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RESEARCH ARTICLE

Effect of Iron-Carbon Micro-Electrolysis-Fenton on the Dewatering Performance of Sludge

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Abstract
In this paper, combined with iron-carbon micro-electrolysis-Fenton method, the sludge was adjusted, and the cracking performance and dewatering performance of the sludge were studied. Single factor experiments show that when the amount of iron powder is 1.2 g/L, the reaction time is 45 min, H_2 O $_2$When the dosage was 4.2 g/L, the protein and polysaccharide content in the sludge decreased by 46.8 and 20.6, respectively. Compared with the original sludge %. Compared with the original sludge, the COD of the supernatant of the solution increased by 10.1%. The minimum moisture content of the treated sludge cake was 69%, and the SRF value was significantly reduced.The lowest value is 2.687×10 ^{12} m/kg. During the micro-electric dust removal sludge, the Fe $^{2+}$can form a Fenton reagent with H_2 O $_2$, thereby reducing the amount of additional iron powder that needs to be added in the conventional Fenton reaction. Three-dimensional fluorescence spectroscopy analysis showed that the humic acid and fulvic acid in the supernatant of the iron-carbon micro-electrolysis-Fenton conditioning solution increased more than after single electrolysis, indicating that the dehydration performance of the sludge was better.The Fenton reagent is formed , thereby reducing the amount of iron powder that needs to be added extra in the conventional Fenton reaction.

Keyword Iron Carbon Micro Electrolysis · Sludge cracking · Dehydration performance

Introduction

Sludge is a by-product produced in the sewage treatment process of sewage treatment plants, which contains a large amount of organic, inorganic, heavy metals and pathogenic microorganisms. With the continuous improvement of the level of urbanization, sewage treatment facilities and treatment methods are also continuously improved and updated. As of the end of 2016, all cities in China had built 2,039 sewage treatment plants with a daily treatment capacity of 149 million M^3 (Chen et al. 2007). However, with the completion and operation of the sewage treatment plant, there will be a large amount of surplus sludge. If the moisture content is 80%, the total annual output of sludge will exceed 35 million tons. If a large amount of surplus sludge is not effectively treated, the pollutants in the sludge will be transferred to the atmosphere, water and soil, causing secondary pollution to the environment and directly affecting human health (Shaolan et al. 2018). Therefore, it is necessary to properly handle and dispose of the sludge.

The iron-carbon micro-electrolysis technology is mainly based on the galvanic cell formed by the electrode material in the solution, the electrochemical reaction and other reactions on the electrode surface, thereby destroying the chain ring of macromolecular organic matter or cyclic organic matter. Then improve the biodegradability of wastewater. (Feng et al. 2015) Concentrated wastewater can be treated SSE, the Results shows that biodegradability can be improved. inaddition, the iron - MICROELECTROLYSIS MIT y is also used forremove Nitrogen and phosphorus in groundwater (Gjjt 221-2005 2005) and nitrate (Gao and Yu 2004).

The main reaction mechanism of iron-carbon micro-electrolysis is as follows:

$$\text{Anode (Fe)}: Fe(s) - 2e^- \rightarrow Fe^2 + (aq) \quad E\theta\left(Fe^2 + /Fe\right) = -0.44V$$

$$Fe^{2+}(aq) - e^- \rightarrow Fe^{3+}(aq) \quad E\theta\left(Fe^{3+}/Fe^{2+}\right) = +0.77V$$

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$$\text{Cathode (C)}: 2H^+(aq) + 2e^- \rightarrow \quad E\theta(H^+/H_2) = 0.00V$$

The cathode reaction under aeration conditions is as follows:

$$\text{(strong acid)}O_2(g) + 4H^+(aq)4e^- \rightarrow 2H_2O \quad E\theta(O_2/H_2O) = +1.23V$$

$$\text{(weak acid)}O_2(g) + 2H^+(aq)2e^- \rightarrow 2H_2O \quad E\theta(O_2/H_2O2) = +0.68V$$

$$\text{(neutral, weakly basic)}O_2(g) + 2H_2O + 2e^- \rightarrow 4OH^-(aq) \quad E\theta(O_2/OH^-) = +0.40V$$

Under strong acid and aeration conditions, the potential difference e is the largest, indicating that the micro-electrolysis reaction has a good treatment effect under acidic conditions. Fe Produced by electrolysis^{2+}And Fe $^{3+}$produced by micro- electrolysiscan form Fe(OH) Forms $Fe(OH)_2$ and $Fe(OH)_3$ precipitates They all have strong adsorption and flocculation effects.$^+$In the new ecology [H] produced by the absorption of electrons by cathode carbon, it has strong activity. It can react with organic pollutants in wastewater through oxidation-reduction reactions, and convert large molecules into small molecules, thereby improving the biodegradability of wastewater.In addition, in recent years, Fenton's method has been widely studied and applied to improve the performance of sludge dewatering with good results. Hong et al. (Guan et al. 2018) used the Fenton method to treat the remaining activated sludge. The results show that an appropriate amount of Fenton reagent can effectively promote the conversion of TB-EPS to L-EPS and S-EPS, and the degree of binding is low, and the oxidative decomposition and pollution of organic substances such as EPS can be caused. The internal water and bound water of the cells in the sludge are released in large quantities, thereby improving the dewatering performance of the sludge. Zhang et al. It was also found that adding hydrogen peroxide at the end of the micro-electrolysis improved COD removal rate (Garcia-Segura et al. 2016).

