Application of Activated Carbon Adsorption in Industrial Wastewater Treatment

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Abstract

With the rapid development of economy and industry, the yield of industrial wastewater is increasing. Industrial wastewater contains various toxic substances and is hard to biodegraded, which will have many adverse effects on the related environment. This paper introduces the adsorption mechanism and characteristics of activated carbon, meanwhile, expounds its application in treating oily wastewater,dyeing wastewater and heavy metal wastewater. Furthermore, the development and prospect of activated carbon was put forward.

Keywords

Activated carbon; industrial wastewater; treatment; application.

1. Introduction

As modern industry develops, the national economy has made tremendous progress. Simultaneously, the content of refractory and toxic substance in industrial wastewater is also increasing, which resulting in environmental and ecological imbalance and even a threat to the survival of mankind. According to statistics, China's annual industrial wastewater discharge is generally 8×10^8 m^3[1], which contains both organic and inorganic toxic ingredients. With strong adsorption capacity, a large surface and low-cost price, activated carbon is widely used in industrial wastewater treatment[1,2].

2. The overview of activated carbon

Activated carbon is a material produced from carbonaceous source materials, such as coal, coconuts, nutshells, peat, wood, and lignite. The primary raw material used for activated carbon is any organic material with high carbon content. The carbon-based material is converted to activated carbon through physical modification and thermal decomposition in a furnace under a controlled atmosphere and temperature. The finished product has a large surface area per unit volume and a network of submicroscopic pores where adsorption takes place.

2.1 The classification of activated carbon

Activated carbon comes in two variations: Powder Activated Carbon (PAC) and Granular Activated Carbon (GAC). PAC has strong adsorption capacity and lower prices, but it is difficult to regenerate. Although GAC is more expensive, it can be reused. To ensure the effect in the treatment of industrial wastewater, GAC is mostly used.

2.2 Activated carbon adsorption

Adsorption is a process where a solid is used for removing a soluble substance from the water. In this process activated carbon is the solid. Activated carbon is produced specifically so as to achieve a very big internal surface (between 500 - 1500 m^2/g). This big internal surface makes activated carbon ideal for adsorption.

Adsorption capacity and adsorption rate is the main indicator to measure the performance of activated carbon adsorption. Adsorption capacity expresses in the amount of adsorption, while adsorption rate

means the amount that a per unit weight of adsorbent adsorb in per unit time. Adsorption speed determines the action time of wastewater and adsorbent in water treatment.

2.3 Factors that influence the performance of activated carbon in water

(1)The pore size and structure of Activated carbon. In general, the activated carbon with small particle pore size and fast diffusion rate has strong adsorption ability.

(2)The type of compound to be removed. Compounds with high molecular weight and low solubility are better absorbed.

(3)The concentration of the compound to be removed. The higher the concentration, the higher the carbon consumption.

(4)Presence of other organic compounds which will compete for the available adsorption sites.

(5) pH of the waste stream. For example, acidic compounds are better removed at lower pH.

3. The adsorption mechanism of activated carbon

Physical adsorption is the primary means by which activated carbon works to remove contaminants from liquid or vapor streams. Carbon's large surface area per unit weight allows for contaminants to adhere to the activated carbon media. The large internal surface area of carbon has several attractive forces that work to attract other molecules. These forces manifest in a similar manner as gravitational force; therefore, contaminants in water are adsorbed (or adhered) to the surface of carbon from a solution as a result of differences in adsorbate concentration in the solution and in the carbon pores.

4. The characteristics of activated carbon adsorption

(1)Simple process .It does not require any coagulant and oxidant.

(2)Low cost and simple operation. The primary raw material is coal, wood and nutshells, furthermore, it doesn’t require high technical requirements.

(3)Large surface area. Dense pores and loose structure make it high-temperature-resistant, water-resistant, corrosion-resistant, acid-proof and alkali-proof .In addition, it is not easily broken because of its stiffness and flexibility.

(4)Selective adsorption. In heavy metal wastewater treatment, it has good adsorption selectivity and strong stability for heavy metal ions.

(5)No secondary pollution. The refractory material can be buried with activated carbon to prevent recontamination of water bodies.

(6)Renewable. Currently recycling methods include thermal regeneration, biological regeneration, chemical regeneration and electrochemical regeneration. Activated carbon can be reused through regeneration.

5. Application of activated carbon adsorption in treating industrial wastewater

5.1 Oily wastewater treatment

With the rapid development of petroleum and related industries, the petroleum pollution widely ranges in oil exploration, oil refining, machinery manufacturing, automotive cleaning, which has caught a serious damage to the environment. For the large oil spill in Chinese Bohai Bay in 2011, a direct impact made adverse effects on the economic development of the Bohai Bay region, including fishing, shipping, tourism and energy industries. There are many oily water treatment methods such as gravity separation, air flotation, filtration and adsorption, but most of these methods are expensive, and have high operating requirements. Activated carbon is only used in deep water purification to remove suspended oil, dispersed oil and emulsified oil from water due to the limited adsorption in this system. Statistics show that the concentration of the oil content after treatment can be reduced to 0.1 ~ 0.2mg / L.

