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Study on Application of Activated Carbon in Water Treatment

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Abstract. Activated carbon is a good non-polar adsorbent. Because of its huge specific surface area and micropore, good adsorption performance and recycling, it can be used together with a variety of substances to adsorb various properties of wastewater. This paper mainly introduces the structure, adsorption mechanism, modified activated carbon, microbial bound activated carbon, microwave bound activated carbon and the future research direction of activated carbon.

1. Introduction

According to the statistics of relevant government departments, there are more than 4000 sewage treatment plants built and operated in cities and towns in China, and the sewage treatment capacity reaches 173 million m^3/d [1]. There are a lot of sewage treatment plants operating and under construction in our country, but the actual operation effect is not ideal. In the actual operation process, due to the problems of funds, treatment process and treatment equipment, it leads to the operation of wastewater treatment plant, and the treatment efficiency is low. Although most of the discharge can meet the standards, it can still lead to a large number of pollutants in the intake water. According to the current research situation at home and abroad, water treatment technology is widely studied, including activated sludge, biofilm, coagulation sedimentation, etc. This paper mainly describes the study on application of activated carbon adsorption in water treatment. Hu Zian found that activated carbon is a very good adsorbent in water treatment, and itself is a green and pollution-free material. Its loose porous environment and high specific surface area provide it with excellent purification ability [2].

2. Structure of Activated Carbon

2.1. Physical structure of activated carbon

Activated carbon is composed of three parts: graphite microcrystal, single plane reticular carbon and amorphous carbon, among which graphite microcrystal is the main part of active carbon. The microcrystalline structure of activated carbon is different from that of graphite. That interlayer spacing of the microcrystalline structure is between 0.34-0.35 nm. Even if the temperature is higher than 2000 ºC, it is difficult to transform into graphite. This kind of microcrystalline structure is called non-graphite microcrystal, and most of activated carbon belongs to non-graphite structure. The microcrystalline arrangement of graphite structure is regular and it can be transformed into graphite after treatment. Non-graphite microcrystalline structure makes activated carbon have developed pore structure, and its pore structure can be characterized by pore size distribution. The pore purview distribution of activated carbon is very wide, ranging from 1 nm to thousands of nm. The pore size of activated carbon can be divided into three categories: the pore size is smaller than 2 nm, the pore size is mesoporous in 2-50 nm, and the pore size is larger than that in 50 nm.

2.2. Chemical structure of activated carbon
The interior of activated carbon has crystal structure and pore structure, and the surface of activated carbon also has chemical structure. The adsorption performance of activated carbon depends not only on the physical (pore) structure of activated carbon, but also on the chemical structure of activated carbon surface. In the preparation of activated carbon, the edge chemical bond of the aromatic sheet formed during carbonization stage breaks to form an edge carbon atom with unpaired electrons. These marginal carbon atoms have unsaturated chemical bonds and can react with heterocyclic atoms such as oxygen, hydrogen, nitrogen and sulfur to form different surface groups. The presence of these surface groups undoubtedly affects the adsorption properties of activated carbon. The surface groups of activated carbon are acidic, alkaline and neutral. Liu Mingxuan founded that there were carbonyl, carboxyl, lactone, hydroxyl, ether, phenol and so on, which could promote the adsorption of alkaline substances by activated carbon. Basic surface functional groups mainly contain cyclic ketones and their derivatives, which can promote the adsorption of acidic substances on activated carbon [3].

3. Adsorption Mechanism of Activated Carbon
Because of activated carbon has a large specific surface area and developed micropores, the activated carbon has a strong adsorptivity and a large adsorption capacity. The physical adsorption properties of activated carbon are mainly related to the specific surface area and pore structure of activated carbon. The total surface area of activated carbon pore wall is generally as high as 500-1700 m^2/g and small micropores compared with other adsorption materials(radius<0.02 nm) is especially developed, which is also the main reason for the strong adsorption ability and adsorption capacity of activated carbon. The total specific surface area of activated carbon is determined by small micropores, and the transition pore (0.02-1 nm) plays an important role in the channel, and the large micropore (radius is 1-100 nm) is the entrance of the microsystem of the adsorption material [4]. Hu Zian found that the adsorption process of activated carbon is very complicated and involves the interaction of many forces (van der Waals' force, electrostatic action, complexation reaction, etc.), the surface of activated carbon contains mainly carbonyl, carboxyl, lactone and phenolic hydroxyl groups, many oxygen-containing functional groups together determine its adsorption performance. There are three main modes of action: the first is to give electrons-to be affected by electrons, the second is electrostatic action, and the third is coordination reaction [2].

4. Practical Application of Activated Carbon

4.1. Modified Activated Carbon Adsorption
The adsorption ability of activated carbon is excellent in the same type of adsorbent, but sometimes it is better to treat some special wastewater by improving its properties slightly on the original basis. Huang Xishou et al. studies shows that under the condition of water bath, using 0.25 g carbon-sodium dodecylbenzene sulfonate (SDBS) as adsorbent to adsorb lead (10 mg/L) in simulated wastewater of 100 ml, water bath oscillating reaction was carried out at room temperature. The pH = 7, and the adsorption rate of lead could reach 98.0%. Adsorption of 200 mL with 0.02 g carbon SDBS wastewater with 100 μg/L nickel ion concentration, water bath oscillation at room temperature, the pH = 7, and the adsorption rate of nickel is up to 96.3% [5]. Wu, Y. et al. [6] studies shows that the efficiency of treating phenol-containing wastewater with copper-loaded activated carbon is more than 90%. Citric acid modified activated carbon enhanced the adsorption of Cr (VI), the removal rate of Cr (VI) from the anaerobic fermentation broth of pig wastewater by modified coconut shell charcoal was

61.32%, the removal rates of TN and TP were 18.27% and 4.70%, respectively, the removal rate of Cr (VI) by modified coconut shell charcoal was increased by nearly 50% points compared with that before modification. However, the adsorption rates of TN and TP decreased, the reason is citric acid modified activated carbon enhanced proprietary adsorption of Cr (VI) [7].

