

Enhancing the Dewaterability of Oily Cold Rolling Mill Sludge Using Quicklime as a Conditioning Agent

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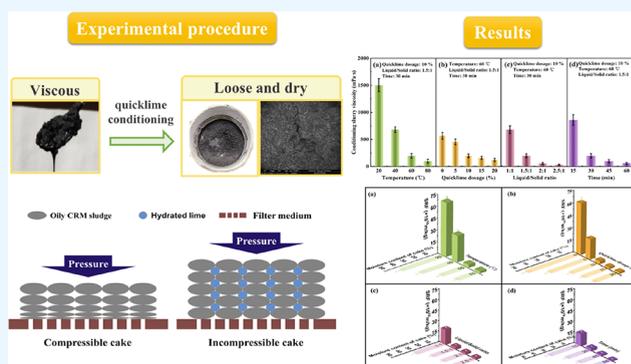
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ABSTRACT: The high moisture and viscosity characteristics of oily cold rolling mill (CRM) sludge led to limitations in its recycling. In this paper, the results of using quicklime as a conditioning agent to improve the dewaterability of the oily CRM sludge cake were reported. Quicklime was selected as the best conditioning agent through conditioning–dewatering experiments because it could effectively reduce the viscosity of oily CRM sludge and improve the dewaterability of the oil sludge filter cake. The optimal conditioning effect was obtained when the quicklime dosage was 10%, the temperature was 60 °C, the liquid/solid ratio was 1.5:1, and the time was 30 min. The reduction of specific resistance to filtration was 95.9%, and the coefficient of compressibility of the filter cake decreased from 1.11 to 0.89. The dewatering rate increased from 9.0 to 52.6%. The oily CRM sludge cake formed an incompressible rigid porous structure because of conditioning with quicklime. In addition, after conditioning with quicklime, the oil content, chemical oxygen demand, and turbidity of the filtrate decreased, and the composition of the dried filter cake met the requirements of ironmaking raw materials. Using quicklime to condition the oily CRM sludge provided a green approach to waste recovery and sustainable management.



1. INTRODUCTION

The oily cold rolling mill (CRM) sludge is a solid waste generated from the cold rolling steel process comprising a dense slurry of iron fines in lubricating oil and water with other impurities including heavy metal.¹ The oil in CRM sludge is derived from lubricants and equipment used in the cold rolling process of steel products.² According to statistics, about 0.9 tons of oily sludge was generated for every 1000 tons of rolling steel in China.³ Because of the content of hazardous organic compounds, oily CRM sludge could cause a negative impact on soil, air, and human health. As the policy of solid waste not leaving the factory was issued, it required iron and steel enterprises to dispose oily sludge by themselves rather than by outsourcing. At the same time, the reuse of iron in oily CRM sludge is also economically necessary to reduce the production costs of the steel industry. By transforming or reusing the oily CRM sludge, metal and mineral resources can be recovered and the impact on the environment can be reduced.⁴ For steel enterprises, recycling waste and reducing raw material consumption is more conducive to reducing costs and improving competitiveness in the industry.⁵

The treatment and disposal of oily CRM sludge to realize resource utilization mainly involve reducing oil content (OC)

and separating water and other wastes from the oily sludge.^{6,7} The high moisture content of oily CRM sludge adversely affects the removal of oil and the reuse of the solid phase. At the same time, it is also the main reason for the large volume of oily CRM sludge.⁸ Oily sludge dewatering is the removal of water to change the sludge from a semisolid state to a damp solid state. This physical change significantly reduces the volume of oily sludge, thus reducing treatment costs.⁹ However, it is obvious that the dewaterability of oily CRM sludge is poor and needs to be significantly improved.

At present, mechanical dewatering is generally used to reduce the moisture content of oily sludge solids under mechanical pressure.^{10,11} However, the cost of oily sludge dewatering could be high when the filtration rate of the oily sludge cake is slow. Nowadays, it is still necessary to effectively improve oily sludge dewatering.¹² In the wastewater treatment

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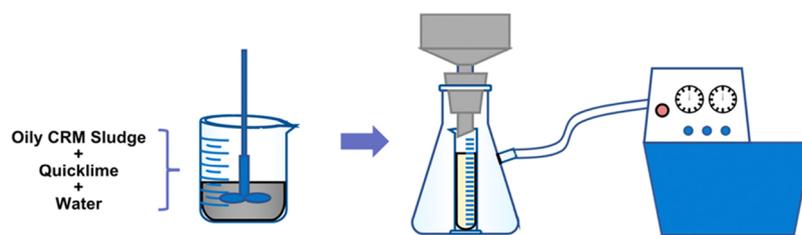


