Development Status and Application of Polysilicate Flocculants

Zhao Chen¹, Liu Ping*¹

¹Department of Hydraulic Engineering, Henan Vocational College of Water Conservancy and Environment, Zhengzhou, Henan, 450008, China

*Corresponding author’s e-mail: 18703639253@163.com

Abstract. Flocculation method plays an important role in water treatment. The quality of flocculation depends to a large extent on the performance of flocculant. As a new type of inorganic polymer flocculant, polysilicate flocculant has good effects in removing turbidity, removing algae, removing color and removing organic substance. This paper comprehensively introduces several polysilicic flocculants, analyzes their flocculation performance, development and application.

1. Introduction

In response to China's excessive water resources development, water shortage, water environment pollution and other issues, the state has promulgated a series of policies and measurements to prevent water pollution, prompting people to study low-energy, high-efficiency water treatment methods [1]. The flocculation method plays a important role in water treatment. Flocculation is to accumulate the suspended solids and colloids in the water under the action of the flocculation, thereby accelerating the sedimentation of the particles and achieving the effect of solid-liquid separation.

In the flocculation process, the quality of the flocculant directly affects the water treatment effect. Polysilicate flocculant is a new type of inorganic polymer flocculant developed on the basis of polysilicic acid and traditional flocculants such as aluminum salt and iron salt. It has the characteristics of good flocculation effect, low price and wide application range [2-3], and has become a hot spot in the research field of inorganic polymer flocculants. Polysilicic acid is an anionic flocculant, often used as a coagulant, and has a strong polycondensation effect. As the polycondensation reaction progresses, the molecular weight increases and eventually turns into a gel. The unstable nature of polysilicic acid determines that it can only be used now, so it limits the use of polysilicic acid in many fields [4]. In the early 1990s, domestic scholars began to try to combine polysilicic acid with traditional metal salt flocculant, which not only delayed the gel time, but also enhanced its flocculation performance [5-6]. In this paper, the research progress of polysilicate flocculants in recent years is summarized, which is convenient for scholars to further study polysilicate flocculants.

2. Polysilicate containing a single metal ion

The most studied monovalent metal ions are polysilicate flocculants of aluminum and iron. Gao Baoyu et al. used NMR and chemical analysis methods to study the interaction between aluminum ions and polysilicic acid in polyaluminum silicate. The results show that polysilicic acid has a certain complexation and adsorption on aluminum ions [7]. Wang Xiangang et al. used the fly ash produced
by the coking plant as raw material, and treated the polyaluminum silicate to produce coal washing wastewater by calcination, alkali fusion and acid leaching treatment. Studies have shown that the optimal preparation conditions for the synthesis of polyaluminum silicate are pH=3, $n_{Na2CO3} : n_{SiO2} = 0.7:1$, $n_{HCl} : n_{Al2O3} = 4:1$ [8]. Shinan et al. used sodium chlorate, water glass and ferrous sulfate as raw materials to prepare polysilicate ferrite to treat Songhua River water by copolymerization method to study the importance of the factors affecting the preparation of flocculants. The results show that the amount of oxidant> initial w (SiO$_2$)> polysilicate iron reaction time> silicic acid polymerization time> sulfuric acid dosage [9].

The aluminum salt flocculant produces large flocs and good decolorization effect, but the flocs are loose and not dense, and easy to leave aluminum residue, causing secondary pollution; The flocules produced by the iron salt flocculant are dense and have a fast sedimentation rate, but the flocs are small, the effluent color is large, and the sweeping effect is small [10]; Therefore, researchers have tried to compound zinc salts with polysilicic acid. Liu Heqing et al. used transmission electron microscopy and scanning electron microscopy to observe zinc polysilicate and compare it with polyaluminum silicate. Studies have shown that zinc polysilicate is a chain-like, layered structure. Within a certain range, as the molar ratio of zinc to silica increases, zinc ions and polysilicic acid polymerize into a chain-like structure, and under certain conditions, the flocculation effect of zinc polysilicate is better than that of polyaluminum silicate and PAC [11]. Wang Xuefeng et al. studied the mass fraction of SiO$_2$ as 2.0%, the molar ratio of zinc to silicon to 1.5, the activation time and maturation time were both 1 h, and the turbidity of the configured Forma turbidity standard solution was 99.6% and 99.1% [12].

3. Polysilicate containing binary metal ions

Polyaluminum silicate composite has a strong adsorption and bridging ability of polysilicic acid, large flocs of aluminum salt, good decolorization performance, dense floc body of iron salt and fast sedimentation rate. So, this composite has become a hot research topic. Wang Bingjian et al. used composite method and copolymerization method to prepare polyaluminum ferric silicate, treated Gaolin simulated water sample, Yellow River water and refinery wastewater, and studied polysilicic acid content, iron content and water sample pH value through different preparation conditions. And compared with the commonly used PAC, research shows that aluminum polysilicate has better turbidity, degreasing and COD removal ability than PAC; Under the condition of certain preparation conditions, the flocculation performance of polyaluminum ferric silicate prepared by copolymerization method is better than that of polyaluminum ferric silicate prepared by composite method; When the water sample’s pH=6-10, the flocculation effect of aluminum polysilicate ferrite is better [13]. In order to more clearly compare the flocculation effect of polyaluminum ferric silicate and polyaluminum silicate, Zhu Kaijin et al. added the prepared polyaluminum ferric silicate and polyaluminum silicate to the smelting wastewater in the same dosage. Studies have shown that the removal rate of SS and chromaticity of aluminum polysilicate aluminum is as high as 90%, while the removal rate of polyaluminum silicate is 78% and 75%, respectively [14].

