Degradation Effect of UV Synergistic Biomass Activated Carbon Materials on Phenol Pollutants in Water

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Abstract: The purpose of the study is to purify the water containing phenol pollutants. The degradation effect of phenol pollutants in water is studied through the combined action of UV and biomass-activated carbon. First, the phenol solution is prepared in the laboratory to simulate the polluted water. Second, the phenol adsorption effects of UV synergistic biomass activated carbon, biomass activated carbon and ordinary industrial activated carbon under different influencing factors are compared by experiments. Finally, the results are analyzed and the conclusions are drawn. The results show that the UV synergistic biomass activated carbon has the strongest degradation ability for phenol, and the highest removal rate is 66.5% when the shaking time is 65 minutes. The adsorption ability of the industrial activated carbon for phenol is the worst. When the initial concentration of phenol is 25mg/L, the maximum phenol removal rate is 96.8%. The maximum phenol removal rate of biomass activated carbon appears in the initial concentration of phenol and the phenol removal rate is 60 mg/L. The reaction temperature has little effect on the phenol removal rate of UV synergistic biomass activated carbon and biomass activated carbon. The phenol removal ability of UV synergistic biomass activated carbon reaches the highest when the dosage of activated carbon is 2.0 g, and the rates are 96.4% and 91.1%, respectively. When the pH of the solution is 7, the removal rate of UV synergistic biomass activated carbon reaches a maximum of 97%. When the pH of the solution is 6, the removal rate of biomass-activated carbon reaches the maximum. When the pH of the ordinary industrial activated carbon is 7, the removal rate is the maximum. Due to different influencing factors, UV synergistic biomass activated carbon has the strongest phenol degradation ability. This study provides a reference for the purification of polluted water.

1. Introduction
Phenol is a degradable organic pollutant, a toxic chemical substance. It is easily absorbed by the human body after contacting with it, causing heart and lung damage [1]. As people pay more and more attention to the environment, the removal of phenol in wastewater is one of the hottest water purification. In particular, the high concentration of phenols in biorefinery wastewater has received widespread attention [2]. At present, the removal methods of phenol in wastewater mainly include distillation, extraction, adsorption, membrane, oxidation, and biological treatment [3]. In this paper, biological treatment, namely degradation, is used, with ultraviolet and biomass activated carbon to purify water bodies containing phenolic pollutants.

Biomass activated carbon refers to an activated carbon with immobilized microorganisms, which has a longer life span than ordinary activated carbon. Microorganisms have the characteristics of rapid degradation of organic matter in wastewater, so biomass activated carbon has both the functions of adsorption and aerobic degradation. Biomass activated carbon is formed by technological processing of
common biological organic matter in life. The raw materials of biological organic matter include animal and plant biomass and other types of biomass [4]. China produces a large amount of biomass waste every year. The development and utilization of biomass waste to prepare high-performance activated carbon can be used for the prevention and control of water pollution by using its adsorption capacity, which also has certain positive significance for the development of environmental protection [5]. The preparation methods of biomass activated carbon include carbonization method, activation method, chemical method, chemical and physical combination method. At present, the most commonly used preparation method is activation method, such as combining conventional pyrolysis, chemical activation process to synthesize biomass activated carbon with pine nuts as raw material [6]; zinc chloride is used as activator to prepare biological and activated carbon through chemical activation [7]; phosphoric acid is used as the activator and wood chips as raw materials to prepare biomass activated carbon [8]. The combination of chemical and physical methods is also more common, such as the use of the chemical composition of special steel slag ultrafine powder based on the chemical and physical combination to modify waste walnut shells to prepare steel slag-based biomass activated carbon [9].

Ultraviolet rays can destroy the DNA molecular structure of microbial cells and achieve the effect of sterilization and disinfection. At present, short-wave sterilizing ultraviolet (UVC) with strong penetrating power is often used in water treatment. The advantages of ultraviolet disinfection include fast disinfection speed, short disinfection time, more thorough virus removal, and no secondary pollution [10]. Using strong ultraviolet rays to irradiate the water stream that has been added with biological activated carbon can prevent the growth of bacteria on the biological activated carbon. There have been many studies on the application of ultraviolet disinfection to sewage treatment. The most common one is to use fecal coliforms as indicator microorganisms to study the disinfection effect of ultraviolet rays [11, 12]. Since phenolic pollutants are harmful to the human body and the environment, this article combines ultraviolet rays and biomass activated carbon materials to purify water. In this paper, while purifying the phenolic water body using biomass activated carbon, strong ultraviolet light irradiation is added. The purification effect of polluted water is summarized and discussed, and compared with the purification effect of water without ultraviolet radiation and ordinary industrial activated carbon treatment. The innovation of the article lies in the combination of ultraviolet rays and biomass activated carbon to purify water polluted by phenols. The research content of the article provides a reference for the treatment of water pollutants.

2. Experimental Method and Parameter Setting of Phenol Removal

2.1 Experimental drugs and instruments
The specifications of the drugs used in this experiment are analytically pure phenol, hydrochloric acid, sodium hydroxide, and deionized water prepared by the laboratory. Biomass activated carbon is produced by Henan Water Equation Water Purification Co., Ltd., and ordinary industrial activated carbon is produced by Henan Fang Yuan Environmental Protection Material Co., Ltd.

