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Sludge Activated Carbon Prepared by High Dehydration and Carbonization Equipment and Adsorb Phosphorus in Wastewater

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Abstract. Sludge activated carbon (SAC_{hdc}) was prepared by high dehydration & carbonization equipment and used for adsorption phosphorus in wastewater. The sludge can be dehydrated until water content below 60%, then carbonized by the high dehydration & carbonization equipment. The SAC_{hdc} used as absorbent in phosphorus of wastewater treatment. The experimental results showed that the adsorption capacity of phosphorus could reach 4.598 mg/g, and adsorption rate was above 91%, the pseudo-second-order kinetic equation and Freundlich isotherm model could describe the phosphorus adsorption process of SAC_{hdc}. SAC_{hdc} prepared and used as absorbent realized the sludge harmless and resource utilization.

Keywords. SAC_{hdc}, phosphorus, adsorption effect

1. Introduction

With the acceleration of urbanization and the gradual increase of population, a large amount of sewage would be generated and in urgent need of treatment [1-3]. Sewage treatment plants would produce more sludge when they treat sewage. If the sludge was not properly treated, it would have an impact on the environment. Incineration and landfill were the most common treatment and disposal of sludge, but this would bring secondary pollution to water and atmosphere [4]. Sludge has a high moisture content and contains a large amount of organic matter. From the perspective of sludge carbonization and resource utilization, carbonization sludge can be used as adsorbent and catalyst, etc. [5, 6]. Research showed that use alum mud as phosphorus adsorbent has become a win-win technology for water treatment and wastewater treatment [7]. Phosphorus in sewage caused water pollution, the activated carbon made of sludge could adsorb phosphorus in sewage, it could not only make better resource utilization of sludge, but also make sewage get a good treatment [8, 9]. In this experiment, the independent research and development of the integrated sludge high dehydration & carbonization equipment, SAC_{hdc} was made by high dehydration & carbonization

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equipment, SAC_{hdc} used to adsorb phosphorus in sewage, explored the adsorption effect and adsorption mechanism of SAC_{hdc} on phosphorus under different conditions. Through characterization analysis, kinetics and thermodynamics, the adsorption effect of SAC_{hdc} as an adsorbent on phosphorus in sewage was studied, so that sludge could be better treated and disposed [10-12].

2. Material Preparation and Method

2.1. Experimental Materials and Instruments

Sludge was transported from Hefei Binhu Sewage Treatment Plant. Ascorbic acid, ammonium molybdate, potassium antimony tartrate and potassium dihydrogen phosphate were purchased from Tianjin Bodi Chemical Co., Ltd. All the above chemicals and reagents were analytically pure, and deionized water was used in the study. The instrument was an independent research and development of integrated sludge high dehydration & carbonization equipment.

2.2. The Preparation of SAC_{hdc}

SAC_{hdc} was prepared by integrated sludge high dehydration & carbonization equipment, and the specific steps were as follows. The sludge from Hefei Binhu Sewage Treatment Plant was transported to the laboratory, and used the high dehydration & carbonization equipment, as shown in Figure 1. The sludge was pumped into the pump and then added to the liquid medicine, after MF040-06 special high pressure plate frame filter press in the depth of high pressure to reduce the moisture content to 60%. After entered the high dehydration & carbonization equipment in the absence of oxygen conditions to heated the drying system to reduce the moisture content to 20%-30%, and then entered the carbonization machine in the absence of oxygen conditions for gas-solid separation cracked, taken the final residue in the sample bag with labels for reserve.

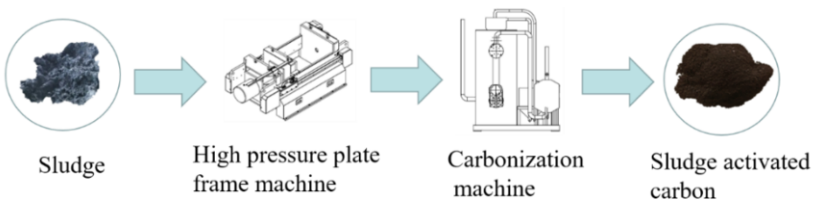

Figure 1. Flow chart of SAC_{hdc} preparation.

