Study on Adsorption Performance of Lignite Activated Carbon for Coal Gasification Wastewater

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Abstract. In order to ensure the excellent adsorption performance, this paper chose lignite activated carbon to study the adsorption performance of typical pollutants phenol, indole and quinoline in coal gasification wastewater, and analyzed its adsorption performance under single matrix and co-substrate conditions. The experimental results showed that among the three kinds of organic substances, lignite activated coke has the strongest adsorption capacity for phenol, while the adsorption capacity for quinoline was relatively low. Under mixed matrix conditions, activated coke has strong adsorption selectivity for phenol and indole.

1. Introduction
Modern coal chemical industry was located in the arid and semi-arid areas where water resources are scarce, such as Inner Mongolia Autonomous Region and Xinjiang provinces. The effective treatment, reuse and even zero discharge of wastewater are used to achieve resource utilization, which solves the industry's water resource problems and achieves high-quality development in the industry [1]. The development and application of zero-discharge wastewater technology is gradually expanding, but it also faces the problem of crystalline salt disposal [2], especially the high organic content in crystalline salt, which can't be reused. The reason was related to the quality of raw water and the pretreatment process. Coal gasification was the typical representative of modern coal chemical industry. The water quality and volume of wastewater vary greatly depending on the gasification technology. Among them, Lurgi-Gasification wastewater contains more phenols, alkanes and heterocyclic organics [3-4], the relative content of phenol was as high as 57.86% [5], and the concentration of COD was high. This type of wastewater must be effectively treated, discharge up to standards and even zero discharge of liquids to promote the green and sustainable development of modern coal chemical industry.

Coal gasification wastewater was similar to coking wastewater, which was phenol-containing wastewater, containing indole, quinoline and other fused-ring organic pollutants. These substances have greater toxic effects, high chemical structure stability, and poor biodegradability. Although the content was not large, which was unable to achieve ring-opening and chain-scission of molecular structure, and meet the processing requirements using anaerobic and aerobic conventional processes [6,7]. The conventional treatment route was a treatment process with biochemistry as the core. The COD concentration of biological effluent was generally 200-500 mg/L. The remaining refractory organic matter made the effluent COD and chromaticity difficult to meet the emission standards, and this part of the organic matter can only be extended by hydraulic power. It was difficult to remove methods such as residence time. In order to ensure the quality of effluent water, various
enhanced treatment methods have gradually become the research hotspot of coal gasification wastewater treatment technology.

Zhuang Haifeng et al. [8] prepared a straw-based activated carbon-supported metal Fe oxide ozone catalyst for coal gasification wastewater by using agricultural waste rice straw as raw materials. As more hydroxyl radicals are produced, COD, cyanide and phenols were removed efficiently. Respectively 55.5, 46.5 and 85.5%, the biodegradability of the treated effluent was increased, and the toxicity was reduced. Jia Shengyong et al. [8] used MBR membrane bioreactor coupled with activated carbon PAC enhanced system for coal gasification wastewater. Under the condition of activated carbon dosage of 4g/l, the MBR-PAC system can reduce COD to 83mg/L, while in the case of 5g/L granular activated carbon, the COD of coal gasification wastewater can be reduced to 39mg/L. The dust of the generator and the pulverized coal produced in the process of lignite beneficiation and coke smelting have both acidic and basic centers on the surface. They are added to the aeration tank and have certain adsorption properties for wastewater [10]. Xu Bing et al. [11] used gasification residual coal and coke for wastewater treatment, which has a certain purification effect. Zhai Xiang et al. [12] used semi-coke from Yan'an Zi long coal pyrolyzed at 550°C to prepare active semi-coke, and studied its adsorption performance for phenol and p-nitrophenol to simulate phenol-containing wastewater. The results of laboratory studies that have been carried out show that the activated coke based on lignite has developed mesopores and has good decolorization and dephenolization functions [13]. Li Ruozheng et al. [14] used activated coke to adsorb typical coal gasification wastewater, which significantly improved the biodegradability of wastewater, combined with a biological aerated filter for advanced treatment, the effluent COD can be below 50mg/L.

Based on the excellent adsorption performance, this paper chose lignite activated carbon to study the adsorption performance of typical pollutants phenol, indole and quinoline in coal gasification wastewater, and analyze its adsorption performance under single matrix and co-substrate conditions.

2. Simulate static adsorption of typical organic pollutants

Phenol, indole and quinoline were selected as the research objects, and the adsorption performance of activated coke was investigated by simulating wastewater. According to the UV absorption spectrum characteristics of indole and quinoline, the measurement wavelengths are 270nm and 277nm, respectively.

Weigh 0.500g of phenol, indole and quinoline with an analytical balance, and dissolve them in a 1L volumetric flask to make a stock solution with a concentration of 500mg/L. Prepare the stock solutions into 7 standard solutions with different concentrations, including 0mg/L, 10mg/L, 20mg/L, 25mg/L, 30mg/L, 40mg/L, 50mg/L, and operate at 256nm, 270nm, 277nm wavelength Measure the absorbance and make a standard curve.

