Magnetic Coagulation Technology for Coal Gasification Wastewater Treatment

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Abstract

Coal gasification wastewater is refractory for its high colority, complex water quality components, heavy toxicity and poor biochemical purification ability. This study focused on the wastewater treatment of coal gasification in a coal chemical enterprise by magnetic coagulation technology. Under the optimum condition, the removal rate of COD, turbidity and solube SiO2 were 27.6%, 97.0% and 68.4%, respectively. And the average recovery of magnetic powder was up to 97.38%. This paper provides technical guidance for the engineering application of the magnetic coagulation in coal gasification wastewater.

Keywords: influencing factors, recovery, economic analysis

Introduction

At present, the treatment of polluted wastewater from coal gas production has become an important factor restricting the further development of coal gas industry. Coal gasification wastewater is a kind of typical industrial organic wastewater with high concentration, complex components and strong toxicity, which mainly comes from washing, condensation and fractionation (Lan LL 2019). Magnetic coagulation technology (MCT) is a novel rapid coagulation technology. In the MCT, the magnetic powder is purposely added on the basis of the traditional coagulation technology, and the combination of the flocs with the magnetic powder increases the flocs density and accelerates the solid-liquid separation (Lv M et al. 2019; Luo LQ et al. 2017). Thus, the refractory organic matter which is mostly in suspended and colloidal state in coal gasification wastewater can be removed effectively.

This study focused on the wastewater treatment of coal gasification by MCT. The optimum treatment conditions, the recovery and reuse of the magnetic powder and the technical and economic feasibility were analyzed.

Material and Methods

Material

The raw water was sampled from the primary settling tank of a coal chemical enterprise in Henan Province, which was from the gasifier prior to chemical-conditioning (cationic polyacrylamide). The quality of the wastewater is shown in tab. 1.

Coagulation experiment

The coagulation experiments were undertaken on a TJ6 (Wuhan Hengling Technology Co., Ltd., China) jar tester with six beakers of 1 L. Appropriate PAC and magnetic powder were dosed under a 2 min rapid mix stage at 120 rpm, and then PAM was added with a 10 min flocculation stage at 40 rpm before a 15 min settlement period. The supernatant sample was collected from the beaker 2 cm below the surface for determining the removal of COD, turbidity and SiO2.

Table 1 *Water quality of coal gasification wastewater.*

T °C	pH	COD mg/L	Turbidity NTU	SS mg/L	SiO_2 mg/L	NH_3-N mg/L	T-P mg/L
32-38	8.2-8.8	200-500	92-125	180-230	132-150	45-60	0.27-0.36

Magnetic powder recovery test

The procedure was as follows: removed the supernatant and transferred the magnetic flocs into a 500 mL baker, followed by a 5 min rapid stirring of 200 rpm and a 3 min adsorption stage by magnet block on the bottom of baker, removed the supernatant and washed the magnetic powder with deionized during the adsorption, the same process was repeated until supernatant was clarified, and then weighed the magnetic powder after drying in oven at 50 °C.

Indexes analysis

The COD digestion instrument (5B-1BV8, Lanzhou Lianhua Environmental Protection Technology Co., Ltd., China) was used to determine COD (Yuan MT 2018); the turbidity was measured via a 2100AN turbidimeter (Hach Company, US). The SiO2 was determined by spectrophotometry (National Standard of China, GB/T 12149-2007).

Results and Discussion

Optimization of magnetic coagulation process parameters

Effects of PAC dosage on the treatment efficiency

As shown in fig. 1, the removal efficiency of COD, turbidity, SiO2 increased gradually with the increase of PAC dosage. At 120 mg/L of PAC, the removal efficiency of COD, turbidity and SiO2 achieved 26.6%, 96%, 63.71%, respectively. Further increasing of PAC did not cause the obvious increase of removal efficiency. This may be attributed to that the high dosage of coagulant leaded to the colloidal re-stability by increasing counter-charge polymerized ions (Luo GH et al. 2019a). Therefore, the dosage of PAC was determined to be 120 mg/L.

Effects of PAM dosage on the treatment efficiency

It can be seen that obvious removal appeared when the dosage of PAM was 0.5-1.5 mg/L, and increased slightly as dosage increased continually (fig. 2). PAM is able to increase pollutants removal with adsorption-bridging and sweep-floc formation, but excessive dosage can decrease the settling velocity due to the exclusion of polymer (Luo GH et al. 2019b). Therefore , the 1.5 mg/L PAM dosage was chosen for subsequent experiments.

