

PAPER • OPEN ACCESS

Review On The Application Of Magnetic Flocculation Technology In Water Treatment

To cite this article: Quankang Zhou *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **295** 042107

View the [article online](#) for updates and enhancements.

Review on the Application of Magnetic Flocculation Technology in Water Treatment

Quankang Zhou^{1,*}, Ziqiao Yu², Yunqian Ma¹

¹School of Environmental Science and Engineering, Qilu University of Technology, Jinan, Shandong, 250353, China

²Yantai Luda Environmental Impact Assessment Co., Ltd, Yantai, Shandong, 264000, China

*Corresponding author: 475073982@qq.com

Abstract. This paper introduces the characteristics of magnetic flocculation technology and discusses its mechanism. It also analyses the experimental and engineering literatures of magnetic flocculation technology for treating different wastewater and sewage. The wide application and high efficiency of this technology in the field of water treatment are described. The application prospect and development trend of this technology are also prospected.

1. Introduction

The magnetic flocculation technology is an organic combination of conventional coagulation and magnetization technology. The technology is inoculated with magnetic powder and coagulant. The magnetic flocculant is formed by combining the pollutant with the magnetic flocculant, which makes the original non-magnetic pollutant magnetic. Then the magnetic flocculant is separated from water by high gradient magnetic separation technology or its own high-efficiency sedimentation, so that the pollutants can be removed^[1]. Magnetic flocculation technology has many advantages, such as good treatment effect, small area, good settling performance, compact sludge and low water content. As a new water treatment technology in recent years, magnetic flocculation technology has been developed rapidly in water treatment and various kinds of sewage and wastewater treatment, and has been applied in engineering practice. In this paper, the mechanism and application of magnetic flocculation technology are studied, and the development prospect of this technology is analyzed^[2].

2. Mechanism of magnetic flocculation technology

2.1. Adsorption of magnetic flocculation technology

Adsorbent is a solid substance which can effectively adsorb some of its components from gas or liquid. Whether adsorbent has adsorption depends on the contact angle of solid-liquid phase. When the contact angle is less than 90°, the adsorbent is hydrophilic. However, when the contact angle is greater than 90° and less than 180°, the adsorbent is lipophilic. Adsorbents with good dispersion in water have good adsorption effect on pollutants.

The experimental results show that when the contact angle of magnetic powder is 45.5°, it belongs to hydrophilic substance and has adsorption effect on water-soluble substance. Therefore, magnetic powder can absorb suspended and colloidal substances in water by its large specific surface area.



2.2. Increasing collision opportunities

According to coagulation kinetics, when the concentration of suspended solids in water is very low, the collision rate of particles will be greatly reduced and the coagulation effect is poor^[3-5]. The diffusion of magnetic particles in water increases the number of suspended particles and increases the collision chance of colloidal substances. And the weak magnetic field produced by the magnetic powder makes the charged colloids around the magnetic powder move by Lorentz force, which promotes the collision between suspended and colloidal substances. In this way, the probability of flocculation of particles in water is greater, and the flocculation effect is strengthened^[6].

2.3. Effect on the ζ potential

The ζ potential is a measure of the strength of mutual exclusion and attraction between particles. The higher ζ potential show the more stable the dispersion system of colloid in water. Reducing or eliminating ζ potential of colloidal particles can reduce the peak of repulsion energy and then destabilize the colloids. The results show that the ζ potential of raw water is 11.7 mV. When flocculant was added to raw water, the ζ potential was 9.81 mV and when magnetic powder is added into raw water, the ζ potential is 8.7 mV^[7].

2.4. Nuclear magnetic interaction

The magnetic powder added into water combines with suspended matter in water to form a "magnetic complex" with magnetic powder as the core. These "magnetic complexes" attract each other under the action of magnetic force, forming flocs with large particle size and high density, which are more resistant to hydraulic shear force and are not easy to break^[8]. Moreover, because the magnetic powder is the core of the magnetic complex, the density of flocs increases and settlement speed is accelerated, so that the area occupied by subsequent treatment units such as sedimentation tank decreases^[9].

3. Application of magnetic flocculation in water treatment

3.1. Municipal Sewage

Municipal sewage is an important cause of water pollution, and its treatment effect has been paid more and more attention. Compared with traditional biological treatment, chemical enhanced primary treatment with coagulant has the characteristics of less natural constraints, less land occupation, shorter process, faster treatment speed, lower capital construction and operation costs, and flexible operation^[8,10]. In addition, magnetic flocculation technology has many advantages, such as simple and economical, rapid settling and separation, low sludge moisture content and so on. Therefore, it has become a very competitive method of municipal wastewater treatment^[8,11].