![Fig.1 standard curve of indole](image-url)
2.1. Simulate static adsorption of typical organic pollutants

The fixed single substrate concentration was 50mg/L, the adsorption temperature was 25°C, the active coke dosage was 10g/L, 5g/L, 2.86g/L, 1g/L four gradients, according to the static adsorption method, the single substrate static. The results of the adsorption test were showed in the table.

| dosage (g/L) | phenol equilibrium (mg/L) | adsorption (mg/g) | indole equilibrium (mg/L) | adsorption (mg/g) | quinoline equilibrium (mg/L) | adsorption (mg/g) |
|--------------|---------------------------|-------------------|---------------------------|-------------------|----------------------------|------------------|
| 10.00        | 2.9                       | 4.71              | 17.2                      | 3.28              | 43.1                       | 0.69             |
| 5.00         | 8.6                       | 8.28              | 26.35                     | 4.73              | 44.45                      | 1.11             |
| 2.86         | 15.92                     | 11.36             | 32.74                     | 5.75              | 46.4                       | 1.25             |
| 1.00         | 28.77                     | 21.23             | 43.88                     | 6.12              | 48.14                      | 1.86             |

Under the same initial concentration and single substrate condition, the equilibrium concentration of phenol, indole, and quinoline will gradually decrease as the dosage increases. The experimental results showed that the active coke has the strongest adsorption capacity for phenol and a certain adsorption capacity for indole, while the adsorption capacity for quinoline was relatively low.

2.2. Adsorption of co-substrates

Carry out the organic matter adsorption test under the mixed co-substrate condition, the concentration of phenol, indole and quinoline were all 50mg/L, and the total concentration of pollutants was 150mg/L. The co-substrate adsorption temperature was 25°C, and the active coke dosage was 10g/L, 5g/L, 2.86g/L (water-coke ratio 350:1), 1g/L, according to the static adsorption method, a single-substrate static adsorption test. The results were showed in the table.

| dosage (g/L) | phenol equilibrium (mg/L) | adsorption (mg/g) | indole equilibrium (mg/L) | adsorption (mg/g) | quinoline equilibrium (mg/L) | adsorption (mg/g) |
|--------------|---------------------------|-------------------|---------------------------|-------------------|----------------------------|------------------|
| 10.00        | 3.6                       | 4.64              | 21.26                     | 2.87              | 46.16                      | 0.38             |
| 5.00         | 9.4                       | 8.12              | 29.41                     | 4.12              | 46.45                      | 0.71             |
| 2.86         | 22.91                     | 9.03              | 36.74                     | 4.42              | 47.44                      | 0.85             |
| 1.00         | 36.77                     | 13.23             | 44.92                     | 5.08              | 49.03                      | 0.97             |

The test results showed that the removal rate of the three organic substances was lower than that of the single organic substance matrix adsorption under the mixed matrix condition, indicating that there was a competitive adsorption of the three organic substances, and the competitive order of the three
was phenol > indole > quinoline. The surface functional groups in activated coke can associate with phenol, the aromatic ring forms bonds, and the adsorption capacity was strong. Indole is weakly aromatic, has a greater affinity for activated coke, and was more stable in adsorption. The results of co-substrate adsorption were basically consistent with the related literature. Zhao et al. [110] studied the adsorption of phenol and indole mixtures on powdered activated carbon, indicating that phenol is more easily adsorbed than indole. In the presence of low concentrations of phenol, due to the surface of activated carbon. Because of its characteristics, activated carbon has a higher adsorption capacity for indole, and a stronger adsorption capacity for indole, a heterocyclic compound that was more difficult to biodegrade. Comprehensive analysis showed that activated coke has strong adsorption selectivity for phenol and indole.

3. Adsorption analysis

Lignite activated carbon has a large number of mesopores, and its pore diameter matches the molecular diameter of the target pollutants in coal gasification wastewater, which was beneficial to adsorption. After the activated coke was adsorbed, COD and chroma were reduced, and the water quality was significantly improved. According to the characteristics of competitive adsorption, the selective adsorption capacity for characteristic phenols and indole was strong, which was related to the competition of adsorption sites and the theory of pore clogging. From the perspective of the equilibrium concentration and adsorption capacity of the system, the lignite activated carbon has different advantages in adsorption pore sizes and sites for the three substances. The adsorption analysis of phenol, indole and quinoline under single matrix and co-matrix conditions showed that activated coke has different adsorption pore sizes and sites for indole. The selective adsorption capacity of indole was relatively strong.

4. Conclusion

Under the same initial concentration and single substrate condition, the equilibrium concentration of phenol, indole, and quinoline will gradually decrease as the dosage increases. The experimental results showed that among the three kinds of organic substances, lignite activated coke has the strongest adsorption capacity for phenol, while the adsorption capacity for quinoline was relatively low. Under mixed matrix conditions, lignite activated coke has strong adsorption selectivity for phenol and indole.

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