Effects of magnetic particle on the treatment efficiency

The particle size of magnetic of 200 and 300 mesh removed organic matter effectively as shown in fig. 3. It can be interpreted as the large particle size of magnetic powder weakened the adsorption capacity, and the specific gravity was not conducive to solid-liquid separation (Qiu JX et al. 2018). Small particle size has the problem of low flocs density and poor compression and settling performance. Finally, magnetic powder of 200 mesh was selected due to the removal

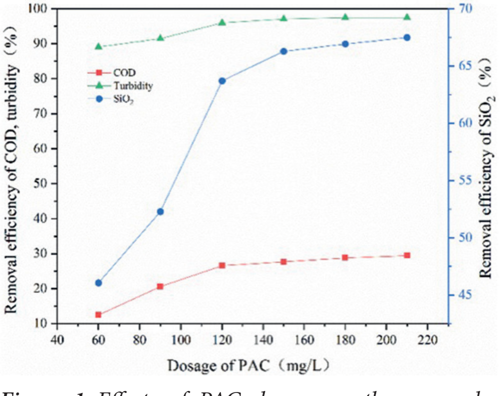

Figure 1 *Effects of PAC dosage on the removal efficiency of coal gasification wastewater (PAM 1.5 mg/L, 200 mesh magnetic powder 200 mg/L, desilicating agent 200 mg/L, pH 8.5).*

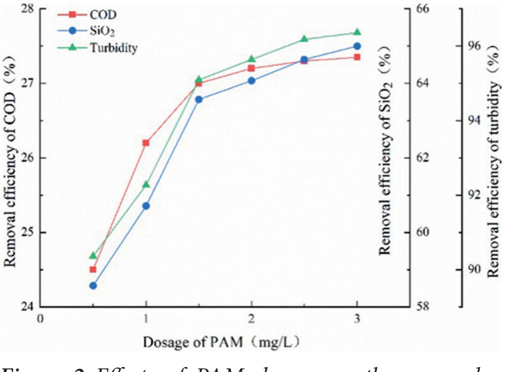

Figure 2 *Effects of PAM dosage on the removal efficiency of coal gasification wastewater (PAC 120 mg/L, 200 mesh magnetic powder 200 mg/L, desilicating agent 200 mg/L, pH 8.5).*

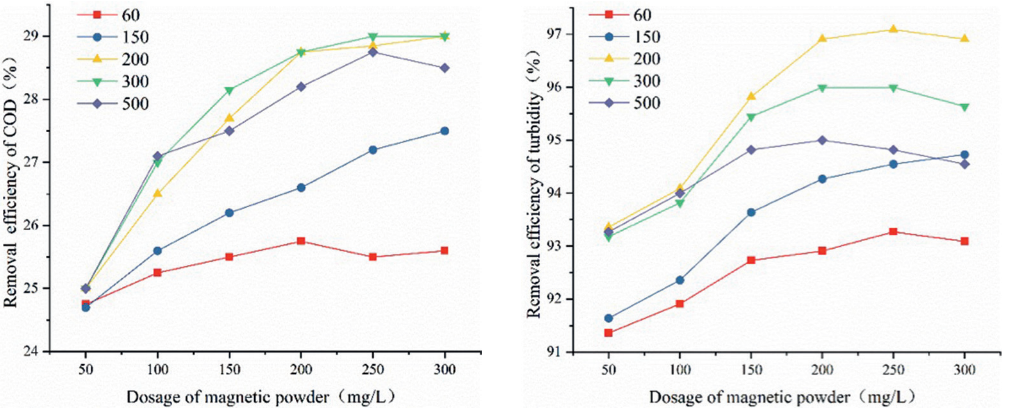

Figure 3 *Effects of particle size of magnetic on COD, turbidity of coal gasification wastewater (PAC 120 mg/L, PAM 1.5 mg/L, pH 8.5).*

efficiency of turbidity by magnetic powder of 200 mesh was higher than 300 mesh.