Many studies have shown that iron-carbon micro-electrolysis combined with Fenton reaction has a better treatment effect (Han et al. 2016 ; Hu etc. 2019).Van waited. It is proposed that the micro-electric field of iron and carbon can accelerate electron transfer, and the electric field effect promotes Fenton oxidation (Chen et al. 2014). Wang et al. studieD is advanced treatment of landfill leachate by iron-carbon micro-electrolysis Fenton treatment. It was found that the hydrogen peroxide-enhanced iron-carbon (Fe-C) micro-electrolysis reactor is promising and effective in treating mature Landfill leachate chnology (Zhang et al. 2012a). Lan et al.The process of combining internal micro-electrolysis and Fenton oxidation-coagulation is used to treat wastewater containing EDTA-Cu(II). Ť His results show that the combined process is an efficient and low-cost processing method (Hjjt 399- 2007 2007).Therefore, this article proposes the possibility of iron-carbon micro-electrolysis and Fenton technology for pretreatment of sludge. According to the protein, polysaccharide and SCOD content of the sludge, the pyrolysis performance of the sludge was studied, and the specific resistance of sludge filtration (SRF water content) and the dehydration cake were indexed, and the filtration performance and dehydration performance were measured. Analyzed. The performance of sludge was studied.

Experimental

Experimental Materials

The sludge was taken from the remaining sludge in the second sedimentation tank of the Fifth Sewage Treatment Plant in Xi'an. The recovered sludge was immediately placed in a refrigerator at 4°C, and then naturally settled for 24 h, and then the supernatant was poured out. The basic characteristics of concentrated sludge are determined by the sludge test method of municipal sewage treatment plant sludge test method (Han et al. 2019) (CJ/T221-2005). table1The basic characteristics of concentrated sludge are listed.

Laboratory instrument

Guohua Electric Co., Ltd. JJ-4 digital display six coupler;101-a electric blast drying oven, Tianjin Test Instrument Co., Ltd.; dzkw-4 electronic constant temperature water bath, Beijing Zhongxing Weiye Instrument Co., Ltd.; HC-3018R high-speed Refrigerated centrifuge, Anhui Zhongke Zhongjia Scientific Instrument Co., Ltd.; Zhengzhou Great Wall Science, Industry and Trade Co., Ltd. SHB-III circulating water vacuum pump; 754 UV-Vis Spectrophotometer, Shanghai Hanyu Hengping Scientific Instrument Co., Ltd.; Company;FS-5 Fluorescence Spectrometer, Edinburgh, UK.

Measurement items and methods

Water content of sludge cake

Determine the moisture content of the sludge cake according to the gravimetric method in the "Sewage Treatment Plant Sludge Testing Method" (cj/t221-2005), and determine the dewatering performance.

Filter resistance

Specific filtration resistance (SRF) refers to the resistance of sludge filtration. The size of SRF is used to characterize the dewatering performance of sludge. The larger the SRF value, the worse the sludge dewatering performance. SRF is measured by the Buchner funnel method (Lan et al. 2012).

Table 1 Basic characteristics of sludge

Density (g/ml)	pH value	Moisture content (%)	SCOD (mg/liter)	TS (g/l)	VS (g/l)	SRF (m/kg)
1.009	6.8	98.4	143.5	16.25	10.34	3.991×10^{13}

Other reagents and materials: reduced iron powder, analytically pure. Activated carbon, analytically pure; hydrogen peroxide, analytically pure

Three-dimensional fluorescence spectrum analysis

The three-dimensional fluorescence spectrum of the supernatant in the sludge was measured by FS-5 fluorescence spectroscopy. The excitation wavelength (Ex) is 235-400 nm, the emission wavelength (Em) is 345-600 nm, and the step size is 1 nm.

Other indicators

The EPS in the sludge sample was extracted by thermal extraction (Liu and Fang 2003). The protein was measured by the Folin method (He and Wei 2010); the polysaccharide was measured by the indolinone method (Lu et al. 2003). Chemical oxygen demand (COD) is determined by the potassium dichromate method (Ning et al . 2014).

Iron-carbon micro-electric demodulation sludge

Take a 200 mL sludge sample in a beaker, adjust the pH value, add a certain amount of iron powder and activated carbon, stir evenly with a six-coupler, start the aeration device for testing, and react at room temperature. Measure the moisture content of the treated sludge.

Iron-carbon micro-electrolysis-Fenton joint regulation

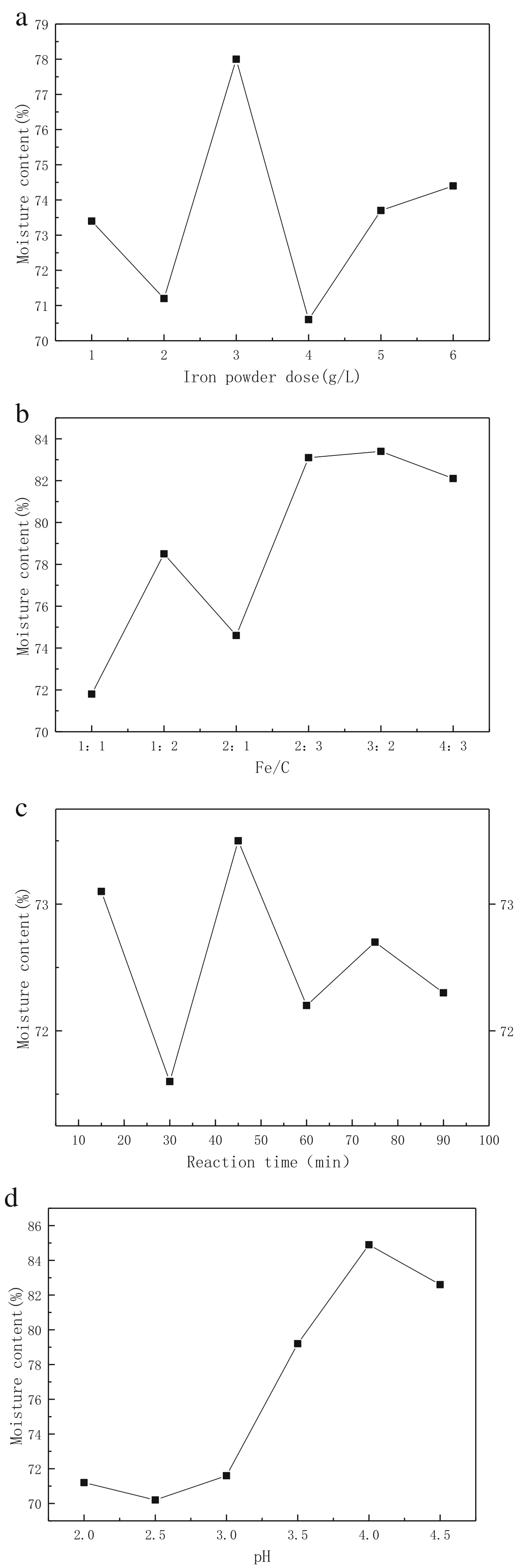
The 200-mL sludge sample was placed in a beaker. Under the optimal conditions of the above microelectrolysis treatment, different amounts of iron powder and H_2O_2 were added for the test, and the reaction was carried out at room temperature. The moisture content of the sludge cake after conditioning and the contents of COD, protein, and polysaccharide in the supernatant were measured.