The instruments used in this experiment are DR6000 ultraviolet-visible spectrophotometer, constant temperature oscillator, electronic balance, electric heating constant temperature blast drying box. Since the conventional ultraviolet water quality processor generally emits short-wave UVC with a wavelength between 180-260nm during water quality treatment, the ultraviolet irradiation device is selected as a UVC short-wave ultraviolet lamp with a wavelength of 254nm in this experiment, which is produced by Shanghai Yaozhuang Testing Equipment Co., Ltd..

2.2 Experimental method
(1) Configuration of phenol solution
In this study, a laboratory-prepared phenol solution is used to simulate the water body containing phenolic pollutants. The preparation process is shown in Figure 1.
It can be seen from Figure 1 that 0.03, 0.06, 0.09, 0.12, 0.15g of dried phenol are weighed with an electronic balance, and deionized water is added to dissolve in a beaker and then transferred to a 1000mL volumetric flask. The concentration of the phenol solution is respectively 30, 60, 90, 120, 150mg/L.

(2) Plotting of phenol standard curve
1.0, 1.5, 2.0, 2.5, 3.0ml phenol standard solution (50mg/L) is added to five 550ml colorimetric tubes respectively, which are diluted to the mark with deionized water, shaked well. 1cm cuvette is used, with deionized water as a reference, and the absorbance of each solution is measured at 260nm, and a standard curve is drew.

(3) Phenol removal rate
The absorbance of the phenol solution before and after the experiment is measured by ultraviolet spectrophotometry, the concentration of phenol before and after the experiment is calculated by the standard curve, and the removal rate of phenol is calculated by the following formula.

\[ H = \left( \frac{S_0 - S}{S_0} \right) \times 100\% \]  \hspace{1cm} (1)

In formula (1), H is the removal rate of phenol, S0 is the initial concentration of the phenol solution, and S is the concentration of the phenol solution after degradation.

(4) UV synergy method
The ultraviolet collaborative experiment method of this research uses a 254nm UVC short-wave ultraviolet lamp to irradiate the polluted water body, and the irradiation time is the whole process of the biomass activated carbon to purify the water body. The specific parameters are given in the influencing factor experiment.

2.3 Experimental procedures for different influencing factors
There are three experiments. The first group is equipped with UV synergic biomass activated carbon to purify phenol-containing water, the second group is equipped with biomass activated carbon to purify phenol-containing water, and the third group is equipped with ordinary industrial activated carbon to purify phenol-containing water.

In these experiments, the five influencing factors of the three experiments for the removal of phenol solution are compared. The specific experimental parameters and experimental procedures are shown in Figure 2.
Add 2g activated carbon and 100mL phenol solution with a concentration of 60mg/L into a 250mL conical flask, and place the conical flask in a constant temperature oscillator with a temperature of 25°C and an oscillation speed of 100r/min, with oscillation time of 25min, 30min, 40min, 65min and 90min.

Add 2g activated carbon into a 250mL conical flask, then add phenol solution with concentrations of 30mg/L, 60mg/L, 90mg/L, 120 mg/L and 150mg/L, and put the conical flask in a thermostatic oscillator with a temperature of 25°C and an oscillation speed of 100r/min, and the oscillation time is set to 65min.

Add 2g activated carbon and 100mL phenol solution with the concentration of 60mg/L into a 250mL conical flask, set the oscillation speed of a constant temperature oscillator at 100r/min for 65min, and set the temperature at 15°C, 25°C, 35°C, 45°C and 55°C respectively.

1g, 1.5g, 2g, 2.5g and 3g of activated carbon and 100mL of phenol solution with a concentration of 60mg/mL were added into a 250mL conical flask. The conical flask was placed in a thermostatic oscillator with a temperature of 25°C and an oscillation speed of 100r/min, and the oscillation time was set to 65min.

In a 250mL conical flask, 2g activated carbon and 100mL phenol solution with a concentration of 60mg/mL were added. Add HCl and NaOH to adjust that pH value of the solution, the pH values of the solutions were adjusted to 5, 6, 7, 8, 9 and 10 respectively. The conical flask was placed in a constant temperature oscillator with a temperature of 25°C and an oscillation speed of 100r/min, and the oscillation time was set to 65min.

Figure 2 Experimental parameters of different influencing factors of phenol removal by biomass activated carbon

It can be seen from Figure 2 that the influencing factors set in this paper are the oscillation time of the phenol solution, the initial concentration of phenol, the reaction temperature, the amount of biomass activated carbon and the pH of the solution. The first experiment is irradiated with a 254nm UVC short-wave ultraviolet lamp for the entire oscillation process; the activated carbon used in the second group of experiments is biomass activated carbon; the activated carbon used in the third experiment is industrial activated carbon. After the above experimental operations are completed, the supernatant of the solution is taken and measured the absorbance with an ultraviolet-visible photometer to obtain the phenol concentration before and after the solution is purified, which is substituted into formula (1) to obtain the phenol removal rate.
3. Analysis of Phenol Removal Results

3.1 Initial concentration of phenol solution
On the basis of the previous text, a standard curve diagram of the phenol solution is drew as shown in Figure 3.