2.3. Experimental Steps of Sac_{hdc} Adsorption

Phosphorus solution and distilled water were added to the conical bottles, respectively, then 1 g SAC_{hdc} was put into the reaction. The absorbance was measured after the reaction. The concentration was calculated according to the standard curve, and then the adsorption rate was calculated.

The adsorption rate was (E, %):

$$E = (C_0 - C_e) / C_0 \times 100\% \quad (1)$$

The adsorption capacity was (q, mg/g):

$$q = (C_0 - C_e)V_2 / (1000m) \quad (2)$$

In the equation, M—the phosphorus content of the sample was measured, mg; V_1—sample volume for determination, mL; C_o, C_e—initial and equilibrium concentrations, mg/L; V_2—phosphorus waste water volume, mL; m—SAC_{hdc} dosage, g.

2.4. Analytical Method

SU8010 cold field emission scanning electron microscope (SEM) was used to scan and characterize structure of SAC_{hdc}. The SAC_{hdc} was characterized and analyzed by Fourier transform infrared spectrometer (FT-IR) and X-ray diffractometer (XRD).

3. Results and Discussion

3.1. The Characteristics of the SAC_{hdc}

The material structure of SAC_{hdc} was shown in Figure 2. As can be seen from Figure 2, SAC_{hdc} observed at different multiples were generally distributed in granular form and have some large or small pores on their surfaces. When the multiples were large, SAC_{hdc} were distributed loosely and their pore sizes were obvious. These void joints of different shapes and sizes could make materials shuttle back and forth, which was of great helpful for SAC_{hdc} adsorption.

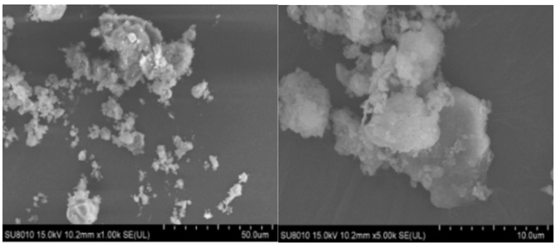

Figure 2. SEM spectra of SAC_{hdc}

FT-IR and XRD were used to characterize and analyze the SAC_{hdc}, the results were shown in Figures 3a and 3b. Figure 3a was the analysis of SAC_{hdc} by FT-IR. Peaks appeared at about 500-1200 cm^{-1}, 1500 cm^{-1} and 3500 cm^{-1}, indicated that the SAC_{hdc} contained C-N, O-H stretching bonds and C=O (1500 cm^{-1}) symmetric bonds.

Figure 3b showed atomic detection of SAC_{hdc} by XRD, and the peak area and peak height indicated the content and strength of SAC_{hdc}. It can be seen from the diffraction peaks in Figure 3b at 2θ angles of 20.80, 26.50, 29.20, 39.30, 36.50, 48.40, 50.00, 59.90 indicated that the SAC_{hdc} contains C, SiO_2 and $CaCO_3$.

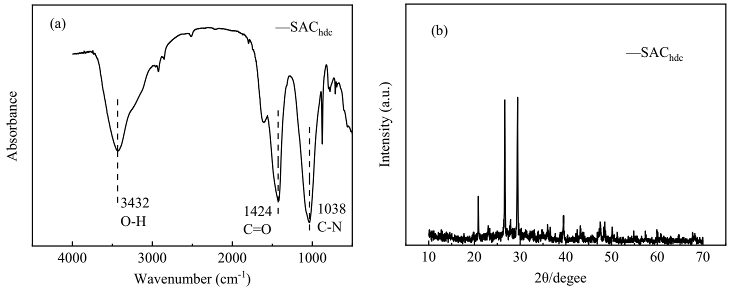

Figure 3. (a): FT-IR spectra; (b): XRD patterns.

3.2. Factors Affecting Adsorption Efficiency SAC$_{hdc}$

In aqueous solution, SAC$_{hdc}$ characteristics have the influence of environmental temperature of aqueous solution, pH of aqueous solution, adsorption kinetics, adsorption isotherm and so on. The adsorption capacity and adsorption rate of SAC$_{hdc}$ at different adsorption conditions were shown in Figures 4a-4d.