Results and discussion

Effects of iron-carbon microelectrolysis treatment on sludge dewatering

Iron powder dosage has a significant impact on sludge dewatering performance. In this study, the initial conditions were pH 3.0, reaction time 30 min, Fe/C 1:1, and aeration rate 1.5 L/min. The dewatering performance of sludge with iron powder dosage of 1 g/L, 2 g/L, 3 g/L, 4 g/L, 5 g/L, and 6 g/L was investigated. Results are shown in Fig. 1a. It can be seen that when the iron powder dosage is 4 g/L, the sludge moisture content reaches a minimum value of 70.6%. As the dosage is gradually increased, the moisture content of the sludge did not change much. The reason may be that when the iron powder dosage continues to increase, the iron-carbon contact is uneven due to the influence of the aeration intensity, and the excessive iron powder cannot fully contact the activated carbon, thereby suppressing the electrode reaction. Therefore, the optimum iron powder dosage was 4 g/L. Furthermore, the reaction time was 30 min, the amount of iron powder was 4 g/L, the initial pH was 3, and the aeration rate was 1.5 L/min. The dewatering performance of sludge was investigated when the Fe/C was 1:1, 1:2, 2:1, 2:3, 3:2, and 4:3, respectively. As shown in Fig. 1b. The sludge moisture content reached a minimum of 71.8% when the iron-to-carbon ratio was 1:1. When the iron-carbon ratio is around 1:1, the moisture content of the sludge differs greatly. The appropriate iron and carbon dosing ratio could effectively exert the effects of microelectrolysis reaction. When the proportion of iron-carbon addition was unscientific, the reaction could not be maximized whether it is excessive iron or excessive activated carbon. Han et al. found that the Fe/C ratio was 1:1 for nitrobenzene in different proportions of iron-carbon mixture (Fe/C = 2:1, 1:1, 1:2). The removal rate was 98.2%. When Fe/C is greater than 1:1, the The removal rate of nitrobenzene gradually decreases, because when iron and activated carbon are used in the same amount,the maximum number of microscopic primary batteries (Statistical bulletin of urban and rural construction 2017) is likely to be formed.

It can be seen from Fig. 1c that under the conditions of iron powder dosage of 4 g/L, initial pH of 3.0, and Fe/C of 1:1, the moisture content of sludge remains basically unchanged under different reaction times, which indicates that the iron-carbon microelectrolysis reaction time has little effect on sludge dewatering performance. For economic reasons, the optimal reaction time is 30 min. Previous studies found that pH value significantly affected the reaction rate of iron-carbon microelectrolysis. In this study, the initial pH values were 2, 2.5, 3, 3.5, 4, and 4.5 to explore the sludge dewatering performance. The other conditions were as follows: reaction time 30 min, iron powder 4 g/L, Fe/C 1:1. It can be seen from Fig. 1d that the moisture content of the sludge cake is low at the initial pH of 2.0~3.0, between 70 and 71%, when the pH is increased



◀ **Fig. 1** a Effects of iron powder dosage on sludge moisture content. b Effects of Fe/C on sludge moisture content. c Effects of reaction time on sludge moisture content. d Effects of initial pH on sludge moisture content

from 3 to 4. During the process, the water content suddenly increased, and when the pH was 4.0, the moisture content of the sludge was as high as 84%. In addition, Zhang et al. used potassium ferrate to study sludge dewatering under different pH conditions. When the pH value was less than 3, the moisture content of the sludge cake was below 76%. When the pH was 4–6, the water content was both are up to 84%(Shen et al. 2018). It indicates that the initial pH is an important factor affecting its dewatering performance. Therefore, for the microelectrolysis reaction, an initial pH of 2.5 is the optimum reaction condition.

According to the moisture content of the sludge cake, when the iron-carbon microelectrolysis method is used in the iron powder dosage of 4 g/L, the reaction time is 30 min, and the initial pH is 2.5, the sludge moisture content reaches the The lowest value of 70.2%, and the microelectrolysis can effectively crack the sludge flocs, releasing a large amount of bound water, reducing the moisture content of the sludge, and improving the sludge dewatering performance.

