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Sorption of Pb (II) using hydrogen peroxide functionalized activated carbon

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ABSTRACT

Activated carbon (AC) was oxidized by 30% H_2O_2 under the ultrasonic condition for different hours, which is characterized by transmission electron microscopy (TEM). It was found that the H_2O_2-oxidized AC becomes much porous compared with the AC. The Brunauer, Emmett and Teller (BET) surface area was measured using the nitrogen sorption experiment, suggesting that the surface area of AC increased after oxidation by H_2O_2. In addition, the sorption behavior of Pb^{2+} onto the AC and H_2O_2-oxidized AC was investigated. When the pH value gradually increases from 2 to 4, the sorption percentage of Pb^{2+} remarkably enhances. Upon further increasing the pH from 4 to 6, the sorption percentage increases slightly. At all pH values, the H_2O_2-oxidized AC shows higher sorption capability to Pb^{2+} compared with the AC. At pH 5, the sorption kinetics of Pb^{2+} onto AC and H_2O_2-oxidized AC were examined, which were in accord with the pseudo-second-order rate equation. The equilibrium sorption density of Pb^{2+} greatly increases onto the H_2O_2-oxidized AC. Otherwise, the sorption thermodynamics of Pb^{2+} was also studied, obeying the Langmuir sorption model. At the same temperature, the maximum sorption density of Pb^{2+} considerably increases onto the H_2O_2-oxidized AC.

1. Introduction

Water pollution by heavy metals is an important economic and environmental issue all over the world. Among heavy metal ions, Pb^{2+} attracts more attention due to the heavy toxicity and various adverse health effects [1]. Pb^{2+} easily accumulates in the environment and produces toxic effects on plants and animals, even at low concentrations, since Pb^{2+} is not biodegradable. Thus, examining the sorption behavior is important and valuable for developing effective and convenient way to remove Pb^{2+}.

Different carbon-based materials such as activated carbon (AC) are widely used and attract great interest for environmental studies because they are viewed as super-sorbents with microporous structure and much higher sorption capacity. For example, the sorption behavior of Pb^{2+} onto crop-residue-derived black carbon [2], Na_2S treated granular AC [3] and AC derived from coconut shell [4] was studied. Otherwise, various cation exchangers such as calcite [5], bentonite [6] and hydroxyapatite [7] were studied as the potential sorbents for Pb^{2+} since Pb^{2+} is positive charged. Recently, a variety of biosorbents were also developed for the sorption of Pb^{2+} such as *Bacillus cereus* biomass [8], *Chlorella vulgaris* [9] and *Pleurotus ostreatus* immobilized in calcium alginate gel [10].

In this work, we found that the properties of AC obviously improved after the ultrasonic oxidation with H_2O_2. For instance, the number of micro-pores and the surface area remarkably enhance after oxidation treatment. Otherwise, the pH value of H_2O_2-oxidized AC decreases in comparison with that of AC. These phenomena clearly reveal that the H_2O_2-oxidized AC probably exhibits higher sorption capability to Pb^{2+}. Therefore, the sorption behavior of Pb^{2+} onto AC and H_2O_2-oxidized AC was investigated with great detail. At first, the influence of solution pH value was studied. It was found that the sorption density of Pb^{2+} onto AC and H_2O_2-oxidized AC improved with increasing the pH value from 2 to 6. At all pH values, the sorption density of Pb^{2+} onto the H_2O_2-oxidized AC greatly increases, indicating that the oxidation treatment enhances the sorption ability of AC. Subsequently, the sorption kinetics and thermodynamics of Pb^{2+} onto AC and H_2O_2-oxidized AC were examined. The equilibrium sorption density and maximum sorption density considerably increase onto the H_2O_2-oxidized AC, suggesting that the H_2O_2-oxidized AC possesses higher sorption efficiency towards Pb^{2+}.