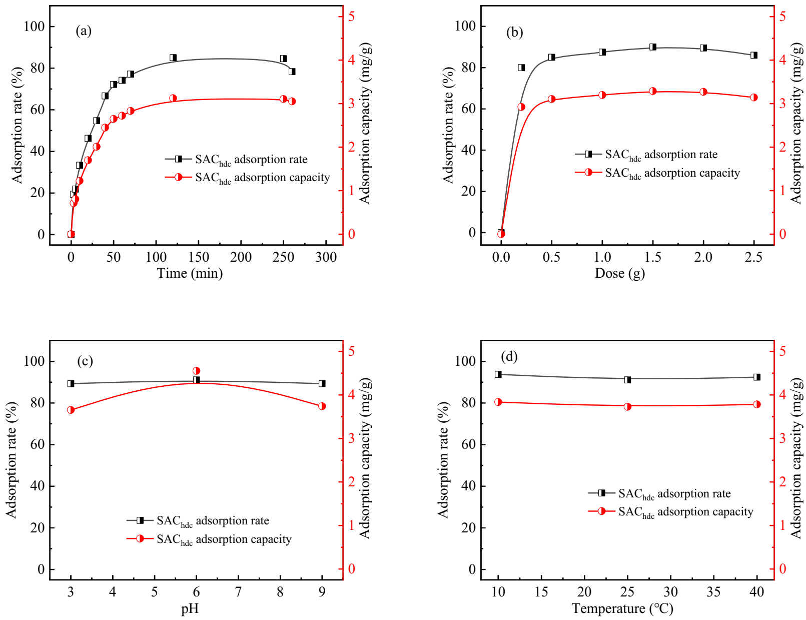

Figure 4. (a): The effects of time on the adsorption; (b): The effects of dose on the adsorption; (c) The effects of pH on the adsorption; (d): The effects of temperature on the adsorption.

As can be seen from Figure 4a, when 120 min, the adsorption rate gradually stabilized, the SAC$_{hdc}$ for phosphorus adsorption rate at 85.07%, adsorption volume of 3.124 mg/g. At the end, the adsorption was even reduced. So 120 min can be used.

As can be seen from Figure 4b, when the dosage of SAC$_{hdc}$ increased to 1.50 g, the adsorption capacity increased to 3.288 mg/g, and the adsorption rate increased to 90%. Both values reach the maximum. So 1.00 g can be selected as the best SAC$_{hdc}$ dosage.

As can be seen from Figure 4c, when pH was 6, the best adsorption, the adsorption rate was 91.07%, and the amount of adsorption capacity was 4.553 mg/g. So neutral conditions were selected.

As can be seen from Figure 4d, temperature had no significant influence on the adsorption effect of phosphorus from sewage by SAC_{hdc}, so room temperature was used for the experiment.

3.3. Kinetics and Thermodynamics of SAC_{hdc}

3.3.1. Kinetics of SAC_{hdc}

In order to better explore the adsorption of phosphorus by SAC_{hdc} in kinetics, so adopts pseudo first and pseudo second order kinetic equation to fit [13]:

Pseudo-first-order kinetics equation was:

$$n(q_e - q_t) = \ln q_e - k_1 t \quad (3)$$

Pseudo-second-order kinetics equation was:

$$t / q_t = 1 / (k_2 q_e^2) + t / q_e \quad (4)$$

In the equation, q_e—balance q, mg/g; q_t—moment q, mg/g; k_1—constant, min^{-1}; k_2—constant, g/(mg· min).

Through the analysis of pseudo-first-order and second-order kinetic linear equations, the relationship between the concentration of the adsorption object and the adsorption time can be used to describe the adsorption kinetics as shown in Figures 5a and 5b, and the adsorption kinetic parameter table can be obtained.

It can be seen from the data analysis in Figures 5a and 5b and Table 1 that the pseudo-second-order kinetic model was relatively good to describe the kinetic of phosphorus adsorption by SAC_{hdc}, indicated the adsorption process of phosphorus in this adsorption reaction, and the chemical adsorption mechanism plays a great role in this stage.