Effects of magnetic powder dosage on the treatment efficiency

The results showed that the pollutants removed effectively once the magnetic powder was dosed to the sample water until a stead-state removal was reached (fig. 4). At 200 mg/L of magnetic powder, the removal efficiency of COD, SiO2 and turbidity was 27.75%, 68.36%, 97%, respectively. It has been accepted that increasing the dosage of magnetic powder within a certain range is equivalent to increasing the crystal nucleus, which accelerates reaction by the collision, adsorption and condensation, but the excessive dosage leads to the magnetic powder collides with each other (Chen WS et al. 2004). It was appropriate to choose dosage at 200 mg/L.

Effects of initial pH on the treatment efficiency

The adjustment of pH was an effective method to enhance removal efficiency in coagulation process, in this process, the flocs size and structure can be changed, influencing the solid-liquid separation effect (Cao BC et al. 2011). As shown in fig. 6, a peak shape with a highest removal efficiency (30.75%, 71%, 97.36%) at pH 6.0, in the range of 6 to 8, the removal declined slightly. When pH value up, the removal efficiency became worse, which is due to the compounds dissolve (pH>9-10), producing negative charge that reduce the coagulation effect.

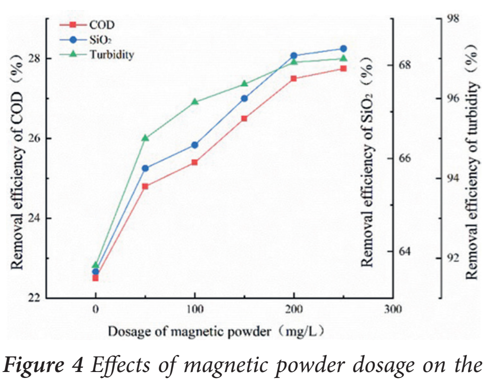

Figure 4 *Effects of magnetic powder dosage on the removal efficiency of coal gasification wastewater (PAC 120 mg/L,PAM 1.5 mg/L, desilicating agent 200 mg/L, pH 8.5).*

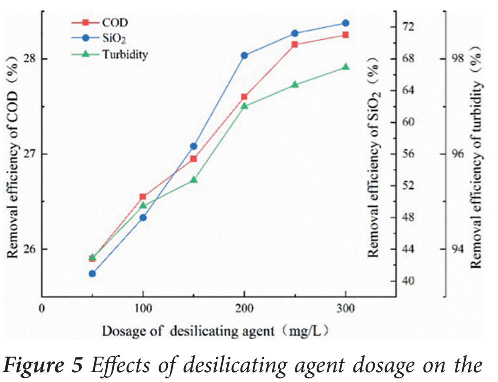

Figure 5 *Effects of desilicating agent dosage on the removal efficiency of coal gasification wastewater (PAC 120 mg/L, PAM 1.5 mg/L, 200 mesh magnetic powder 200 mg/L, pH 8.5).*

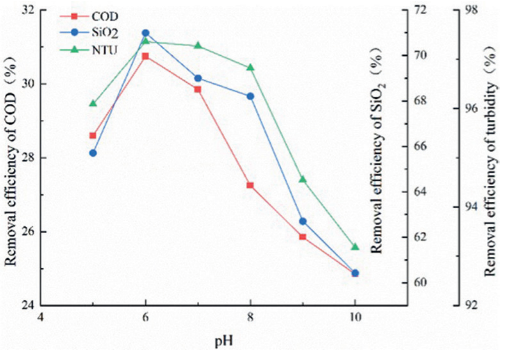

***Figure 6** Effects of pH on the removal efficiency of coal gasification wastewater (PAC 120 mg/L, PAM 1.5 mg/L, 200 mesh magnetic powder 200 mg/L, desilicating agent 200 mg/L).*

Optimization of operation parameters based on orthogonal test

Four important factors and three levels near the optimum point were determined by preliminary single factor experiments: the dosage of PAC (90 mg/L, 120 mg/L, 150 mg/L), the dosage of magnetic powder (150 mg/L, 200 mg/L, 250 mg/L), initial pH (6, 7, 8) and the dosage of desilicating agent (150 mg/L, 200 mg/L, 250 mg/L). Results showed that: PAC of 120 mg/L, PAM of 1.5 mg/L, initial pH value 7.0, magnetic powder (200 mesh) of 200 mg/L, desilicating agent of 200 mg/L were optimal when removal and cost were comprehensively considered.