Effect of iron-carbon microelectrolysis-Fenton joint conditioning on sludge cracking degree

Studies have shown that extracellular polymers (EPS) account for about 60–80% of sludge biomass, and the main components of protein and polysaccharide are important factors affecting sludge dewatering performance(Van der Zee 2003). Under the optimal treatment conditions of the above iron-carbon microelectrolysis, H_2O_2 was added to the sludge to explore the optimal reaction conditions of the microelectrolysis-Fenton.

In order to obtain the optimal reaction conditions of microelectrolysis-Fenton reaction, the initial conditions were pH 2.5, reaction time of microelectrolysis was 30 min, Fe/C was 1:1, aeration rate was 1.5 L/min, Fenton reaction time was 60 min, H_2O_2 dosage was 3.0 g/L, and rotation speed was 300 r/min. The sludge cracking degree was investigated when iron powder dosage was 0.3 g/L, 0.6 g/L, 0.9 g/L, 1.2 g /L, 1.5 g/L, and 1.8 g/L, respectively. It can be seen from Fig. 2a that the protein and polysaccharide content in the sludge EPS reached the lowest value when the iron powder dosage was 1.2 g/L, which was 391.7 mg/L and 69.5 mg/L, respectively. The lowest value of 477.5 mg/L was reached. Fe^{2+}produced by microelectrolysis catalyzes the oxidation of H_2O_2 to remove proteins and polysaccharides in EPS. The removal rate of protein reaches 43.8%, the removal rate of polysaccharide reaches 33.4%, and the iron required for joint reaction

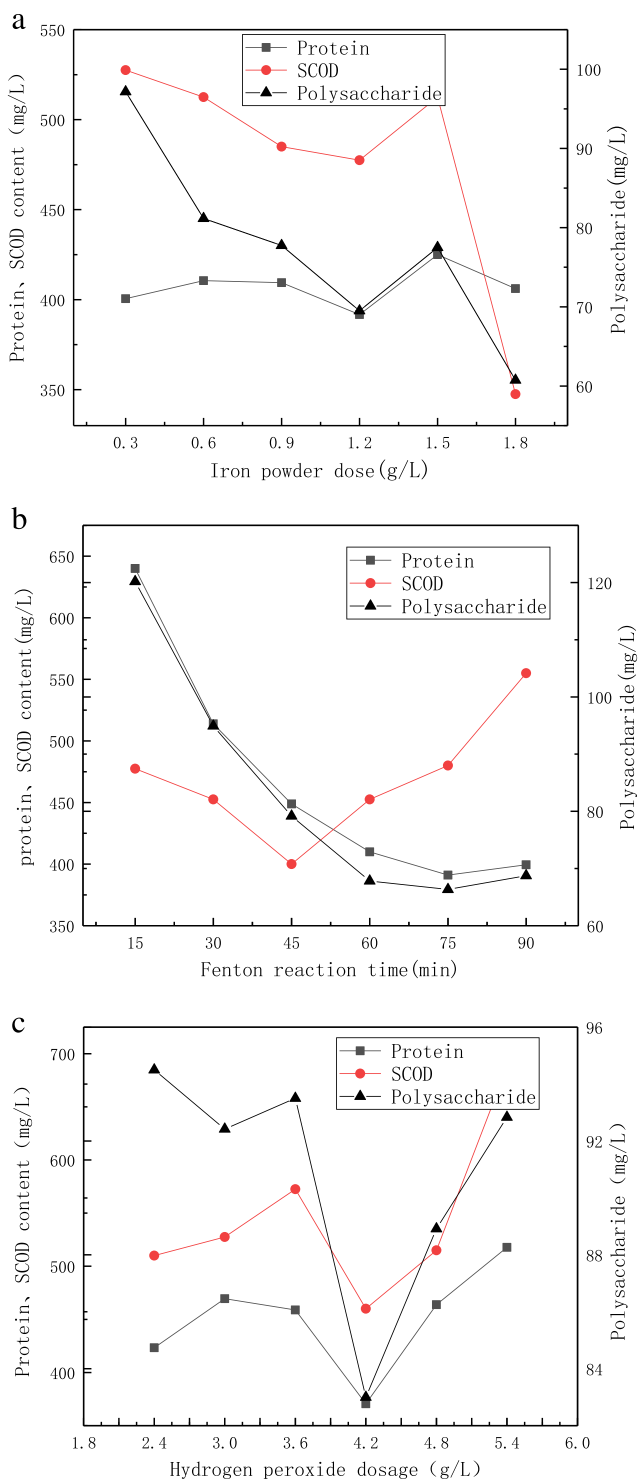


Fig. 2 a Effects of iron powder dosage on sludge cracking degree. **b** Effects of Fenton reaction time on sludge cracking degree. **c** Effects of H_2O_2 dosage on the sludge cracking degree

The amount of powder added is also smaller than that of the single microelectrolysis reaction.

To explore the degree of Fenton reaction time (15 min, 30 min, 45 min, 60 min, 75 min, 90 min) on the cracking degree of sludge. The dosage of iron powder is 1.2 g/L. Other initial conditions are pH 2.5, Fe/C 1:1, aeration rate 1.5 L/min, and microelectrolysis reaction time 30 min. After adding H_2O_2, the Fenton reaction started. The dosage of H_2O_2 was 3.0 g/L and the rotation speed was 300 r/min. It can be seen from Fig. 2b that before the Fenton reaction time is 45 min, the protein, polysaccharide content, and SCOD value of the sludge EPS gradually decrease, and the lowest value is reached at 45 min, 448.9 mg/L, 79.2 mg/L, and 400 mg/ L, respectively. When the reaction time continues to increase, the three remain basically unchanged. Ning dehydrated the dyed sludge by ultrasonic-assisted Fenton and found that the sludge disintegration reached a maximum at the reaction time of 50 min(Wang et al. 2016). The reason for the analysis may be that after the sludge is treated by the microelectrolysis reaction, the sludge EPS is oxidized and cracked, and the protein and polysaccharide content are increased. When H_2O_2 is added, Fe^{2+}catalyzes the production of •OH by H_2O_2, Fenton reaction occurs, and the existing OH radical oxidizing solution contains polysaccharides. Substances such as proteins cause a decrease in their content. When the reaction time was 45 min, the protein, polysaccharide content , and SCOD basically reached the lowest value. As the reaction time continued to increase, the protein, polysaccharide content, and SCOD value remained basically unchanged, indicating that the sludge EPS was completely oxidized and destroyed.

