts of

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surface functional groups (Safaei Khorram et al., 2016; Wang et al., 2017). Although its specific surface area and micropore volume are much lower than that of activated carbon, biochar is still regarded as a good replacement for commercial activated carbon because of its abundant functional groups and lower cost (Zhou et al., 2016). Recently, biochar has been used widely as an effective adsorbent for removal of heavy metals and organic compounds from wastewater (Chen et al., 2008; Guo et al., 2014; Jiang et al., 2017a, 2017c; Pan et al., 2013; Shen et al., 2017; Zafar et al., 2017). Among these pollutants, much attention has been paid to the adsorption of dyes by biochar due to their toxic effects and high concentrations in wastewaters. For instance, Nautiyal et al. (2016) used *Spirulina platensis* algae to prepare biochar which exhibited excellent adsorption performance toward Congo red. Ding et al. (2016) investigated the simultaneous adsorption of methyl red and methylene blue onto woody biochar in different concentration combinations. Sewu et al. (2017) examined the adsorption ability of crystal violet onto biochar produced from Korean cabbage, and the Langmuir maximum adsorption capacity was as high as 1304 mg/g.

Surfactants, as a key component of industrial and household waste, are routinely deposited in numerous ways on land and into water systems (Emmanuel et al., 2005; Metcalfe et al., 2008). These commonly are organic substances with amphiphilic structures, indicating that they contain both hydrophobic groups and hydrophilic groups, which allow them to adsorb various pollutants such as heavy metal ions and organic molecules (Flores et al., 2017; Gamba et al., 2017; Shah et al., 2017; Stofela et al., 2017; Zhang et al., 2017). As reported, surfactants can interact with geosorbents and impact their adsorption behavior toward pollutants (Koh and Dixon, 2001; Park et al., 2011; Richards and Bouazza, 2007; Xi et al., 2010). Surfactants also can bind to released nanomaterials, change their physicochemical characteristics, and then affect their adsorption mechanism (Liu et al., 2014; Rajesh and Ramagopal, 2016). It was reported that a surfactant (*i.e.*, cetylpyridinium chloride) can coat onto activated carbon and mineral substances to improve their removal performance for heavy metals from water (Choi et al., 2009; Lin et al., 2011; Sánchez-Martín et al., 2008). Furthermore, several papers have demonstrated that dissolved surfactants could impact the adsorption of organic pollutants by biochar. For example, Han et al. (2013) reported the influence of a cationic surfactant on pentachlorophenol adsorption by biochar; and the cationic surfactant cetyltrimethyl ammonium bromide could be coated onto the biochar surface *via* ion-exchange with abundant exchangeable cations, such as Mg^{2+}, Na^{+}, and K^{+}, and then impacted the pentachlorophenol adsorption.

Considering its increasing production and application, biochar has inevitably been released into the environment. Understanding the adsorption behavior of biochar toward toxic dye in the presence of surfactant has multiple important environmental implications, including assessing (i) the feasibility of using biochar as an adsorbent in engineered treatment of toxic dye, (ii) the fate and transport of toxic dye by biochar in the environment, and (iii) the potential environmental and health risks of biochar-adsorbed toxic dye in ecological systems. In this work, therefore, the physicochemical characteristics of biochar with surfactant coating such as sodium dodecyl sulfate (SDS) were investigated. In addition, the effect of the presence of SDS on the adsorption behaviors of methylene blue (MB) onto biochar was also examined.

1. Material and methods

1.1. Materials

The biomass used in this work was peanut shell obtained locally from the farms in Changsha City, Hunan Province, China. MB (3,7-bis{dimethylamino}-phenazathionium chloride, $C_{16}H_{18}ClN_3S{\cdot}3H_2O$, molecular weight 373.9) was obtained from Tianjin Hengxing Chemical Reagent Co., Ltd. (Tianjin, China). SDS was purchased from Shanghai Yabang Chemical Reagent Co., Ltd. (Shanghai, China). All other chemicals including HCl, NaOH and NaCl were provided by Guangdong Xilong Chemical Co., Ltd. All chemicals employed in this experiment were analytical reagent grade and used without any further purification. The water used in this work was Milli-Q water (18.25 MΩ/cm) obtained from a Millipore Milli-Q water purification system.

1.2. Preparation of adsorbent

The biochar was prepared as described by a previously published paper (Jiang et al., 2015). Briefly, 10-g biomass was added to a 250-mL beaker with 100-mL $Zn(NO_3)_2$ solution (1 mol/L). Then, the mixture was stirred continuously in a temperature-controlled water bath shaker at 40°C for 24 hr. After being dried, the mixture was pyrolyzed by a lab-scale tubular reactor (SK-G08123K, China) in a N_2 environment (400 mL/min) at 550°C for 1 hr. After cooling, the resulting biochar was washed with water, and dried in an oven at 65°C. After that, 1 g of prepared biochar was added into 100 mL of SDS solution (3, 1 and 0.6 mg, respectively). The mixture was also shaken in a temperature controlled water bath shaker at 120 r/min for 24 hr. Then the SDS-coated biochar was collected by filtration and dried at 65°C for 12 hr. The products were named 0.6 SDS-biochar, 1 SDS-biochar, and 3 SDS-biochar, respectively. Finally, the prepared samples were stored in a desiccator for further use (Mi et al., 2016).

1.3. Adsorbent characterization

Fourier transform infrared (FT-IR) spectroscopy measurements were performed using a Fourier Transform Infrared Spectrometer (Nicolet 5700 Spectrometer) using the KBr pellet technique in the range of 4000–400/cm. The Brunauer–Emmett–Teller (BET) surface area and the pore size distribution were determined by using N_2 adsorption–desorption (Quantachrome, USA) at 77 K over a relative pressure range from 0.0955 to 0.993. C, H O, Q6 N and S contents of samples were determined using an elemental analyzer (Elementar, Vario EL III). Thermal analysis of the precursor was done by thermogravimetry-differential scanning calorimetry (TG–DSC) on a Netzsch STA 449C instrument (conditions: air atmosphere, temperature ramp from 25 to 900°C, rate 20°C/min). The zeta potential of samples was obtained using a zeta potential meter (Zetasizer Nano-ZS90, Malvern) by adjusting the solution pH from 2.0 to 11.0.

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