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Preparation and Effect on the Coal Slime Water of Poly-ferric-aluminum-silicate-sulfate

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***Abstract*—*Poly-ferric-aluminum-silicate-sulfate was synthesized by using sodium silicate, ferric sulfate and aluminum sulfate as materials. With single factor analysis and orthogonal experiment, the optimum coagulation parameters of PFASS have also been discussed. The results indicated that the best parameters were molar ratio (Al + Fe)/Si 1.2, reaction temperature 60 ˚C, reaction time 10 min, dosage of poly-ferric-aluminum-silicate-sulfate 20 mg/L, the best flocculation results can be achieved (*the removal rate of turbidity to coal slime water was up to 96.2%) under these conditions.*

Keywords - the removal rate of turbidity; coal slime water;

poly-ferric-aluminum-silicate-sulfate

I. INTRODUCTION

Coal slime water is industry wastewater from coal preparation plant, including many coal particles and clay particles. With the closed water circuit and the increasing requirements for environmental protection, the treatment to the coal slime water is becoming increasingly important. It has been proved that one of the important steps in wastewater treatment process is coagulation, which is used for the destabilization of colloidal suspensions as well as the removal of suspended solids and organic matters [1] and [2].The flocculation and precipitation process ,not only can effectively reduce the treated water turbidity and color, remove a variety of organic polymers and certain heavy metals (mercury, lead), but also improve sludge dewatering performance, so is widely used in wastewater treatment.

The poly-ferric-aluminum-silicate-sulfate (PFASS) is a new type of inorganic silicate polymer coagulant, which is simultaneously introduced in two metal ions (Al, Fe). This makes it have the effect of bridging adsorption and charging neutralization, and full use of aluminum and iron flocculant advantages, weakening each other's weaknesses [2]. So, the poly-ferric-aluminum-silicate-sulfate brings together the advantages, such as bonded together and bridging adsorption performance of silicate bonding, large flocs and the decolorization performance of Aluminum coagulant, high floc density and quick settling rate of ferric coagulant [3] and [4].

Therefore, in this paper, the study focuses on the influence of all kinds of parameters on the coagulation performance of PFASS.

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II. MATERIALS AND METHODS

A. Materials

The coal slime water was got from Jinda Coal Preparation Plant, Shenmu, Shaanxi Province; Sodium silicate (reagent grade) was obtained from Tian'jin Tianli Chemical Reagent Factory (Tian'jin, China); Ferric sulfate and aluminum sulfate (reagent grade) were obtained from Xi'an Chemical Reagent Factory (Xi'an, China).

B. Preparation of poly-silicate

The sulfuric acid (H_2SO_4) was analytical reagent and was diluted to 30 (w/w, %) before using in this work [5].Take 11.83 g sodium silicate mixed with 88ml deionized water, meanwhile slowly stirred with magnetic stirrer at room temperature (25 °C). Then, with 30% sulfuric acid to adjust PH value of the solution about 5.6 [5].

C. Preparation of the poly-ferric-aluminum-silicate-sulfate

When the poly-silicate was prepared, mixed with a certain amount of aluminum Ferric sulfate and aluminum sulfate by changing different molar ratio (Al+ Fe)/Si(molar ratio Al/Fe always was defined 2), then stirred 30 min with magnetic stirring apparatus at room temperature (25 °C) and the PFASS was prepared [6].

D. The effort of all kinds of parameters and Analytical methods

1) Single factor analysis

To determine the influence of all kinds of parameters on coagulation efficiency, experiments were carried out in 500ml beakers using a conventional jar test apparatus. Coal slime water was dosed with different amounts of PFASS ranged between 5 and 35mg/L and stirred rapidly at 150 rpm for 3 min after adding the coagulant at temperature during 25 and 85 °C, followed by slowly stirred at 50 rpm during the time arranged from 3 to 25 min and precipitated for 30 min, in order to allow the growth of the flocs. Finally, the supernatant was withdrawn with a plastic syringe from about 2 cm below the surface of the test water for analysis. The turbidity of the pre- and post-treatment sewage was measured by WGZ-200 turbidimeter, in accordance with the Chinese National Standard GB 13200-1991. The removal rate of turbidity formula was:

$$\eta = \frac{A - B}{A} \times 100\%$$

Where η is mean the remove rate of turbidity; A is mean turbidity of pre-treatment coal slime water; B is mean turbidity of post-treatment coal slime water.