To explore how different H_2O_2 dosages (2.4 g/L, 3.0 g/L, 3.6 g/L, 4.2 g/L, 4.8 g/L, 5.4 g/L) can crack the sludge, the selected initial conditions are pH 2.5, the microelectrolysis reaction time is 30 min, Fe/C is 1:1, and the aeration rate is 1.5 L/min. Then H_2O_2 was added to start the Fenton reaction. The reaction time was 45 min and the rotation speed was 300 r/min. It could be seen from Fig. 2c that when the dosage of H_2O_2 was 4.2 g/L, the contents of protein and polysaccharide in the EPS of the sludge reached the lowest values, which were 370.6 mg/L and 83 mg/L, respectively. The SCOD value also reached a minimum of 460 mg/L. When H_2O_2 was added, Fe^{2+} formed in the solution catalyzed the production of •OH by H_2O_2, and the strong oxidizing •OH radical oxidized the existing proteins, polysaccharides, etc.; the protein and polysaccharide content is reduced (Wang et al. 2018), and the generated •OH increases, and the ability to oxidize the sludge also increases. When H_2O_2 is added, the dosage is 4.2 g/L. At the time, the EPS protein and polysaccharide content of the sludge were the least, and the EPS was completely destroyed. As the dosage of H_2O_2 increases. Excessive H_2O_2 would rapidly oxidize Fe^{2+} produced by microelectrolysis to Fe^{3+}, which will not produce enough •OH, and excess H_2O_2 would undergo free radical scavenging reaction, reducing the content of •OH and the utilization of H_2O_2 (Ying et al. 2012 ; Zhu et al. 2014).

Effect of iron-carbon microelectrolysis-Fenton combined conditioning on sludge dewatering performance

The main parameters for the evaluation of sludge dewatering performance are the specific resistance of sludge (SRF) and water content. In general, when the SRF is greater than 10^{13} m/kg, sludge dewatering is difficult; when the SRF is less than 4×10^{12} m/kg, the sludge is easily dehydrated, and mechanical dehydration (Zhang et al. 2012a) can be employed. The selected initial conditions are pH2.5, the reaction time of microelectrolysis is 30 min, Fe/C is 1 :1, the aeration rate is constant at 1.5 L/min, the Fenton reaction time is 60 min, the dosage of $H_2O_2$is 3.0 g/L, the speed is 300 r/min, and the sludge when the iron powder dosage is 0.3 g/L, 0.6 g/L, 0.9 g/L, 1.2 g/L, 1.5 g/L, and 1.8 g/L dehydration performance. It can be seen from Fig. 3a that as the iron powder dosage increases gradually, the moisture content and SRF value of the sludge cake first decrease and then rise, reaching the lowest value near 1.2 g/L, and the water content. It is about 72.5% and the SRF value is 2.774×10^{12} m/kg. As the dosage continues to increase, the sludge moisture content becomes larger and the SRF value also increases. The reason may be that when the amount of iron powder is insufficient, microelectrolysis cannot produce enough Fe^{2+} , which catalyzes the small amount of OH generated by H_2O_2 , and the effect of oxidizing EPS is poor; when the iron powder is excessive, Fe^{2+} is oxidized to Fe^{3+} , and the oxidation effect is not satisfactory, which affects the dewatering performance of the sludge. In addition, compared with the traditional Fenton method, the advantage of combining the microelectrolysis method with the Fenton reagent is that the combination of the two methods can effectively utilize the large amount of Fe^{2+} contained in the wastewater treated by the microelectrolysis method, and only need to add H_2O_2 , that is, the Fenton reagent can be formed without the need to add an agent containing Fe^{2+}In addition, the activated carbon introduced into the system can act as a framework building agent. It not only effectively removes Fe^{2+} in wastewater but also makes full use of activated carbon to meet the environmental protection requirements of waste treatment.

The reaction time and reaction effect of the Fenton reaction time will also affect the reaction time. The reaction time is too short. The reaction of Fe^{2+} and H_2O_2 has not been completed, the treatment ability is weak, and the pollutants cannot be sufficiently removed. Excessive time will not only increase the consumption of medicines but also a large amount of Fe^{2+} will be oxidized to Fe^{3+} . The dosage of iron powder is 1.2 g/L, other initial conditions are pH 2.5, Fe/C is 1:1, aeration rate is 1.5 L/min, and reaction time is 30 min. After adding H_2O_2 to start the Fenton reaction, the dosage of H_2O_2It is 3.0g/L, the speed is 300r/min, and the Fenton reaction time is 15 minutes, 30 minutes, 45 minutes, 60 minutes, 75 minutes and