3.2. Wastewater containing phosphorus

Phosphorus in drinking water is mainly removed by precipitation with coagulant and alum formation with insoluble phosphorus. When the flocculation effect is good, most phosphorus can be removed by flocculation precipitation. However, in the conventional flocculation phosphorus removal, the flocs are generally loose, the settling performance is poor, the treatment structure occupies a large area and the effluent effect is instable. The magnetic flocculation can enhance the flocculation effect, increase the floc size, compactness and sedimentation, thus enhancing the removal effect of total phosphorus in the system^[12].

3.3. Oily wastewater

The magnetic powder has good adsorption capacity for oil and colloidal substances in wastewater. Flocculants can separate oil from water by encapsulating oil and other suspended substances to form flocs. Wang^[13] found that the combination of flocculant and magnetic powder is better than flocculant or magnetic powder alone in treating oily wastewater, and the removal rate is increased by 30%-40%. Yao^[14] showed that when the oil content of wastewater was 120-700 mg/L and COD was 2100 mg/L,

the removal rate of oil and COD could reach about 80% by high gradient magnetic separation.

3.4. Papermaking wastewater

Papermaking wastewater contains a lot of fibers, pigments and inorganic salts and the organic matter concentration and turbidity are very high. The BOD can usually reach 5-40 g/L. In general, flocculation and sedimentation are used as pretreatment process, followed by biochemical treatment and other processes, and discharge after meeting the standards. At present, most waterworks adopt conventional coagulation and sedimentation process, and COD removal rate is only 10%. Huang^[15] reported that the removal rate of papermaking wastewater can be increased to about 30% by using magnetic flocculation and magnetic separation technology, which has obvious advantages.

3.5. Coking wastewater

Coking wastewater contains not only high concentration of organic matter, but also tar in coking wastewater will adhere to the surface of microbial micelles, inhibit the oxidation of microorganisms, and then affect the biochemical treatment effect. Therefore, pretreatment before biochemical reaction is effective for coking wastewater treatment. Zhang^[16] applied magnetic flocculation technology to beaker test of coking wastewater. The results show that the removal rates of COD and turbidity of coking wastewater by conventional coagulation are 55% and 85%. But magnetic flocculation technology can increase the removal rate to 63% and 92% respectively.

3.6. Heavy metal wastewater

Wastewater from heavy metal industry pollutes the environment seriously, which is a major difficulty in industrial wastewater treatment. Conventional treatment methods of heavy metal wastewater include chemical precipitation, redox, ferrite, electrolysis, evaporation and concentration, ion exchange resin and so on, but these methods have the problems of large investment and high operation cost. Pang^[17] has proved the feasibility and superiority of the treatment of heavy metal wastewater by magnetic flocculation-large gradient magnetic filtration process. The results show that magnetic flocculation process has a good removal effect on iron, copper and lead ions, but has no obvious removal effect on manganese and zinc ions.

4. Development and Prospect

The application scope of magnetic flocculation technology is expanding. Its treatment targets are also extended from magnetic pollutants to non-magnetic pollutants. It is not only used to treat municipal wastewater, phosphorus wastewater, oil wastewater, paper wastewater, etc., but also magnetic flocculation technology has been applied in the field of water treatment in recent years. Because of its simple process and easy operation and management, a portable integrated water purification equipment with magnetic flocculation technology has been developed, and good water purification effect has been achieved.

The property and price of magnetic powder loaded in magnetic flocculation process have become one of the important factors affecting the wide application of this technology. Small particle size magnetic powder may not only have superparamagnetism, but also be less dragged by hydraulic force. It is more evenly dispersed in water and easier to collide effectively with suspended solids. However, due to the high cost of raw materials or the difficulty of processing, it is limited in practical application. In addition, the development of cheap magnetic powder has become an important way to solve this problem.

In the conventional magnetic flocculation process, because the flocculant and magnetic powder are added separately, there are many influencing factors, which cannot guarantee the treatment effect. Therefore, the preparation of magnetic flocculants with magnetic and flocculating properties is of great significance. Using polyacrylamide and chitosan, concentrated sulfuric acid, ethanol-acetone as modifiers, magnetic flocculants were prepared by complex interaction between flocculants and magnetic powder surface (such as adsorption, encapsulation, chemical bond, etc.). The results show

that magnetic flocculant has better treatment effect than conventional flocculant.