![Figure 3 Standard curve of phenol concentration](image)

It can be seen from Figure 3 that the correlation coefficient of the phenol concentration standard curve in this experiment is 0.9994 > 0.99, which is more feasible. In the following text, the absorbance after degradation of phenol can be substituted into Figure 3 to obtain the purified concentration of the phenol solution, and then substituted into formula (1) to calculate the phenol removal rate.

3.2 Phenol removal rate under the influence of phenol solution oscillation time
Figure 4 shows the effects of the oscillation time of the phenol solution on the three groups of water purification methods.

![Figure 4 Effects of oscillation time on phenol removal rate](image)
It can be seen from Figure 4 that under the three groups of conditions, the adsorption capacity of activated carbon for phenol increases with time, and the adsorption effects become saturated after a certain period of time. The UV synergistic biomass activated carbon has the strongest ability to degrade phenol. When the oscillation time is 65 minutes, the saturation removal rate is first reached, which is 66.5%, the adsorption capacity of biomass activated carbon is second, and the adsorption capacity of industrial activated carbon for phenol is the worst. It analysed that the reason is that ultraviolet radiation inhibits the bacterial growth of biomass activated carbon, but as the oscillation time increases, the phenol attached to the activated carbon desorbs, so the removal rate begins to decrease.

3.3 The removal rate of phenol under the influence of the initial concentration of phenol solution

The effects of the initial concentration of phenol solution on the three groups of water purification methods are shown in Figure 5.

![Figure 5](image)  
**Figure 5** The effects of the initial concentration of phenol on the removal rate of phenol

It can be seen from Figure 5 that when the initial phenol concentration is 25mg/L, the phenol removal rate of UV synergistic biomass activated carbon is 96.8%, while the maximum phenol removal rate of biomass activated carbon without ultraviolet radiation appears when the initial phenol concentration is 60mg/L, ordinary activated carbon reaches the highest phenol removal rate when the initial concentration of phenol is 90mg/L, which is 72.3%. After the three groups reached the highest removal rates, the initial concentration of phenol increased and the removal rate decreased. The reason is that the activated carbon has a certain adsorption capacity. If the adsorption capacity is exceeded, that is, the initial concentration of phenol is too large, it will cause the activated carbon to be supersaturated and reduce the removal rate.

3.4 Phenol removal rate under the influence of reaction temperature of phenol solution

The effects of the reaction temperature of the phenol solution on the three groups of water purification methods are shown in Figure 6.
It can be seen from Figure 6 that the reaction temperature has little effect on the phenol removal rate of UV synergistic biomass activated carbon and biomass activated carbon. The phenol removal rate of ordinary activated carbon is inversely proportional to the increase in temperature. It is guessed that the reason may be the pores of ordinary industrial activated carbon. The structure is worse than that of biomass activated carbon, and the increase in temperature will cause the phenol molecules to fail to attach to the activated carbon.

3.5 Phenol removal rate under the influence of activated carbon dosage

The effects of the amount of activated carbon on the three groups of water purification methods are shown in Figure 7.
It can be seen from Figure 7 that the phenol removal abilities of the three groups of activated carbons all increase with the increase of the amount of activated carbon. The phenol removal abilities of the UV synergistic biomass activated carbon and biomass activated carbon reach the highest when the amount of activated carbon is 2.0g, which are 96.4% and 91.1% respectively. The removal rate of ordinary activated carbon reaches the highest 69.8% when the amount of activated carbon is 2.5g. When the amount of activated carbon continues to increase, supersaturation will occur, thereby reducing the phenol removal rate.

3.6 Phenol removal rate under the influence of solution pH

The effects of the pH of the solution on the three groups of water purification methods are shown in Figure 8.

![Figure 8 The effect of solution pH on phenol removal rate](image)

It can be seen from Figure 8 that the pH of the solution has little effect on the phenol removal rate of biomass activated carbon. When the pH of the solution is 7, the removal rate of UV synergistic biomass activated carbon reaches the maximum 97%. The removal rate of biomass activated carbon reaches the maximum when the pH is 6, and the removal rate of ordinary industrial activated carbon reaches the maximum when the pH is 7. After the phenol removal rates of the three groups reach the maximum, as the pH of the solution increases, the removal rate begins to decrease. The reason is that the solution changes from acidic to alkaline, and the phenol ionizes and cannot continue to adhere to the activated carbon.

4. Conclusion

In this paper, a laboratory-prepared phenol solution is used to simulate polluted water for water purification research. By comparing the adsorption effects of three groups of adsorption conditions on phenol under 5 different influencing factors, the UV synergistic biomass activated carbon has the best degradation effect on phenol. This article provides a reference for the purification treatment of phenol-polluted water bodies. However, this article still has certain limitations. It does not consider the effect of different wavelengths of ultraviolet rays with biomass activated carbon on the concentration of phenol in combination. Follow-up studies can carry out in-depth research on this aspect to make the research content more comprehensive.
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