The zinc salt flocculant has the functions of adsorption bridging, electrical neutralization and sweeping of impurities in water, and the compaction of the alumen ustum is dense and the water content of the sludge is low [15]. Gao Wei et al. prepared polyaluminum silicate sulfate treatment of kaolin simulated wastewater, and discussed the effect of various factors on flocculation effect. The results show that when the Zn/Al molar ratio = 1.0 and the (Al + Zn) / Si molar ratio = 1.0, the de-turbidity rate can reach 98% or more. By X-ray diffraction and infrared spectroscopy, the addition of aluminum ions and zinc ions is beneficial to the formation of chain-like structures and enhances the flocculation effect [16]. Wen Yanjie et al. introduced magnesium ions on the basis of polysilicate ferrite to prepare polyaluminum ferric silicate. Through infrared spectroscopy, the participation of magnesium promoted the formation of Si-O-Fe bonds and improved the flocculation effect [17].
4. Polysilicates containing multiple metal ions
In order to improve the flocculation effect, Chen Ling et al. used the waste steel and other materials as raw materials to prepare aluminum polysilicate (II) magnesium, and studied the factors affecting the flocculation performance of aluminum polysilicate (II) magnesium. Then they comparatively treated the printing and dyeing wastewater with monomer green sorghum, aluminum sulfate, magnesium sulfate and PAC. The results show that the removal rates of SS, chromaticity and COD of wastewater treated with aluminum (A) aluminum silicate are 87.9%, 95.7% and 84.2%, respectively, which is far superior to the flocculation effect of the monomer [18]. Wang Yuanhong et al. used the copolymerization method to prepare polyaluminum magnesium magnesium zinc flocculant, and treated the antibiotics in the simulated water samples under the optimal preparation conditions. The results showed that the removal rate of both antibiotics in the water sample reached more than 90% [19].

5. Conclusion and Prospect
Polysilicate flocculants have great potential for development. In order to make such flocculants widely used in water treatment, the following suggestions are made according to the current situation:
(1) A new process for preparing polysilicate flocculants should be carried out to improve the purity and stability of the flocculant;
(2) Improve research on flocculation mechanism to promote the development of new products and optimization of applications;
(3) Carry out research on sludge treatment and metal ion recovery after flocculation and precipitation of polysilicate flocculant.

References
[1] Song X, Sun S, Zhang W. (2017) Research on the Optimization of Water Environment Management in China under the Background of Implementation of Water Pollution Prevention Action Plan. Environmental Protection Science, 43: 51-57.
[2] Han D, Wang J, Liu J. (2009) Progress in preparation and research of polysilicate flocculants. Guangzhou Chemical Industry and Technology, 37: 23-25.
[3] Qiu J, Qiu Z. (2003) Research Progress of Polysilicic Flocculants. Journal of Jiangxi Science, 21: 37-40.
[4] Zhu X, Liu H, Jiang L, et al. (2012) Study on the stability of polysilicic acid. Bulletin Bulletin, 31: 13-18.
[5] Gao B, Wang Z, Tang H. (1998) Research Progress of Polyaluminum Sulfate Coagulant. Progress in Environmental Science, 02: 46-50.
[6] Liu H, Shao J, Liang J. (2005) Study on improving the stability of polysilicic acid. Industrial Water Treatment, 10: 34-36.
[7] Gao B, Li C, Yue Q, et al. (1993) The Interaction between Aluminum Ions and Polysilicic Acid. Environmental Chemistry, 04: 268-273.
[8] Wang X, Yan B, Wei Z. (1993) Study on the treatment of coal washing wastewater by preparing polyaluminum silicate flocculant with fly ash. Silicon Valley, 6: 42-43.
[9] Shi N, Fu Y. (2011) Preparation of polysilicate ferrite and optimization of influencing factors. Journal of Jinan University (Natural Science Edition), 25: 68-73.
[10] Cong T, Ding L, Mao Z. (2014) Research Progress of Polysilicate Metal Salt Flocculants. Contemporary Chemical Industry, 43: 48-50.
[11] Liu H, Wang F, Yuan T. (2001) Electron microscopic characteristics and flocculation effect of polysilicate zinc flocculant. Environmental Chemistry, 02: 179-184.
[12] Wang X, Huang X, Li P. (2013) Preparation and flocculation performance of polysilicate zinc flocculant. Water Treatment Technology, 39: 33-36.
[13] Wang B, Gao B, Yue Q. (2003) Study on the Coagulation Effect of New Inorganic Polymer Composite Flocculant Polymerized Aluminum Ferric Silicate. Journal of Shandong
University (Science Edition), 38: 111-115.

[14] Zhu K, Xue X, Liu F. (2003) Comparison of Coagulation Effect of Polyaluminum Ferric Silicate and Polyaluminum Silicate on Wastewater. Industrial Water Treatment, 6: 26-27.

[15] Zheng M. (2006) Effect of Zinc Salt on Properties of Polyferric Silicate Sulfate. Liaoning Chemical Industry, 35: 257-259.

[16] Gao F, Xue J, Wang L. (2012) Preparation and Morphological Analysis of Polyaluminum Silicate Sulfate Flocculant. Water Treatment Technology, 38: 73-77.

[17] Wen Y, Han C, Zhang L. (2012) Preparation and Application of Polyferric Silicate Magnesium Water Treatment Agent. Journal of Beijing University of Chemical Technology (Natural Science Edition), 39: 90-94.

[18] Chen L, Sha L, Zhang Z. (2011) Preparation of polyaluminum ferric silicate (II) magnesium coagulant and its treatment of printing and dyeing wastewater. Water Treatment Technology, 37: 42-45.

[19] Wang Y, Wei Q, Ji Y. (2017) Preparation of polyaluminum silicate-magnesium-zinc coagulant and its preliminary study on antibiotic performance and mechanism. Journal of Safety and Environment, 03: 255-261.