2) Orthogonal test

According to the analysis of single factor, the experimental factors were chosen and the level of the factors was decided. 9 different experiment conditions were derived and the orthogonal test table was shown in Tab. Ⅰ.

TABLE I. FACTORS AND LEVELS OF THE ORTHOGONAL EXPERIMENTS

Factor	(Al + Fe) /Si molar ratio	Dosage of PFASS (mg/L)	Reaction time (min)
Level 1	0.8	18	10
Level 2	1.0	20	15
Level 3	1.2	22	20

III. RESULTS AND DISCUSSION

A. Affecting factors of the removal rate of turbidity

1) Molar ratio (Al+Fe) /Si

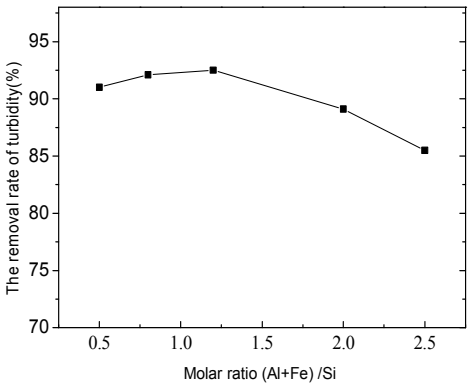

Figure 1. Effect of molar ratio (Al+Fe) /Si to the removal rate of turbidity.

Fig. 1 shows the effect of molar ratio (Al + Fe)/Si to the removal rate of turbidity. From the chart, it can be shown that the flocculation effect of molar ratio (Al + Fe)/Si was obvious. With the molar ratio (Al + Fe)/Si increases, the coagulation effect is significantly enhanced. When molar ratio was about 1.2, the coagulation got the best removal rate. Since then, with molar ratio increases, the flocculation effect start to reduce, which may be attributed to the higher polymerization degree of PFASS .

2) Dosage of poly-ferric-aluminum-silicate-sulfate

Fig. 2 illustrates that dosage of PFASS affect coagulation efficiencies. It is evident that the coagulation performance is improved markedly in low dosages with the increase of the coagulant dosage; however, the removal of turbidity reduces due to too large dosage. A number of studies have shown that the coagulation of organic matter by hydrolyzing metal salts is generally described as a combination of charge neutralization, entrapment, adsorption and complexation with coagulant metal hydrolysis species into insoluble particulate aggregates [7]. When the coagulant dosage is less than the effective one, less coagulating agent adsorption on the surface of the colloidal particles, it is difficulty to form the flocs, and it presents that the coagulation performance of PFASS is poor. As the dosage continued to increase, more and more PFASS are adsorbed on the initial floc surface. Every colloidal particle adsorbs redundant PFASS, and there are no unoccupied surface to bridge as well as the excessive positive charge on the hydrolysate baffled PFASS to adsorb onto the initial flocs, which do not favor the formation of the large flocs.

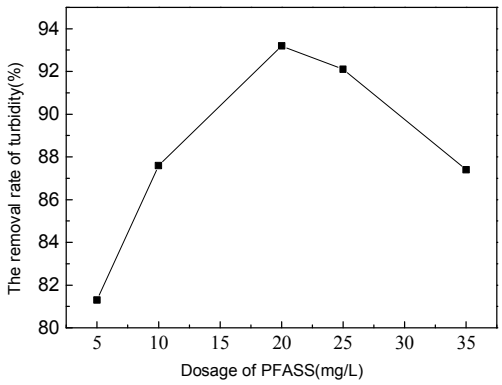

Figure 2. Effect of dosage of PFASS to the removal rate of turbidity

3) Reaction temperature

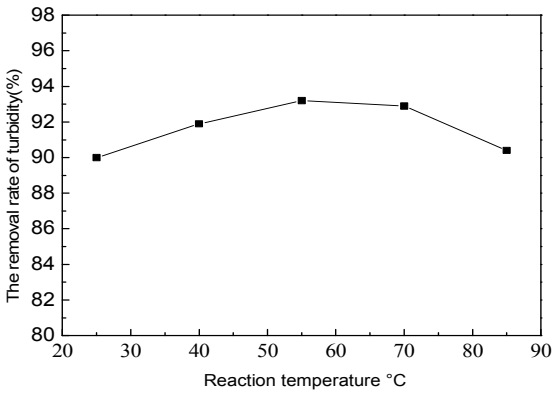

Figure 3. Effect of reaction temperature to the removal rate of turbidity

Fig. 3 shows that reaction temperature has little influence on the removal rate of turbidity. Therefore, 60 ℃ is selected as the optimal temperature.