Figure 1. Experimental process of quicklime conditioning–dewatering of oily CRM sludge.

industry, conditioning agents such as lime,¹³ coal,¹⁴ and lignite¹⁵ are commonly used for sewage sludge dewatering. According to the role in building up the structural strength of the sludge solids and in assisting in filtration, the conditioning agents are called skeleton builders or filter aids. In the petrochemical industry, chemical conditioning agents such as polymeric ferric chloride,^{16–18} cationic polyacrylamide,^{19,20} and so on are usually added to improve the dewaterability of oil sludge. However, because of the high compressibility of the sludge, chemical conditioning does not always work as expected.²¹ To reduce the compressibility of sludge at high pressures, physical conditioning agents are generally used to form sludge cakes with better permeability.^{2,22}

Although there have been many studies on the dewatering of municipal sewage sludge^{23,24} and oily sludge in the refining or petrochemical industries,^{25–27} only a few reports have focused on oily sludge in the steel industry.²⁸ The compositions of oil sludge in the iron and steel industries are different from that in the petroleum industry. The iron content in oily sludge from the iron and steel industries is relatively high,³ so it is necessary to study the simultaneous recovery of iron in the process of oily sludge treatment.

In this study, the possibility of using conditioning agents to improve the dewaterability of oily CRM sludge was investigated. The effects of different conditioning agents on the oily CRM sludge dewaterability were compared, and the conditioning process was optimized. The mechanism of a suitable conditioning agent to improve the oily CRM sludge dewaterability was analyzed. In addition, other benefits of the oily CRM sludge conditioning were investigated through the filtrate change of OC, chemical oxygen demand (COD), and turbidity.

2. MATERIALS AND METHODS

2.1. Materials and Characterization. Oily CRM sludge samples were collected from a steel company in Wuhan, Hubei Province. The OC of the raw sludge was determined according to the Soxhlet extraction method for sludge samples in standard methods.²⁵ The water content (WC) determination method of oily CRM sludge refers to GB/T 260-2016. The solid content (DC) in sludge was calculated by the subtraction method. The four components were determined according to ASTM-D2007-02. The four components of the oil phase directly affect the viscosity of the oily sludge, which mainly includes saturated hydrocarbon, aromatic hydrocarbon, colloid, and asphaltene. Chemical compositions of oily CRM sludge were measured through inductively coupled plasma atomic emission spectroscopy (ICP-AES Optima 30, JobinYvon, France). Particle-size distributions and cumulative volume of the oily CRM sludge solid phase were analyzed using a laser particle size analyzer (Malvern Mastersizer, 2000, Malvern Panalytical Co., the UK). The rheological properties of oily

CRM sludge were measured using a rotational rheometer (Haake VT550, Haake, Inc., Germany).

2.2. Experimental Procedure. First of all, 30 g of oily sludge, a certain amount of conditioning agent, and deionized water were added to the beaker. The quicklime dosage range was 0–20% of the weight of the oily CRM sludge. Then, the viscosity of the mixture was detected after stirring at 200 r/min at a certain temperature for a period of time. Mechanical conditioning was applied to the sludge samples at a temperature of 20–80 °C and a stirring time of 15–60 min. Finally, the conditioned oily CRM sludge was put into a \varnothing 80 mm Buchner funnel and filtered under a pressure of 0.06 MPa until the volume of the filtrate did not increase within 30 s. The filtrate volume corresponding to filtration time was recorded to calculate the specific resistance to filtration (SRF) of oily CRM sludge. The experimental process of oily CRM sludge conditioning–dewatering is shown in Figure 1. To determine the moisture content, the oily CRM sludge cake produced by the filtration process was dried at 105 °C to determine the moisture content.

2.3. Analytical Methods. The SRF is one of the important parameters in this experiment, which is the main evaluation index for improving the filterability of oily CRM sludge by quicklime conditioning. SRF of oily sludge refers to the resistance encountered in the unit filtration area when the unit mass of oil sludge is filtered under a certain pressure. Under the condition of constant oily sludge DC, the lower SRF means a better dewatering performance of oily sludge. The SRF can be calculated by eq 1:¹²

$$\text{SRF} = \frac{2PA^2b}{\mu\omega} \quad (1)$$

where r is the SRF of the filter cake (m/kg), P is the pressure applied on the top of the filter cake (Pa), A is the filter area (m²), b is the slope of the $t/V-V$ filter straight line, μ is the viscosity of the filtrate (Pa s), and ω is the fractional solid content per unit volume of filtrate liquid (kg/m³).