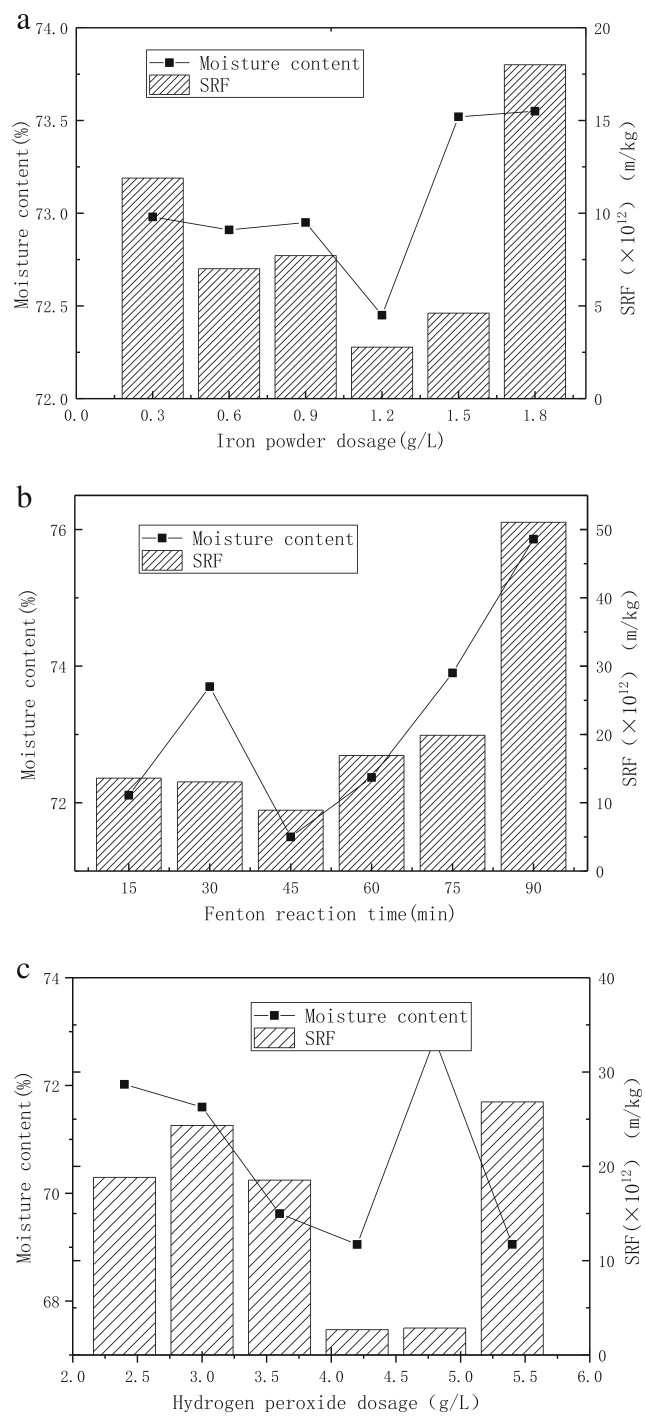


Fig. 3 a Effect of iron powder dosage on sludge dewatering performance. b Effect of Fenton reaction time on sludge dewatering performance. c Effect of dosage of H_2O_2 on sludge dewatering performance

90 minutes. It can be seen from Fig. 3b that under the optimal conditions of iron-carbon microelectrolysis, when the Fenton reaction time is 45 min, the moisture content of the sludge reaches 71.5% and the SRF value is also the smallest. Value 8.913×10^{12}m/kg. The possible reason is that after the micro-