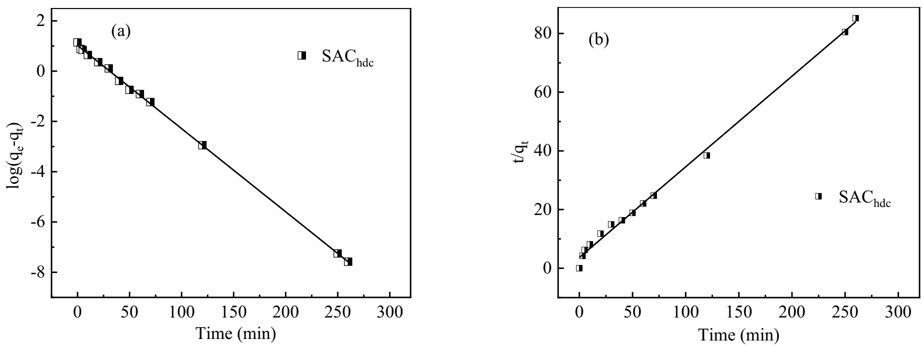

Figure 5. (a) Pseudo-first-order kinetics curve; (b) pseudo-second-order kinetics curve.

Table 1. Adsorption kinetic parameters.

Pseudo first order kinetic parameters			**Pseudo-second-order kinetic parameters**		
q_e/mg/g	K_1/min^{-1}	R^2	q_e/mg/g	K_2/g.mg^{-1}.min^{-1}	R^2
2.778	0.033	0.994	3.237	0.026	0.996

3.3.2. Thermodynamics of SAC_{hdc}

The adsorption kinetics can be described by the relationship between the concentration of the adsorbed object and its adsorption capacity. The adsorption isotherms of Freundlich model and Langmuir model were fitted linearly using isothermal adsorption data, and the parameters of Figures 6a and 6b and adsorption isotherm were obtained.

Freundlich model:

$$\text{n}\, q_e = \ln K_f + 1/n \ln C_e \tag{5}$$

Langmuir model:

$$1/q_e = 1/Q_m + 1/(Q_m K_L)\ 1/\text{C}_e \tag{6}$$

In the equation, q_e—balance q, mg/g; Q_m—saturated adsorption capacity, mg/g; C_e—balance C, mg/L; K_L—constant; K_f—constant.

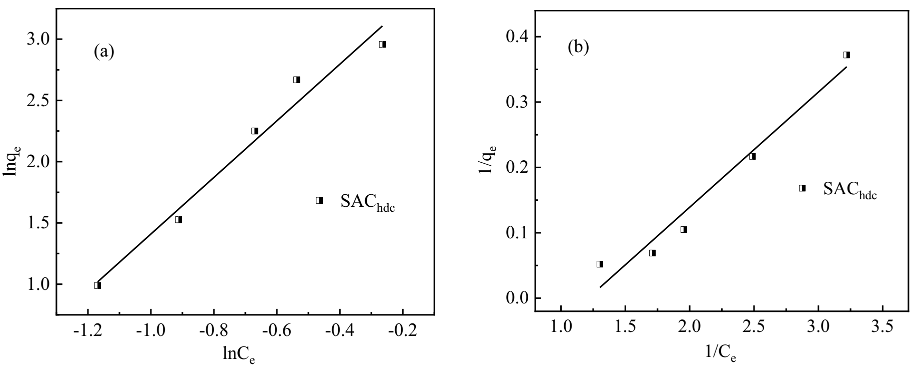

Figure 6. (a): Freundlich adsorption isotherm; (b): Langmuir adsorption isotherm.

Table 2. Parameters of adsorption isotherm.

Freundlich			**Langmuir**		
1/n	K_F	R^2	q_m/mg/g	K_L	R^2
2.311	41.259	0.972	4.695	1.210	0.962

From the analysis of the results in Table 2, it can be seen that the determination coefficient of Freundlich isothermal adsorption model for fitting phosphorus adsorption of SAC_{hdc} was R^2_F > 0.962, so the Linear correlation of Freundlich curve was higher than that of Langmuir curve. It can be concluded that the thermodynamic description of phosphorus adsorption by SAC_{hdc} was better described by Freundlich model second paragraph.

4. Conclusion

SAC_{hdc} was prepared by the independent research and development of the integrated sludge high dehydration & carbonization equipment, which realized high dry dehydration and carbonization of sludge. At the same time, sludge resource utilization made SAC_{hdc} adsorb phosphorus in sewage, the adsorption of SAC_{hdc} fitted for pseudo-second-order kinetics, and the adsorption process confirmed to chemical adsorption. The high dehydration & carbonization equipment broke through the bottleneck of traditional sludge dehydration technology and resource utilization, the sludge can be better treated and reused.

Acknowledgements

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