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Preparation and Application of a Novel Composite Flocculant for Tap Water Treatment

Awa Kangama[1], Defang Zeng[1,]*, Xu Tian[1], Jinfu Fang [1]

[1]*School of Resource and Environmental Engineering Wuhan University of Technology, Wuhan City, 122 Luoshi Road China, 430070*

** Correspondence: Defang Zeng*

ABSTRACT: *A new tap water flocculant had been prepared by using polyaluminium chloride (PAC), polysaccharide (PS) and modified starch (MS) as the main raw materials. The best formula of the composite flocculant was found to be(0.1 % PAC: 0.01% PS: 3% MS = 30: 6: 7). Compared with traditional chemical flocculant polyaluminum ferric chloride (PAFC), the prepared flocculant has turbidity in the treated water of 3.35% and removal rate of aluminum up to 56.17%.In addition, the treatment cost was also reduced by about 5.42% yuan per ton of water. The performance-price ratio of this composite flocculant was higher than that of traditional flocculant, since it had a great effect on decreasing the concentration of* Al^{3+}*, which in treated water was only 0.071* $mg{\cdot}L^{-1}$*. This novel composite flocculant is safer than that of conventional one. So it has the important significance of extending and application in the tap water treatment.*

KEY WORDS: *Tap water treatment; Composite flocculant; Environmentally-friendly type; Aluminum ion*

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I. INTRODUCTION

Water is one of the most critical resources for human beings [1] and it is also the most essential component of the natural environment [2].WHO has confirmed that each year about 2 million people, mostly children under five, die from diarrhea due to lack of drinking water [3].In addition, more than 660 million people lack access to safe drinking water, including 530 million in rural areas [4].The treatment of drinking water or tap water by flocculation represents an important research direction.

The flocculation is one of the most important operations in solid – liquid separation processes in water supply and wastewater treatment [5].

In this study, a novel composite flocculant for the tap water treatment has been prepared flocculant has been found based on lower concentration of $Al3^{+}$ in the treated water. Anovel flocculant was made by combining polyaluminum chloride (PAC), polysaccharide (PS) and modified starch (MS). Because of the decreased dosage of PAC, the concentration of $Al3^{+}$ in the treated water was significantly reduced. PS and MS mainly play the role of flocculation and adsorption.

The remainder of the paper is structured as follows: the experiment method and procedure are presented in the section 2. The experimental results are in detail presented and discussed in section 3 and the section 4 presents the conclusion.

II. MATERIALS AND METHODS

2.1 Raw Water

The raw water was obtained from The Yangtze River of Wuhan in China (turbidity = 105.6 NTU, water temperature of about 20 - 25 ℃, pH = pH 7.2 -7.4).

2.2 Chemicals and Reagents

Polysaccharide (PS, homemade),Polyaluminum chloride PAC (industrial grade I, nanjing chemical industry corporation fine chemical plant),PFS (industrial grade I, nanjing chemical industry corporation fine chemical plant), Industrial starch (degree of gelatinization: 99.9%, moisture content ≤ 8%, Shijiazhuang Yinhe Modified Starch Co., Ltd.),Cationic polyacrylamide (CPAM) with molecular weight of about 3 - 15 million and degree of cationic of about 3% - 100%,suzhoutongsheng industry and trade co., LTD) ,Standard solution of aluminum (concentration : 100mg/ L^{-1})

2.3 Apparatus

Magnetism msier (78-1, Ronghua Equipment Manufacture Co., Ltd, Jiangsu, China); Scattering-type optoelectronic SSmeter (WGZ-100, Jinziguang Apparatus Company, Beijing, China) , BS223S Analytical Balance (Beijing Sartorius Instrument System Co., Ltd.), Electrical inductive coupling plasma mass spectrometer (ELAN6000, Sigma, Boston, USA) , High-speed disperser (GFJO4A, Coating Industry Factory, Shanghai, China),Digital PH meter (pHS-25, Lida Apparatus Company, Shanghai, China),Air dry oven (FN101-3A, Apparatus Company, Changsha, China), Quartz automatic triple water distiller (1810-C, Kanghua Electronic Apparatus Factory, Jiangsu, China).