5.2 Dyeing wastewater treatment

According to incomplete statistics, the world's annual output of dye is over 700,000 tons, 2% of which is directly discharged into the water, and 10% is indirectly discharged in subsequently textile dyeing process[2]. In China, daily emissions of printing and dyeing wastewater is 3000 ~ 4000 kt.100m fabric processing will produce 3-5tons wastewater with complex composition, deep chromaticity, and high value of COD and BOD[3].Activated carbon can remove chromaticity, COD and BOD in dyeing wastewater by its porosity[4]. However, dyeing wastewater treatment is very difficult, and there are few researches on the single use of activated carbon in dyeing wastewater treatment at home and abroad. A common practice is to combine activated carbon with other processes as a carrier or catalyst in order to achieve better decolorization and purification .The methods can be divided into the following three[5].

(1)Combined with oxidizing substances. This method takes advantage of oxidants such as ozone, chlorine dioxide to reduce the chromaticity, while the remaining small molecules are adsorbed by activated carbon[6].It helps to reduce the components of pollution, alleviating the load on the activated carbon adsorption, extending the span of activated carbon.

(2)Combined with biological substances. The common practice is to add activated carbon into the biological aeration tank[7]. In this way, biological substances on the activated carbon can decompose refractory materials in wastewater, and materials after decomposition can be adsorbed.

(3)Combined with iron filings. The conductivity of iron makes redox reaction easier to take place in dyeing wastewater[8].Activated carbon can not only enlarge the surface area to strengthen the redox reaction, but also adsorb impurities after reaction.

5.3 Heavy metal wastewater treatment

Mercury—containing wastewater treatment

Mercury has the largest toxicity among heavy metal pollutants. When it enters the body, it will destroy the function of enzymes and proteins，and further affect their synthesis[9], which pose a threat to human survival.

Activated carbon can adsorb mercury and its compounds, but it is only suitable for treating waste water with low content of mercury. If there are higher concentrations of mercury, you can use a chemical precipitation process, then take activated carbon for further processing[10].

Chromium—containing wastewater treatment

With the rapid development of electroplating industry, emissions of chromium-containing wastewater is also increasing rapidly.Experiments show that the toxic of Cr (Ⅵ) is about 100 times higher than Cr (Ⅲ)[11]. Cr (Ⅵ) can accumulate in the body of human and animal, causing damage to respiratory system and visceral , severely leading to respiratory cancer.

The process mainly includes three aspects[12].

(1)Physical adsorption. Numerous fine pores of activated carbon make it easier to absorp Cr (Ⅵ) in wastewater effectively.

(2)Chemical adsorption. There are a lot of oxygen-containing functional groups on the surface of activated carbon, such as hydroxyl (-OH), carboxyl (-COOH), carbonyl (-CO), which can remove most heavy metal ions by electrostatic adsorption.Experiments show that a solution of Cr (Ⅵ) with concentration of 50 mg / L could have a best result of removal when the value of pH was 3 and adsorption time was 1.5 h[13].

(3)Chemical reduction. In the acid environment, activated carbon can change some high-valence heavy metal ions into low valence with reduction which actually increases the performance of adsorption.

6. The developments and prospects of Activated carbon

6.1 The Research Progress of Activated Carbon

With the rapid progress of science and special requirements of wastewater treatment, the study of activated carbon has developed from its specific surface area and pore structure into the impact of its functional groups on the adsorption properties.

Combine activated carbon with biomembrane

The activated carbon-biomembrane method combines adsorption of activated carbon with oxidation and decomposition of aerobic microorganisms in wastewater treatment[14].It can not only improve the effect, but also significantly extend the span of activated carbon and simplify operations, which has developed a new technology in wastewater treatment.

Use activated carbon as a catalyst carrier

Huge surface of activated carbon provides a large number of reaction sites for the chemical reaction in water, which increases the chance of collision of reactants, accelerating the progress of the reaction. For certain catalysts who are easy to form precipitation (such as certain metal catalysts), its presence can make long-term contact with the reactants without being covered, which has great significance in wastewater treatment with heavy metal ions.

The modification of activated carbon

The modification of activated carbon refers to the change of functional groups in the nature and amount by certain methods. Different methods can have different modified activated carbon. For example, in order to remove organic pollutants, we can reduce the amount of oxygen-containing functional groups like carboxyl and lactone, and at the same time, increase the hydrophobicity of activated carbon.

6.2 The prospects of Activated carbon

The production and application of activated carbon is late both at home and abroad. The United States and Europe began to develop activated carbon industry in the early 20th century. China established activated carbon industry in the 1950s, and it didn't make a large development until 1970s.

Currently, the widespread use of activated carbon is limited because of the high cost and shortage of recycling equipment. If the regeneration of activated carbon can be solved well, the application of activated carbon will be more extensive. At the same time, we should develop different functions of activated carbon according to people's various needs.

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