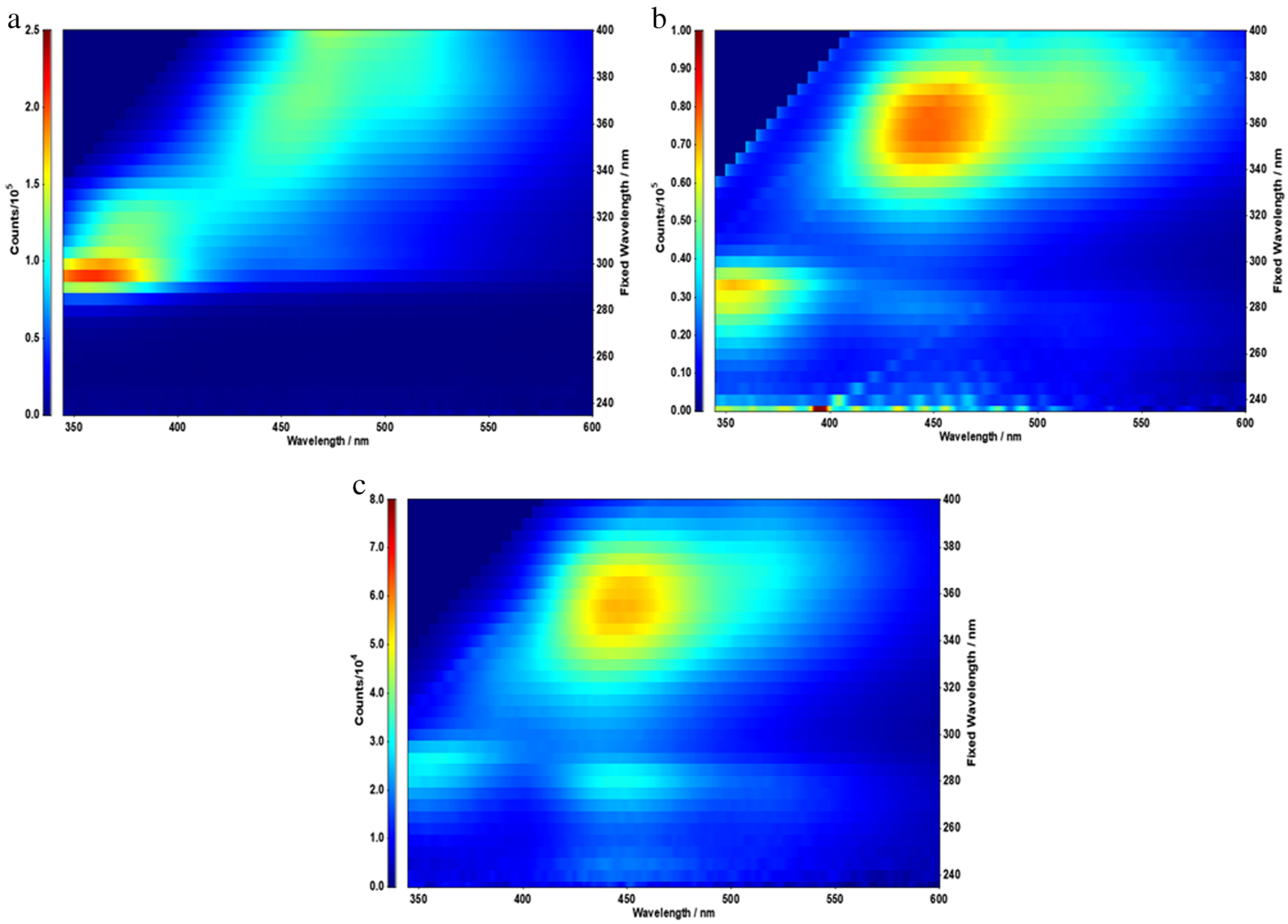
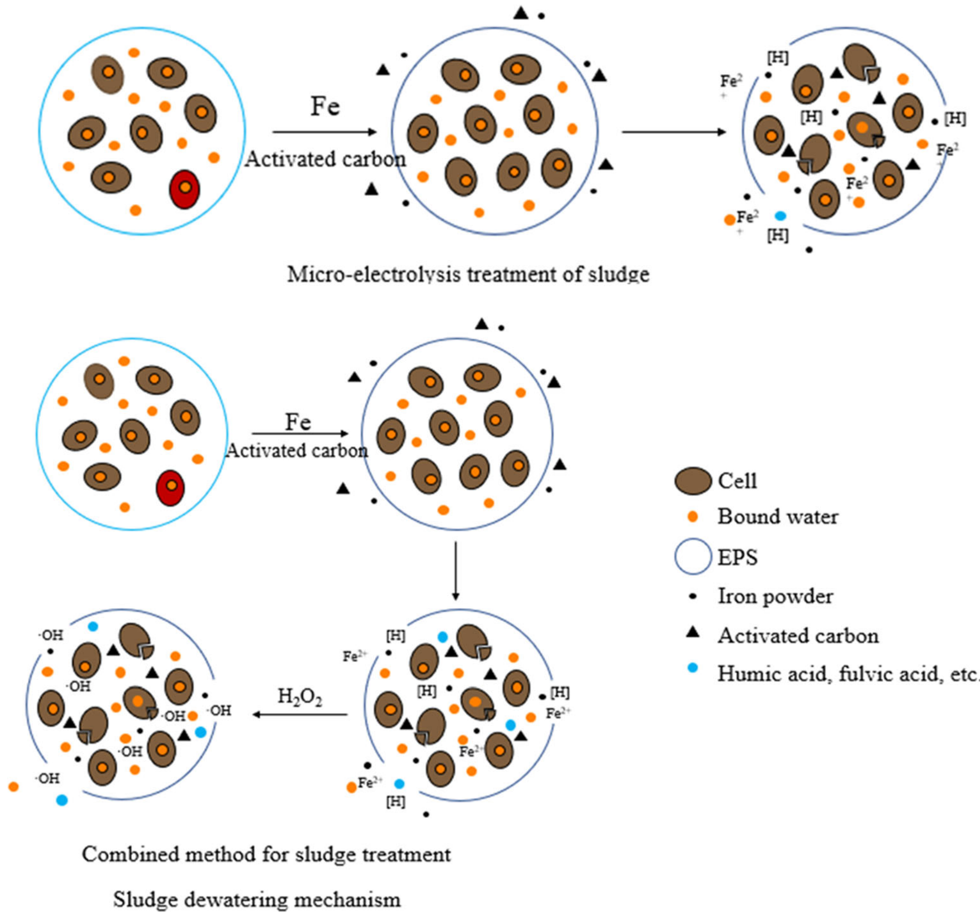


Fig. 4 Three-dimensional fluorescence of sludge sample supernatant : original sludge ; BM icroelectroly SIS-treatment ED slud GE ; c comprehensive treatment of sludge

electrolysis reaction, the sludge EPS is oxidized and cracked. In order to start the Fenton reaction after adding H_2O_2 , the resulting OH-oxidized sludge EPS reduces the content of protein and polysaccharides in the EPS and releases them. The combination of sludge and water is beneficial to the improvement of sludge dewatering performance. When the reaction time gradually increases, the moisture content in the sludge gradually increases, and the dehydration performance becomes worse (Zhou et al. 2013).