2.4 Experimental Methods and Procedures

We use the water sample by measuring its initial value.We place eight samples of 200 ml of raw water are placed in eight 250 ml beakers and different categories and add doses of flocculants with stirring. we shake the solution quickly for 45 seconds at a speed of 120 stir / for 1 minute and then we shake the solution slowly for 15 min at a speed of 30 stir / for 1 minute. We leave the water sample at rest for 25 minutes, then after we measure its turbidity and its aluminum ion content. In this way, we obtain a set of data. from these, we realize the experiment of flocculation and coagulation out by using magnetism msier (78-1, Ronghua Equipment Manufacture Co., Ltd, Jiangsu, China). We measure the turbidity by the Scattering-type optoelectronic SSmeter (WGZ-100, Jinziguang Apparatus Company, Beijing, China). The aluminum ion content determines using an Electrical inductive coupling plasma mass spectrometer (ELAN6000, Sigma, Boston, USA) and a standard Solution of aluminum.

III. RESULTS AND DISCUSSION

3.1 Determination of Component

According to the principle of synergy and complementation of inorganic and organic substances,three single-component flocculant were selected as a group such as Polyalumimunchoride (PAC), Cationic polyacrylamide (CPAM), Polysaccharide (PS), Poly ferric Sulfate (PFS) and Modified Starch (MS) and mixed in the proportion of 1:1:1 and 8 samples were designed and tested to determine the flocculant in terms of lower cost and better removal rate of SS. The composite formulation and experimental results are shown in Fig. 1. and Fig. 2.

