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Application of UV Photocatalytic Degradation of Benzene

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Abstract: Benzene pollution is becoming increasingly serious, and the treatment technology of benzene has attracted much attention. In this paper, a self-made photocatalytic reactor was used to explore the removal rate of benzene under the ultraviolet light with the wavelength of 253.7nm. The results showed that the degradation rate of benzene decreased from 64.29% to 16.26% when the concentration increased from 43mg/m^3 to 256mg/m^3 under the condition of 28W UV light intensity and 50s residence time. Under the condition of 28W UV light intensity and 103mg/m^3 concentration, the residence time increased from 16.5s to 50s, and the benzene removal rate increased from 13.23% to 42.72%.Under the condition of benzene concentration 103mg/m^3 and residence time of 50s, the removal rate of benzene increased from 29.34% to 52.58% in the process of UV light intensity rising from 28W to 48W.It is concluded that decreasing the concentration and increasing the residence time of gas were beneficial to the removal of benzene and increasing the light intensity can improve the removal rate of benzene.

Key Words: Benzene; Photocatalysis; Removal rate

1. Introduction

Benzene is an aromatic hydrocarbon of VOCs, which is usually a colorless transparent liquid with sweet taste, combustion, carcinogenicity and toxicity, as well as a strong aromatic smell. There are many sources of benzene series, mainly from industrial emissions and motor vehicle exhaust [1]. Meanwhile, a large amount of benzene is emitted from raw materials used in building decoration. Benzene is flammable and explosive organic matter, and can cause damage to human nervous system, hematopoietic system and skin. Acute benzene poisoning is mainly manifested as neurological symptoms, accompanied by headache, dizziness, nausea, vomiting and other phenomena [2-3].

With the increase of benzene emissions, the harm of benzene has been paid attention to, so benzene pollution treatment technology has become a research hotspot, the main technologies include adsorption method, absorption method, membrane separation method, biodegradation method, photocatalysis method and low-temperature plasma method [4-5]. Adsorption method is to use adsorbent and volatile organic compounds for physical binding or chemical reaction and remove the contaminated ingredients; Absorption method is to use waste gas contact to transfer volatile organic compounds from waste gas, and then use chemical agents to destroy volatile organic chemical reactions; The mechanism of membrane separation is often explained by the size of membrane aperture as the model, which is caused by the action between separating substances and related to the physical and chemical conditions of membrane mass transfer process and the action between membrane and separating substances [6], so as to achieve the separation of organic substances. Biodegradation refers to the use of microorganisms to digest and metabolize the pollutants in volatile organic compounds and convert the pollutants into harmless water, carbon dioxide and other inorganic salts [7]; Photocatalysis refers to the use of light energy in nature to convert it into the energy needed for chemical reactions, so as to generate catalysis and stimulate surrounding oxygen and water molecules into free anions with oxidizability, thereby degrading benzene[8]. Exhaust gas low temperature plasma technology governance is the main principle of the under high electric field strength, the use of plasma produced by a dielectric discharge at breakneck speed repeatedly bombarding the exhaust gas molecules, to activate, ionization and pyrolysis gas in various ingredients, destroying the

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structure of gas molecule [9-10], through a series of complex chemical reactions such as oxidation, make complicated molecules of pollutants into the safety of the small molecular substances, or make the poisonous and harmful substances into harmless non-toxic or low toxic less harmful substances.

This thesis mainly for benzene waste gas method on the discussion of photocatalytic oxidation, and chose the UV photolysis method is used for further experiments to explore and research, investigation under the condition of the same background gas, the concentration of benzene, light intensity, residence time influence on the removal rate of benzene, tries hard to find in the guarantee of removal efficiency at the same time to save the cost method to develop the economy and high removal rate, low energy consumption degradation device to solve the current benzene pollution of the environment.

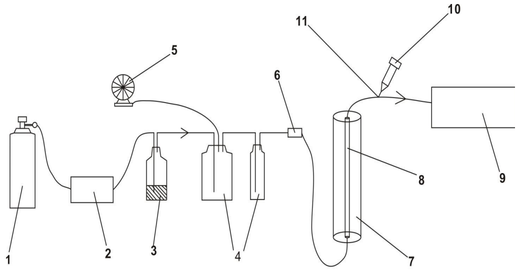
2. Experimental

2.1 Experiment Reagent

Benzene (analytical pure), standard air.

2.2 The Test Process

The experimental device consists of two parts: the distribution system and the photocatalytic reactor. The distribution system consists of air cylinder, gas flow controller, blower, benzene generator, buffer bottle, glass rotor flowmeter and pipeline system. The photocatalytic reactor is composed of a packed fixed bed reactor and an ultraviolet sterilizing lamp tube which is embedded in the packed fixed bed reactor for internal fixation. The packed fixed bed reactor is made of plexiglass and has a cylindrical structure with an effective volume of 1.6L and the characteristic wavelength of the ultraviolet sterilizing lamp is 253.7nm. In the experiment, ultraviolet sterilizing lamp tubes of different powers are installed to adjust different light intensity, and the residence time of gas flowing through the photocatalytic reactor is controlled by adjusting rotor flowmeter. The tail of the photocatalytic reactor is connected with tail gas absorption device through pipeline system. In the experiment, samples were taken by 1mL air-tight needle and analyzed by gas chromatography. Its flow chart and device block diagram are shown in figure 1:



Note:1.Air cylinder 2. Mass flowmeter 3. Benzene generator 4.Buffer bottle5.Blower6. Rotor flowmeter 7. Photocatalytic reactor8.Ultraviolet bactericidal lamp 9. Tail gas absorption device 10. Air-tight needle 11. Sampling port

Fig. 1 The reaction flow diagram

3. Results and discussions

3.1 Effect of Illumination Time on Degradation Efficiency of Benzene

The effective volume of the reactor is 1.6L, the effective volume of the reactor is 65mm, the inner diameter is 60mm, the length is 585mm, and the inlet concentration is 103mg/m^3 under 28W ultraviolet sterilizing lamp. The removal rate of benzene with illumination time is shown in Fig. 2 when the gas residence time is 50s.

According to figure 2, when the photocatalytic reaction reaches 40min, the photocatalytic degradation efficiency rapidly increases to 19.95%.In the remaining reaction time, the photocatalytic degradation efficiency continued to increase at a gradually increasing rate, and finally increased to the maximum value of 42.99% after the reaction time reached 160min, and the energy remained basically unchanged within 240min.The main reason for this phenomenon is that at the initial stage of reaction, O_2 and H_2O molecules in the air are excited by ultraviolet light to produce ·OH and O_2· and other active groups and photogenic electrons, because ·OH and O_2· have strong oxidation properties and can undergo redox reaction with pollutants to achieve the purpose of degradation[11]. With the progress of the reaction, the number of active free radicals and photons in the whole photocatalytic reaction apparatus remains stable, so that the photocatalytic degradation reaches an equilibrium degradation rate and does not increase[12].

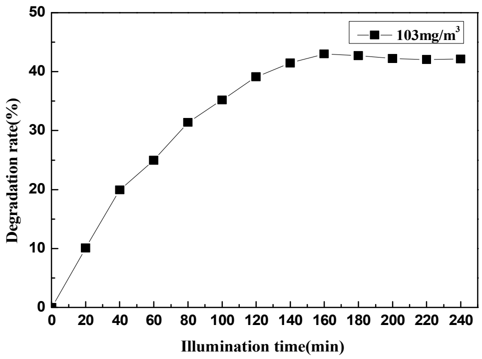


Fig.2 Effect of on degradation efficiency

3.2 Effect of Concentration on Degradation Efficiency of Benzene

Under the conditions of organic glass reactor with 65mm outer diameter, 60mm inner diameter, 585mm long, 1.6L effective volume, 28W ultraviolet bactericidal lamp and air as carrier gas, the gas residence time is 50s. The degradation rate of benzene after photocatalytic reaction for 4H is explored at 43mg/m^3, 103mg/m^3, 166mg/m3, 215mg/m^3 and 256mg/m^3, as shownin Fig.3.

As shown in figure 3, the removal rate of benzene decreases with the increase of benzene concentration. When the concentration was 43mg/m^3, the removal rate was 64.29%. When the concentration was 103mg/m^3, the removal rate was 42.99%. When the concentration was 166mg/m^3, the removal rate was 31.73%.When the concentration was 215mg/m^3, the removal rate was 21.41%. When the concentration was 256mg/m^3, the removal rate was 16.28%.The results show that the photodegradation efficiency decreases with the increase of the initial concentration of benzene. This is because, under a certain amount of light irradiation, ultraviolet light emits a certain number of photons, generating a corresponding amount of free radicals, which leads to the chain reaction of the corresponding amount of benzene. With the increase of benzene concentration, the insufficient free radicals generated in the system lead to the reaction of more benzene, which leads to the reduction of photodegradation efficiency. It is also possible that the intermediate products produced in the degradation process of benzene compete with benzene to absorb incident photons or free radical active substances. When the initial concentration of benzene increases, the concentration of intermediate products also increases, resulting in the intermediate products absorbing more photon energy, while the photon energy absorbed by benzene decreases, and quantum yield decreases. Therefore, as the initial concentration of benzene increases, the photocatalytic degradation efficiency decreases [13].

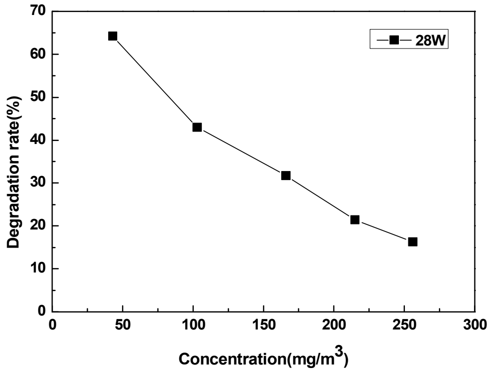


Fig. 3 Effect of concentration on degradation efficiency

3.3 Effect of Total Flow Rate on Degradation Rate

Ultraviolet light is an important variable in this experiment, and its light intensity has a significant influence on the photocatalytic degradation efficiency. FIG. 4 shows the degradation rate of benzene after photocatalytic reaction for 4h, when the residence time is 50s, the initial concentration is 103mg/m^{3}cubed, and the UV intensity is 15W, 28W and 48W, as shown in FIG. 4.