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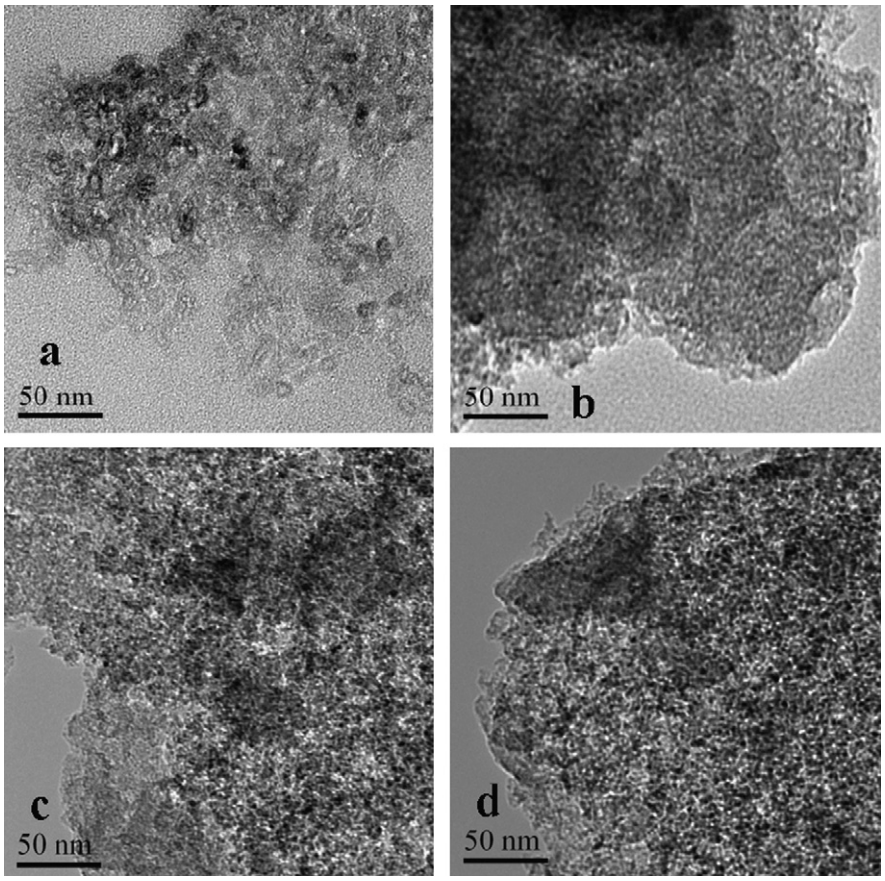

Fig. 1. TEM images of AC (a), AC-2 (b), AC-6 (c) and AC-10 (d).

2. Experimental

2.1. Materials

All the solutions were prepared using redistilled water. AC, $Pb(NO_3)_2$, H_2O_2, HCl and NaOH were purchased from the Sinopharm Group Chemical Reagent Co. Ltd., China.

2.2. Preparation of H_2O_2-oxidized AC

The oxidation treatment of AC was performed as the following procedure: 2.0 g of AC was added in 30.0 mL H_2O_2 (concentration = 30%), then oxidized under the ultrasonic condition for different hours such as 2, 6 and 10 h at room temperature. The oxidized ACs were individually denoted as AC-2, AC-6 and AC-10. After that, the oxidized AC was collected on a filter membrane, then washed with redistilled water, and finally dried at 120 °C overnight.

2.3. Batch sorption

All the batch sorption studies were conducted in 100-mL lined capped glass bottles containing 50.0 mL solution. All batch reactors were placed on a reciprocating shaker (SHZ-82 A, Changzhou Guohua Electric Appliance Company, China) at 140 rpm and under controlled temperature of 25 ± 1 °C. Each experiment was carried out in duplicate and the average value was employed.

Stock solution of Pb^{2+} was prepared by dissolving 30.00 mg $Pb(NO_3)_2$ in 1.00 L redistilled water. The concentration of Pb^{2+} was determined using an AA-6300 atomic absorption spectrophotometer (SHIMADZU, Japan).

Effect of pH value on the sorption of Pb^{2+} was evaluated as follows. 50.0 mL of 30.00 mg L^{-1} Pb^{2+} solution was added in the glass bottle, then the pH value was adjusted using 0.01 mol L^{-1} NaOH and HCl to attain the desired pH value (2.0–6.0) that measured using a Model PHS-3C pH meter (Shanghai Precision & Scientific Instrument Co. Ltd., Shanghai, China). After that, 25.00 mg AC or H_2O_2-oxidized AC was added in the solution, then shaken at 140 rpm for 20 min. Finally, all the suspensions were filtered using 0.22 μm membrane, and then analyzed for Pb^{2+} using AAS. The sorption percentage was determined by the following equation:

$$\text{Sorption percentage} = \frac{C_\text{i} - C_\text{t}}{C_\text{i}}$$

where C_i and C_t are the concentrations before and after sorption (mg L^{-1}), respectively.

Sorption kinetics was conducted to assess the sorption rate and the equilibrium time required to obtain the sorption isotherm. The experiments were performed under desired pH value (5.0 in this work) and the initial concentration of Pb^{2+} was 30.0 mg L^{-1}. In each test, 25.0 mg of sorbent was used, resulting in the sorbent loading of 0.5 g L^{-1}. After various sorption times, the suspension was filtered, and the filtrate was analyzed for Pb^{2+} using AAS. The sorption density of Pb^{2+} at any time (q_t, mg g^{-1}) was calculated by

$$q_t = \frac{(C_\text{i} - C_\text{t})V}{M}$$

where M is the dry mass of the sorbent (g), and V is the volume of the solution (L).

Sorption isotherms were measured at pH 5.0 and the sorbent loading was 0.5 g L^{-1}. After 4 h of shaking at 140 rpm, the suspen-