Magnetic flocculation technology can be used as a pretreatment process in wastewater treatment to reduce the concentration of colloids and suspended solids in water. Biochemical process and other system processes are adopted to make the wastewater meet the discharge standard, and at the same time, the load of the subsequent process is reduced. In the field of water treatment, the combination of magnetic flocculation technology and membrane filtration technology has achieved good results. Particularly, the combination of inorganic ceramic membranes has attracted much attention. Because of the wear and tear of magnetic powder on the equipment, the material selection requirements of the equipment are more stringent. The inorganic ceramic film has the characteristics of high strength and wear resistance, which can meet the material requirements and ensure the long-term stable operation of the equipment. In addition, magnetic flocculation process and membrane filtration process can be used for the removal of high concentration pollutants with high integration and easy to automate management.

Acknowledgement

This work was supported by the Natural Science Foundation of Shandong Province, China [Grant numbers ZR2014EEM044].

References

- [1] Wang C R , Ren X , Li W X , et al. Magnetic Flocculation Technology for Copper and Zinc Ions Removal from the Tin Smelting Wastewater[J]. *Applied Mechanics and Materials*, 2013, 295-298:1284-1288.
- [2] Luo L, Nguyen A V. A review of principles and applications of magnetic flocculation to separate ultrafine magnetic particles[J]. *Separation & Purification Technology*, 2017, 172:85-99.
- [3] Garcia-Martinez H A, Llamas-Bueno M, Song S, et al. Magnetic flocculation of mineral fines in an external magnetic field[J]. *Mineral Processing & Extractive Metallurgy Review*, 2004, 25(2):67-90.
- [4] Williams R A, Jia X. Simulation of magnetic flocculation behaviour of fine minerals[J]. *International Journal of Mineral Processing*, 1991, 32(3-4):175-191.
- [5] Wang Z. Mechanism of optical birefringence effect on a thin film magnetic fluid situated in a magnetic field[J]. *Acta Armamentarii*, 2004.
- [6] Bai S J, Wen S M, Liu D W, et al. Separation of Phosphorus and Magnetic Mineral Fines from Siderite Reductive Ore by Applying Magnetic Flocculation[J]. *Separation Science & Technology*, 2014, 49(9):1434-1441.
- [7] Zhao Y, Liang W, Liu L, et al. Harvesting *Chlorella vulgaris* by magnetic flocculation using Fe_3O_4 coating with polyaluminium chloride and polyacrylamide.[J]. *Bioresource Technology*, 2015, 198:789-796.
- [8] Lipus L C, Kroppe J, Crepinsek L. Dispersion Destabilization in Magnetic Water Treatment[J]. *Journal of Colloid & Interface Science*, 2001, 236(1):60-66.
- [9] Vandyshev V N, Koksharov S A. Thermodynamic Characteristics of Solution of Polar Nonelectrolytes in Magnetized Water[J]. *Russian Journal of General Chemistry*, 2003, 73(6):838-841.
- [10] Tauxe L , Steindorf J L , Harris A . Depositional remanent magnetization: Toward an improved theoretical and experimental foundation[J]. *Earth and Planetary Science Letters*, 2006, 244(3-4):509-529.
- [11] Wang H Q, Mao T G, Xi B D, et al. KMnO_4 pre-oxidation for *Microcystis aeruginosa* removal by a low dosage of flocculant[J]. *Ecological Engineering*, 2015, 81:298-300.
- [12] Li R H , Li X Y . Recovery of phosphorus and volatile fatty acids from wastewater and food waste with an iron-flocculation sequencing batch reactor and acidogenic co-fermentation[J]. *Bioresource Technology*, 2017, 245:615-624.
- [13] Karapinar N . Magnetic separation of ferrihydrite from wastewater by magnetic seeding and

- high-gradient magnetic separation[J]. International Journal of Mineral Processing, 2003, 71(1-4):45-54.
- [14] Yao Y D, Qian X L, Dao tang L I, et al. Oily Wastewater Treatment by High Gradient Magnetic Separation[J]. Journal of Shanghai Jiaotong University, 2003.
- [15] Huang Q R, Huo H H. Application and prospect of magnetic flocculation and magnetic separation technology [J]. Water supply and drainage, 2010, 36(7):150-152.
- [16] Zhe Z , Yun-Long Y . Experimental study on advanced treatment of coking wastewater by magnetic flocculation technology[J]. Industrial Water & Wastewater, 2012.
- [17] Zhi-Bang P , Ji-Lun Y , Bo L , et al. Application and Prospects of Magnetic Flocculation in Water Treatment[J]. Journal of Chongqing University of Technology, 2015.