As can be seen from figure 4, when other conditions control a certain amount, the photocatalytic degradation efficiency increases with the increase of ultraviolet light intensity. When the residence time is 50s, the initial concentration is 103mg/m^3 cubed, and the UV intensity is 15W, the photocatalytic degradation efficiency reaches the minimum value of 29.34%. The reason is that, in the reaction mechanism of photocatalytic reaction, as the intensity of ultraviolet light increases, benzene can absorb more photon energy in the degradation process, quantum yield increases, reaction efficiency increases, and photocatalytic degradation efficiency increases accordingly[14].

When the intensity of ultraviolet light is weakened, the sufficient photon energy absorbed by benzene in the degradation process also decreases, resulting in reduced reaction efficiency and photocatalytic degradation efficiency.

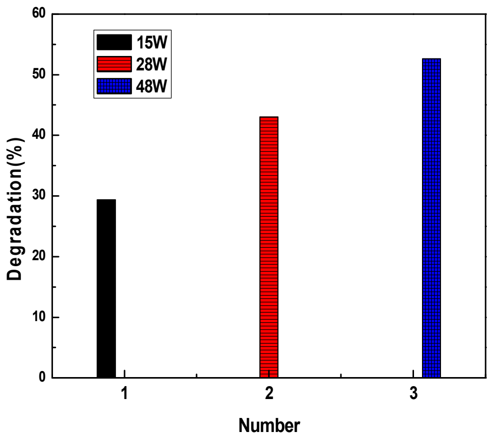


Fig.4 Effect of light intensity on degradation rate

3.4 Effect of Residence Time on Degradation Rate

The effective volume of the reactor was 1.6L, the inlet concentration was 103mg/m^3 under the condition of 28W ultraviolet sterilizing lamp and air carrier gas. The residence time of the gas was 16.5s, 20s, 25s, 33s and 50s. The degradation rate of benzene after photocatalytic reaction for 4h was shown in figure 5. As shown in figure 5, when the residence time of benzene increases from 15s to 50s, the degradation rate of benzene increases significantly, from 13.23% to 42.72%. When the reactor volume is constant, it can be seen that the residence reaction time of benzene is shorter, and the number of active groups and high-energy electrons generated in the reactor is constant, which reduces the probability of collision between benzene and active electrons, so that benzene cannot fully react, leading to the degradation rate decrease[15].

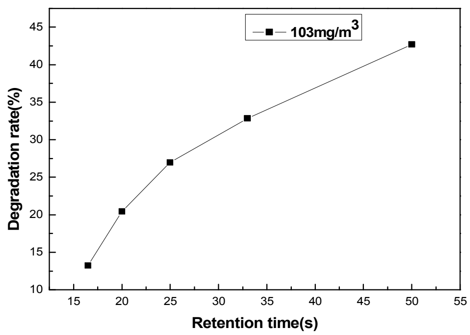


Fig.5 Effect of retention time on degradation rate

4.Summer

In this paper, the effect of benzene concentration, light intensity, residence time and light time on benzene removal rate under certain carrier gas conditions is explored by using the application of pure ultraviolet photocatalysis to degrade benzene. The results are as follows:

(1) The photocatalytic degradation efficiency increases with the decrease of the initial concentration of benzene. The degradation rate increased rapidly in the first 40min of photocatalytic reaction, and was stable after 160min. When the initial concentration of benzene from 43 mg/m^3 increases to 256mg/m^3, the degradation rate of benzene from 64.29% down to 16.28 mg/m^3, this is because, in a certain light, ultraviolet light emitting a certain number of photons, a corresponding amount of free radicals which can lead to a chain reaction of benzene with corresponding quantity the increase of the concentration of the benzene system caused more free radicals that are produced during the reaction of benzene, which results in the decrease of photodegradation efficiency.

(2) The photocatalytic degradation efficiency of benzene increases with the increase of ultraviolet light intensity. When the residence time is 50s, the initial concentration is 103mg/m^3 cubed, and the UV intensity is 48W, the photocatalytic degradation efficiency reaches a maximum of 52.58%. When the residence time is 50s, the initial concentration is 103mg/m^3 cubed, and the UV intensity is 15W, the photocatalytic degradation efficiency reaches the minimum value of 29.34%. The reason is that with the increase of the intensity of ultraviolet light, benzene is sufficient to absorb more photon energy in the degradation process, quantum yield increases, reaction efficiency increases, and photocatalytic degradation efficiency increases accordingly.

(3) The photocatalytic degradation efficiency of benzene increased with the residence time. When the residence time of benzene increased from 15s to 50s, the degradation rate increased from 13.23% to 42.72%.Because when the reactor volume is constant, the residence reaction time of benzene is shorter, and the number of active groups and high-energy electrons produced in the reactor is constant, which reduces the probability of collision between benzene and active electrons, and the degradation rate decreases due to the incomplete reaction of benzene.

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