Recovery and reuse of magnetic powder

The recovery of magnetic powder was determined by three parallel experiments, excellent recovery (97.38% ± 0.46%) may be attributed to a few magnetic powder was lost through flocs residue, hydraulic action and manual operation.

The recovered magnetic powder was used to investigate the influence of the using times on the treatment efficiency, a series of experimental date (27.42% ± 0.24%, 97.13% ± 0.09%, 68.32% ± 0.11%) showed that the magnetic powder was stable and its repeated use had no influence on the treatment of coal gasification wastewater.

Analysis of technical and economic feasibility

Compared with traditional coagulation (fig. 7), the removal of COD, turbidity and SiO2 increased 5.1%, 6.2%, 4.8%, respectively. The sedimentation time was decreased from 30 min to 2 min, and the settlement velocity was 16 times of that traditional coagulation. The formation of dense flocs depends on the particles collision rate, which greatly enhances the settlement velocity and the solid-liquid separation effect in MCT.

On the premise of the same treatment effect, the economic cost of two processes for treating coal gasification wastewater was analyzed (tab. 2). The chemical cost of the MCT was 0.28 yuan/m3, which was 17.6% less than that of conventional treatment process, and the magnetic powder can be recycled for many times after separation. It indicated that magnetic coagulation had cost advantage in treating coal gasification wastewater.

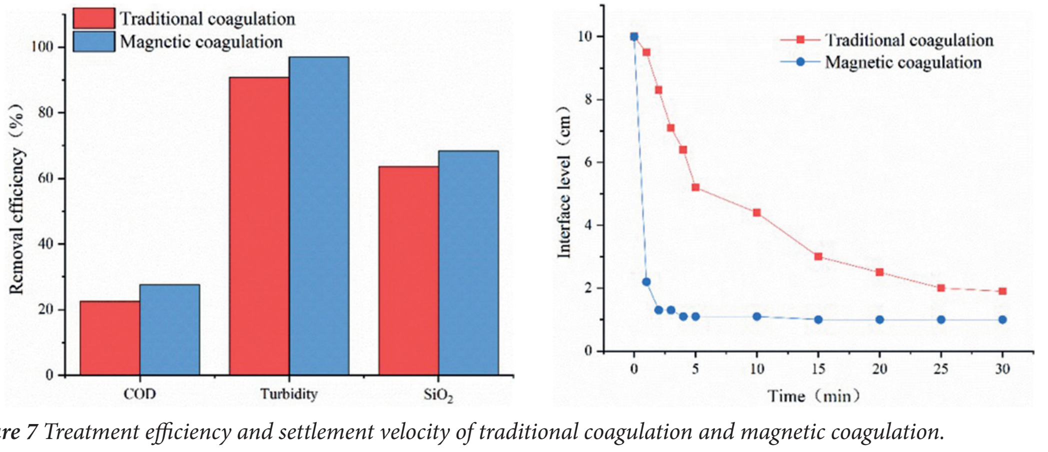

***Figure 7** Treatment efficiency and settlement velocity of traditional coagulation and magnetic coagulation.*

Table 2 Reagent cost comparison.

Items	Traditional coagulation	Magnetic coagulation
PAC (2000 yuan/t)	150 mg/L	120 mg/L
PAM (20000 yuan/t)	2.0 mg/L	1.5 mg/L
Magnetic powder (3000 yuan/t)	/	5 mg/L
Total reagent cost (yuan/m^3)	0.34 yuan/m^3	0.28 yuan/m^3

Conclusions

The results showed that the optimum conditions were as follows: PAC dosage of 120 mg/L, PAM dosage of 1.5 mg/L, initial pH value 7.0, magnetic powder (200 mesh) dosage of 200 mg/L, desilicating agent dosage of 200 mg/L.

The technical feasibility of magnetic coagulation technology was verified. Under the optimum process conditions, the removal efficiency of COD, turbidity and SiO2 was achieved at 27.6%, 97.0%, 68.4%, the concentration decreased to 144.5 mg/L, 3.3 NTU, 44.24 mg/L, respectively.

This study showed that magnetic powder can be recycled and the average recovery of magnetic powder reached 97.38%, the cost of chemical was 17.6% less than that of traditional coagulation. MCT was an effective way to reduce the cost of wastewater treatment in coal chemical enterprises.

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