4.2. Adsorption of activated carbon with microbial characteristics

As a widely used adsorbent, activated carbon cannot solve the adsorption problem of wastewater only by improving its properties. The specific surface area of biological activated carbon is large, and the pore structure is very developed, therefore they can effectively adsorb dissolved oxygen and organic matter in water, biological activated carbon as carrier, it can provide a place for microbes to gather, reproduce, and grow. Where the environmental temperature and nutritional conditions are appropriate, it can play the role of microbial degradation and adsorption of activated carbon at the same time. Lang, J. studies shows that activated carbon as the carrier of microbial immobilization, the treatment performance of p-phenol is increased by about 30%, it shows that activated carbon has synergistic effect with microorganism, its processing ability and efficiency have been greatly improved [8]. Chen, M.et al. found that Polyvinyl alcohol (PVA) as the entrapment agent of immobilized microorganism and the addition of powdered activated carbon to it to accelerate the mass transfer process of the reaction system has the advantages of both adsorption and entrapment [9]. Qi, P.F. et al. studies show that the dosage of O_3 is about 3 mg/L^{-1}, the contact time of O_3 is 15 min, when the contact time of activated carbon empty bed is 9 min, the removal rates of DMP, DBP, D-HP and DOP were 97.6% and 53.8% and 56.0%, respectively, it can be seen that O_3-biological activated carbon process has a good removal effect on PAEs (phthalate) [10].

4.3. Microwave-activated carbon adsorption

By microwave heating or radiation, can improve the adsorption capacity and adsorption ability of activated carbon, especially in the treatment of organic pollutant wastewater, the treatment is better. Chen, J.P. et al. studies show that microwave enhanced cast iron scraps-activated carbon - H_2O_2 treatment of printing and dyeing wastewater, a mixture of cast iron scraps and activated carbon can form many corrosive iron-carbon microbatteries in printing and dyeing wastewater, the precipitated new ecology [H] has strong reductive decolorization effect on dyestuff chromaticity in waste liquid, the dissolved Fe^{2+} can form Fenton reagent with H_2O_2, strong Oxidation decomposition of Non-Dyes in dyeing wastewater decolorization products and other refractory organic compounds [11]. Under microwave radiation, activated carbon shows that it can produce a lot of hot spots with higher energy, causing persulfate to produce more sulfate radical ,therefore increase the degradation rate of phenol, in acidic conditions, it is more favorable for the activation of potassium persulfate to produce sulfate radical, compared with activated carbon or potassium persulfate alone, the removal rate of phenol increased by about 45% [12]. Li, J. et al. found that in microwave field, activated carbon surface produces some "hot spots", the energy of these "hot spots" is much higher than the rest of the world, when the organic matter in the wastewater is adsorbed near that hot spots, it may be oxidized and degraded. In 10 mg/L^{-1} Rhodamine B solution 100 mL, the activated carbon was added 1.5 g, the microwave power is 80% and the radiation time is 20 min, the decolorization rate of Rhodamine B solution can reach 98.5% [13]. Yang, J. et al. studied have shown that HA in natural water can increase the chroma and odour of water body, the formation of urban black and smelly water body is intensified. Using MW-KPS (potassium persulfate)-GAC (activated carbon) Advanced Oxidation process can effectively catalyze the Oxidation of HA, when the initial mass concentration of pH = 8.0, HA is 10 mg/L, the amount of KPS added is 0.5 mmol/L, when the GAC dosage is 50 g/L, after 90s of microwave radiation, the HA degradation effect is the best, the degradation rate was 74% [14]. Peng, M.X. et al. found that using microwave catalytic oxidation to treat waste CD recycling wastewater, the microwave power is 800 W, Radiation for 10 minutes, the dosage of activated carbon is 1g, the dosage of $FeSO_4$ is 0.08 g, the pH = 4, with the addition of 1 mL H_2O_2, the removal rate of COD reached 93.7% [15]. Sun, Q.J. et al. found that treated dyeing wastewater with microwave and activated carbon.

The decolorization rate of dyeing wastewater was 73.6% when microwave power was 700 W, dosage of activated carbon was 5 g, irradiation time was 6 min and pH = 3.0 [16]. Wang, J. et al. found that landfill leachate with microwave and activated carbon, when microwave power was 300 W and pH = 8, activated carbon dosage was 9 g/L, Fe^{+2} = 0.02 mol/L, H_2O_2 = 7 ml/L, when the radiation time was 6 min, the removal rates of COD and ammonia nitrogen reached 68.22% and 78.08% respectively [17]. Zi, P.J et al. found that the treatment of ammonia-nitrogen wastewater by microwave and activated carbon shows that the removal rate of ammonia nitrogen can reach 92.47% when microwave power is 850 W, dosage of activated carbon is 0.5 g, pH = 11, radiation time is 4 min [18].

5. Conclusion

Because activated carbon not only has good adsorption performance and low price, but also can recycle and other excellent performance, it is widely used in water treatment. Foreign water treatment technologies developed earlier than ours and China started relatively late. The application of activated carbon is not good enough, which shows that there is still a long way to go. Activated carbon can be used either alone or in combination with other water treatment technologies. In order to maximize the adsorption capacity of activated carbon in water treatment, better service for water treatment, saving cost, reducing energy consumption and improving efficiency become a basic research criterion. In the modification of activated carbon, combined with microbial properties and microwave-activated carbon research, the application performance of activated carbon in future water treatment will be higher.

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