4) Reaction time

Fig. 4 shows that with the time increases, there is also a maximum value of the removal rate of turbidity. It has an increase in the 2 ~ 10 min, and reaches to maximum of 93%. After then, the removal rate starts to decline.

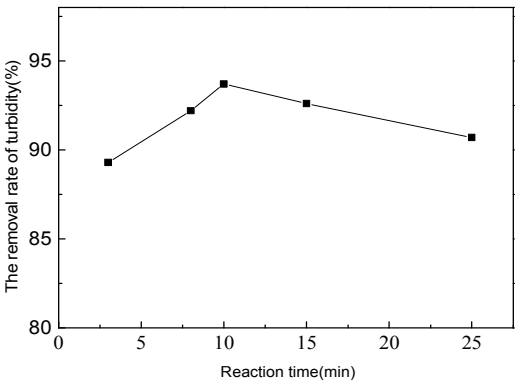

Figure 4. Effect of reaction time to the removal rate of turbidity

B. optimization

Orthogonal test has been designed to obtain the optimal conditions. The results are shown in Tab. Ⅱ.

Tab. Ⅱ demonstrates that the effects of each factor on the remove rate of turbidity are in order of molar ratio (Al + Fe)/Si > dosage of PEASS > reaction time. The results indicated that the best parameters were molar ratio (Al + Fe)/Si 1.2, reaction time 10 min, dosage of poly-ferric-aluminum-silicate-sulfate 20 mg/L, and the removal rate of turbidity to coal slime water was up to 96.2%.

Analysis of variance is showed in Tab. Ⅲ. It illustrates that mole ratio (Al + Fe)/Si markedly influenced the coagulation efficiencies of PFASS to coal slime water. The dosage of PFASS and reaction time play non-marked roles on the flocculation result.

TABLE II. RESULTS OF ORTHOGONAL EXPERIMENT

No.	(Al +Fe)/Si molar ratio	Dosage of PFASS(mg/L)	Reaction time(min)	The remove rate of turbidity(%)
1	0.8	18	10	85.2
2	0.8	20	15	88.6
3	0.8	22	20	85.3
4	1.0	18	15	91.8
5	1.0	20	20	92.8
6	1.0	22	10	92.3
7	1.2	18	20	94.2
8	1.2	20	10	96.2
9	1.2	22	15	95.3
k1	259.1	271.2	273.7	
k2	276.9	277.6	275.7	
k3	285.7	272.9	272.3	
k1/3	86.367	90.400	91.233	
k2/3	92.300	92.533	91.900	
k3/3	95.233	90.967	90.767	
Range	8.866	2.133	1.133	

IV. CONCLUSIONS

- The poly-ferric-aluminum-silicate-sulfate (PFASS) is a new type of inorganic silicate polymer coagulant, which is simultaneously introduced in two metal ions (Al, Fe).
- The coagulant dosage and (Al + Fe)/Si molar ratio markedly influence the coagulation efficiencies of PFASS to coal slime water. The results imply that the coagulation performance is improved significantly with the coagulant dose increasing.
- With single factor analysis and orthogonal experiments, the optimum coagulation parameters of PFASS have also been discussed. The results indicated that the best parameters were molar ratio (Al + Fe)/Si 1.2, reaction temperature 60 °C, reaction time 10 min, dosage of poly-ferric-aluminum-silicate-sulfate 20 mg/L, the best flocculation results can be achieved (the removal rate of turbidity to coal slime water was up to 96.2%) under these conditions.

TABLE III. FACTORS AND LEVELS OF THE ORTHOGONAL EXPERIMENTS

Sources of variation	Sum of squares(SS)	Degree of freedom(df)	Mean square(MS)	F	Critical value	Notability
(Al +Fe)/Si molar ratio	122.427	2	61.2135	170.037	$F_{0.05}$=19	*
Dosage of PFASS(mg/l)	7.327	2	3.6635	10.176		
Reaction time(min)	1.947	2	0.9735	2.704		
Error	0.72	2	0.36			

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