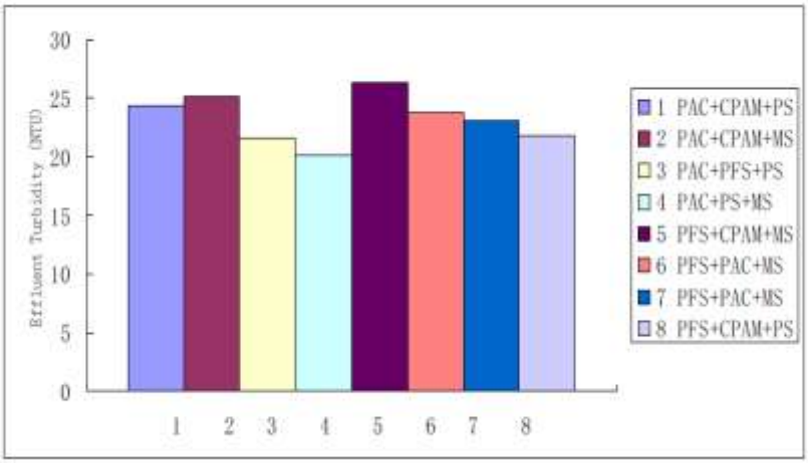

Fig. 1. Turbidity of the treated water of 8 formulations

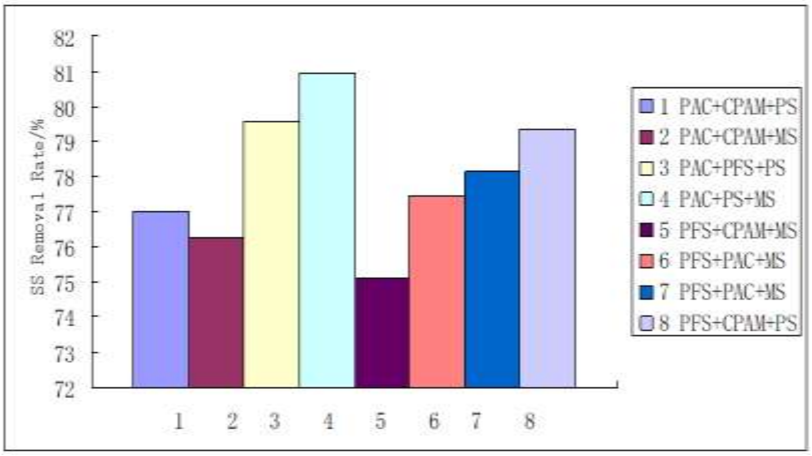

Fig. 2. Removal rate of SS in the treated water using 8 formulations

From Fig. 1. and Fig. 2., it can be seen that the turbidity of the effluent after treatment in the 8 samples was greater than 20 TNU. Comparing samples No. 1-4 with samples No. 5-8, it can be seen that the samples containing the PAC are better than those of PFS and the treatment effect of the composite flocculant which contained CPAM was not satisfactory. The samples containing both CPAM and MS (samples 2 and 5) were worse than other sample. The sample No. 4 had the best treatment effect and it was the optimal combination to be used.Its turbidity of effluent was only 20.1 NUT and removal rate of SS was 80.97%. Moreover, the sample does not contain cationic polyacrylamide (CPAM)and PFS. Therefore, we chose sample No.4 as the best formula for the treatment of our tap water and the formula is composed of 0.1% PAC, 0.01% PS and 3% MS.

3.2 Determining the Dosage of Each Component in the Optimal Component Formulation

The optimal dosage of single-component floculant was determined according to lower cost and better treatment effect.The treatment effect ofthe optimal composite flocculant PAC+PS+MS abbreviate as (PPMS) can be improved by ensuring that the cost of the flocculant does not exceed the cost of the PAFC. As a result, the cost of the PPMS was superior to PAFC one for the improved performance-price ratio and strong market competitiveness.

3.2.1 Determining the Optimal Dosage of PAC

With the dosage of Polysaccharide (PS) and MM maintaining to 0.1 mL,while the dosage of PAC is gradually modified in order to find its optimal dosage. The experimental results are shown in Table 1.

From the Table 1., it can be seen that when the dosage of PAC increases while being less than 0.6 mL, the turbidity of the effluent is significantly reduced. When the dosage of PAC was greater than 0.6 mL, effluent turbidity decreased but the effect of tap water treatment is not very satisfactory, and this inevitably increases the concentration of aluminum ions in the effluents which does not meet the requirements of tap water treatment. Therefore, the optimum dosage of 0.1% of PAC is 0.6 ml. At this stage, the flocculant cost is lower and the treatment effect is better. The concentration of aluminum ions in the effluent is also lower.

Table 1. Results of the optimum dosage of PAC

No.	Ratio of PAC+PS+MS	Dosage of PAC 0.1%/mL	Reagent cost (yuan/ton)	Turbidity of the treated water/NTU	Removal rate of SS /%
1	2:1:1	0.2	0.0079	16.8	84.09
2	3:1:1	0.3	0.0090	11.0	89.58
3	4:1:1	0.4	0.0100	8.52	91.93
4	5:1:1	0.5	0.0111	4.75	95.50
5	6:1:1	0.6	0.0121	3.49	96.70
6	7:1:1	0.7	0.0132	2.91	97.24
7	8:1:1	0.8	0.0142	2.73	97.41
8	9:1:1	0.9	0.0153	2.59	97.55

3.2.2 Determining the Optimal Dosage of Polysaccharide (PS)

In the similar way as in section 3.2.1, the dosage of PAC and Modified Starch (MS) are maintained to 0.6 ml and 0.1 ml, respectively, while the PS dosage is progressively modified in order to find the its optimal dosage. The experimental results are shown in Table 2.

The Table 2. shows that with the dosage of PS increasing, the turbidity of the effluent decreases from the beginning and then increased suddenly. If the dosage of PS is very large, the treatment effect of tap water is not very satisfactory. And when the dosage of PS reached 0.12 mL, the turbidity of the effluent is 2.96 NTU. At this stage, the treatment effect of PS is better and the elimination rate of SS reached 97.20%. Therefore, the optimal dosage of 0.01% of PS was 0.12 ml.