Fenton reaction time is 45 minutes, other initial conditions are pH 2.5, micro-electrolysis reaction time is 30 minutes, the amount of iron powder is 1.2 g/L, Fe/C is 1:1, the aeration rate is 1.5 L/Min, and the rotation speed is At 300 r/min, the H_2O_2 doses were 2.4 g/L, 3.0 g/L, 3.6 g/L, 4.2 g/L, 4.8 g/L and 5.4 g/L, respectively. It can be seen from Figure 3c that when the amount of H_2O_2 is 4.2 g/L, the moisture content of the sludge reaches the minimum 69%, and the SRF value also reaches the minimum 2.687×10^{12} m/kg. According to Figure 2c, with the increase of H_2O_2 dosage , Fe^{2+} catalyzes the increase of OH radicals produced by H_2O_2 and its ability to oxidize sludge. Correspondingly, EPS is destroyed by OH oxidation. When the dosage of H_2O_2 When it is greater than 4.2g/L, it can be observed that the water content of the sludge gradually increases, indicating that the dewatering performance of the sludge becomes worse. Wang Li is equal. The H_2O_2 dosage was studied in the experiment. When the H_2O_2 dosage was increased from 0 mg/g TS to 20 mg/g TS, the water content of the sludge decreased from 86.5 to 73.6%, indicating that H_2O_2 dose. In smaller cases, the dewatering performance of the sludge can be greatly improved, and the continued addition of H_2O_2 will not have a significant impact on the dewatering performance of the sludge (Zhang et al. 2012b). The reason for the analysis may be caused by H_2. O was added 2 when an excessive amount, to generate micro-electrolysis reaction of the of Fe^{2+} is an excess of H_2O_2 oxidation of of Fe^{3+}, a solution of the of Fe^{2+} content is low, reducing the Fenton reaction rate. .When adding H_2O_2When it increases to 5.4 g/L, the water content suddenly drops below 70%, but the SRF value is very large. Taking into account the combined reaction, H_2O is. The dosage is 4.2g/L. At this time, the moisture content and SRF value of the sludge cake are very low, and the amount of H_2O_2 is reduced .

Fig. 5 Sludge dewatering mechanism



Treat excess sludge with micro-electrolysis-Fenton. The optimal reaction conditions are: iron powder dosage 1.2 g/L, Fenton reaction time 45 min, H_2O_2 dosage 4.2 g/L. Compared with a single micro-electrolysis reaction, it reduces the amount of iron powder and reduces the water content of the sludge cake. Liu et al. The effect of Fenton process in sludge dewatering was studied. At pH = 3 , the moisture content of the sludge cake decreased from 86.2% to 75.2% (Zhang 2000), which indicates that proper micro-electrolysis treatment is beneficial to sludge cracking and improves the dewatering performance of sludge.

Analysis of sludge dewatering mechanism

The supernatant of the sludge sample processed by the original sludge treatment, the iron-carbon micro-electrolysis treatment and the combined method is subjected to three-dimensional fluorescence spectroscopy. The results are shown in Figure 4. In Figure 4a, the tryptophan-like protein of the original sludge has the strongest fluorescence peak intensity, while the fluorescence peak intensity of humic acid is weaker. In Figure 4b, the intensity of the fluorescence peak of humic acid in the sludge after micro-electrolysis treatment is the strongest, and the fluorescence peak of tryptophan-like protein and the fluorescence peak of fulvic acid are the weakest. In the combined method of Figure 4c. Compared with the sludge after micro-electrolysis treatment, the content of tryptophan protein substances is reduced, and the content of humic acid and fulvic acid substances is increased. The supernatant after sludge lysis contains the most tryptophan protein. Dissolved organic matter and simple aromatic hydrocarbons are hydrolyzed, and fulvic acid fluorescent substances and humic acid fluorescent substances are released into the liquid phase. This shows that after treatment, the protein substances in the sludge are reduced and converted into humic acid and fulvic acid with strong hydrophobicity, thereby improving the dewatering performance of the sludge, which is consistent with the research results of Zhang et al. (Zhang et al. 2019). The mechanism analysis of sludge is shown in Figure 5 the following.

in conclusion

The iron-carbon micro-electrolysis method can effectively crack the sludge flocs and improve the dewatering performance of the remaining sludge. When the iron powder dosage is 4 g/L, the reaction time is 30 min, and the initial pH is 2.5, the moisture content of the sludge cake is as low as 70.2%, indicating that iron-carbon micro-electrolysis can improve the sludge. Dewatering performance under certain conditions. Treat excess sludge with micro-electrolysis-Fenton. When the iron powder dose is 1.2 g/L, the Fenton reaction time is 45 minutes, and the H_2O_2 dose is 4.2 g/L. The water content of the sludge cake is 69%, and the SRF value is 2.687×10^{12} m/kg, which has the best dehydration performance. It shows that proper micro-electrolysis treatment is beneficial to sludge cracking, and the formed Fe^{2+} can react with H_2O_2 to form Fenton, which improves the dewatering performance of sludge. After the two methods of sludge treatment, the EPS of the sludge is destroyed, the humic acid, fulvic acid and other hydrophobic substances in the supernatant are increased, and the sludge dewatering performance is improved. The iron-carbon micro-electrolysis-Fenton combined reaction has better sludge treatment effect than single micro-electrolysis, the water content and SRF value of the sludge cake are reduced more, and the sludge dewatering performance is better.

Author contribution All authors contributed to the concept and design of the research. Data preparation, data collection and analysis were carried out by Ding Shaolan, Zhao Zhen, Tian Qianqian, Li Danqing and Ren Huijun. The first draft of the manuscript was written by Zhen Zhao, and all authors commented on previous versions of the manuscript. The final manuscript read and approved by all authors.

Ding Shaolan: Ideas; formulate or develop overall research goals and objectives

Zhao Zhen, Tian Qianqian, Li Danqing: Provide research materials, reagents, materials, patients, laboratory samples, instruments, computing resources or other analytical tools; methodological development or design; model creation

Zhao Zhen, Ren Huijun: Preparation, creation and/or introduction of published works, especially writing the first draft (including substantive translation)

funds All funds come from Shaanxi University of Science and Technology. The funds are used to purchase laboratory equipment and chemicals.

Availability of data and information The data set used and/or analyzed in the current study can be obtained from the corresponding author upon reasonable request.

Statement

Moral recognition "Not applicable"

Agree to participate "Not applicable"

Agree to publish Participants have agreed to submit the case report to the journal.

Fight for interests The author declares that there is no conflict of interest.

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