Table 2. Results of the optimum dosage of PS

No.	Ratio of PAC+PS+MS	Dosage of PS 0.01 % /mL	Reagent cost (yuan/ton)	Turbidity ofthe treated water/NTU	Removal rate of SS /%
1	6:0.2:1	0.02	0.0089	8.30	92.14
2	6:0.4:1	0.04	0.0097	5.41	94.88
3	6:0.6:1	0.06	0.0105	4.71	95.54
4	6:0.8:1	0.08	0.0113	4.28	95.95
5	6:1.2:1	0.12	0.0129	2.96	97.20
6	6:1.4:1	0.14	0.0137	3.35	96.83
7	6:1.6:1	0.16	0.0145	4.07	96.15
8	6:1.8:1	0.18	0.0153	4.98	95.28

3.2.3 Determining of the Optimal Dosage of Modified Starch (MS)

Similarly, the dosage of PAC and PS are maintained to 0.6 mL and 0.12 mL, respectively. The dosage of MS is gradually changed in order to find the optimal dosage. The experimental results are shown in Table 3.

Table 3. Results of the optimum dosage of MS

No.	Ratio of PAC+PS+MS	Dosage of MS 3 % /mL	Reagent cost (yuan/ton)	Turbidity of treated water/NTU	Removal rate of SS /%
1	6:1.2:0.2	0.02	0.01146	5.27	95.01
2	6:1.2:0.4	0.04	0.01182	4.65	95.60
	6:1.2:0.6	0.06	0.01218	4.07	96.15
4	6:1.2:0.8	0.08	0.01254	3.51	96.68
5	6:1.2:1.2	0.12	0.01326	2.43	97.70
6	6:1.2:1.4	0.14	0.01362	2.02	98.09
7	6:1.2:1.6	0.16	0.01398	2.28	97.84
8	6:1.2:1.8	0.18	0.01434	2.72	97.42

The Table 3. shows that when the dosage of MS is increasing with the dosage lower than 0.14 mL, the turbidity of the effluent significantly decreases. However, when the dosage of MS is higher than 0.14 mL, the turbidity of the treated water significantly increased. This is because the MS suspension is a kind of emulsion which has a negative influence on the transparency of treated water. When the dosage of MS was 0.14 mL, the turbidity of the treated water is only 2,02 NTU. So the optimal dosage of 3% of MS is 0.14 ml.

In conclusion, the novel composite flocculant was prepared in the following weight proportions: 0.1 % of PAC: 0.01 % of PS: 3 % of MS = 30:6:7. The removal rate of SS of the prepared flocculant reached 98.09%,and the cost of the reagent is 0.01362 yuan per ton of raw water, which is lower than the cost of PAFC by 0.014 yuan per ton of raw water. The advantage of the prepared composite flocculant is that the concentration of $Al3^{+}$is also decreased by using less dosage of PAC at the same time, the Polysaccharide (PS) and Modified Starch (MS) played the role of flocculation and adsorption.

3.3 Annual Test

The economic and technical comparisons between our prepared optimal composite PPMS and PAFC are shown in Figure 3. and Fig. 4.

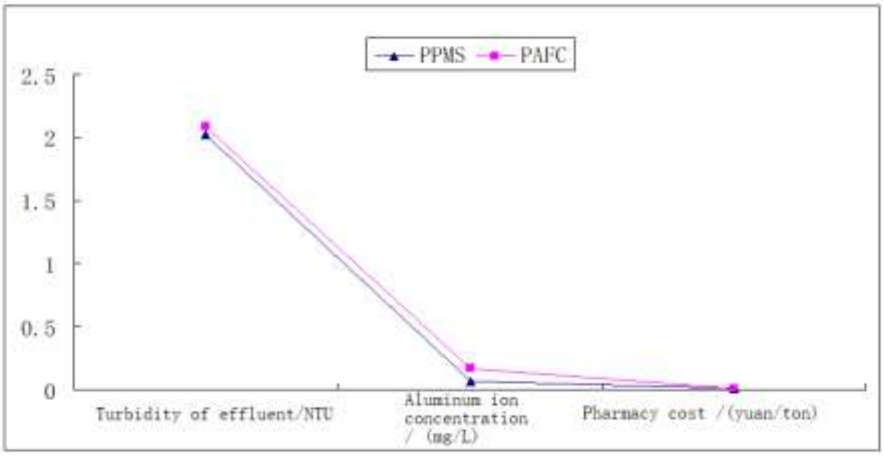

Fig. 3. Main economic and technology indexes of two kinds of flocculants

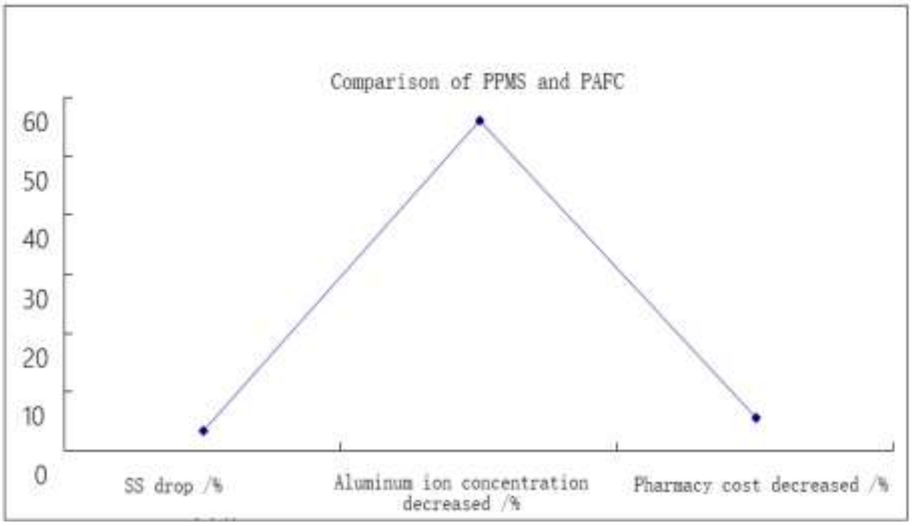

Fig. 4. Comparison of main economic and technology indexes between two kinds of flocculants

Asit can be seen from Figure 3 and Figure 4, the PPMS has a turbidity and a cost slightly lower than that of PAFC but has a much lower concentration of aluminum ions than PAFC. Compared to PAFC, the turbidity of PPMS is 3.35%, its aluminum ion content is 56.17% and its cost is reduced to 5.42%.PPMS has clear environmental and economic benefits, including reducing the aluminum ion content in tap water. The concentration of aluminum ions in the treated water is reduced to 0.071 mg L^{-1}, which is less than 0.2 mg $\cdot L^{-1}$. It can be seen that PPMS has great promotion value and potential in practical application.

IV. CONCLUSION

In this work, a new low cost and effective composite flocculant for the treatment of tap water was prepared by combining polyaluminum chloride (PAC), polysaccharide (PS) and modified starch (MS). The best formula of the prepared composite flocculant(PPMS) was found to be 0.1 % of PAC :0.01 % of PS: 3 % of MS which correspond to weight proportions of 30:6:7).Compared with traditional chemical flocculant polyaluminum ferric chloride (PAFC),the prepared flocculant(PPMS) has turbidity of 3.35% and removal rate of aluminum up to 56.17% for the treated water.In addition, the treatment cost was also reduced by about 5.42% yuan per ton of water. The performance-price ratio of PPMS composite flocculant was found to be higher than that of PAFC, because it had a great effect on decreasing the concentration of $Al3^{+}$, which in the treated water was only 0.071 mg$\cdot L^{-1}$. The use of this composite flocculant to replace conventional flocculant in water treatment will bring great economic and environmental benefits. In order to prove the effectiveness of our optimal composite formula as the future work we will apply the optimal composite formula to other tap water raw water.

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