Filter cake compressibility measures the ability to compact sludge under pressure. Low compressibility means that the sludge cake is hard to compress and can maintain the cake structure and permeability during filtration. The coefficient of compressibility (S), which is usually used to express sludge compressibility, can be obtained by eq 2:²⁹

$$\frac{\text{SRF}_1}{\text{SRF}_2} = \left(\frac{P_1}{P_2} \right)^S \quad (2)$$

where P_1 and P_2 are two different filtration pressures (Pa) and SRF_1 and SRF_2 are specific resistance to filtration at P_1 and P_2 (m/kg), respectively.

The oily CRM sludge and sludge cake were analyzed by an environmental scanning electron microscope (FEI QUANTA

200, FEI, Eindhoven, The Netherlands). The OC of the oily CRM sludge cake was measured according to the Soxhlet extraction method, and the filtrate OC was measured according to the standard of *Water quality-Determination of petroleum, animal fats, and vegetable oils-Infrared spectrophotometry* (HJ 637-2012). Zeta potential of the filtrate was measured with a potential analyzer (Zetasizer 3000, Malvern Panalytical Co., the UK). The COD of the sludge filtrate was measured according to the standard of *Water quality-Determination of the chemical oxygen demand-Dichromate method* (HJ 828-2017).

3. RESULTS AND DISCUSSION

3.1. Oily CRM Sludge Characteristics. The OC, WC, and DC of oily CRM sludge samples are shown in Table 1.

Table 1. Composition of the Oily CRM Sludge Solid Phase (wt %)

water content	solid content	oil content			
		saturated hydrocarbon	aromatic hydrocarbon	colloid	asphaltene
50.09	14.13	4.35	3.98	17.89	9.56

Both the content of water and oil in oily CRM sludge reached a higher level, which accounts for 50.09 and 35.78 wt %, respectively. This is a result of the lubricants used in the cold rolling process. In addition, the DC in the oily CRM sludge was 14.13 wt %. In the 35.78 wt % oil phase, the contents of colloids and asphaltene are 50.00 and 26.71% respectively, while the contents of saturated hydrocarbon and aromatic hydrocarbon are less, 12.17 and 11.12% respectively. The high presence of colloids and asphaltenes in the oil phase tends to increase the viscosity of the sludge, making it tougher to handle.

Chemical compositions of the oily CRM sludge solid phase are shown in Table 2. Total Fe composition was 62.49% in

Table 2. Composition of the Oily CRM Sludge Solid Phase (wt %)

Fe	Fe ²⁺	Fe ³⁺	Si	Ca	Mg	Al	Cr
62.49	31.44	31.05	0.09	0.14	0.02	0.17	0.95
Cu	Mn	Zn	P	C	H	N	S
0.09	0.20	0.02	0.07	4.87	2.15	0.20	0.53

CRM sludge. The contents of Fe²⁺ and Fe³⁺ were 31.44 and 31.05 wt %, respectively. The contents of Si, Ca, and other inorganic elements were low, but the contents of organic elements such as C and H were relatively high.

Particle size distribution of the oily CRM sludge solid phase is shown in Figure 2. As can be seen, the particle size of oily CRM sludge was distributed in the range of 0.6–104 μm . The D₁₀, D₅₀, and D₉₀ of oily CRM sludge were 1.55, 6.71, and 35.86 μm , respectively. D₁₀, D₅₀, and D₉₀ respectively indicate the corresponding particle size when the cumulative particle size distribution of the sample reaches 10, 50, and 90%.

The flow curves and apparent viscosity as a function of shear rate are shown in Figure 3a. The viscosity of the oily CRM sludge was 9415 mPa·s. High viscosity was also the main reason why sludge was difficult to handle, so it was especially necessary to reduce the viscosity of the oily CRM sludge. As the shear rates increased to 600 s⁻¹, the viscosity of the oily

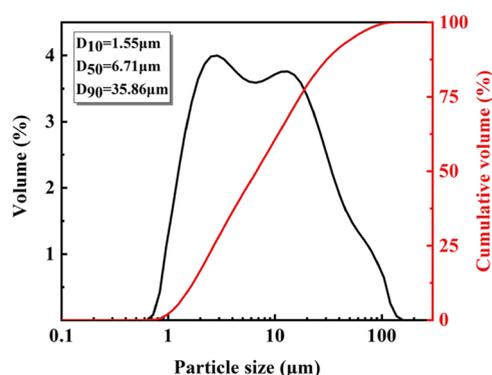


Figure 2. Particle size distribution of the oily CRM sludge solid phase.

CRM sludge gradually decreases to 1099 mPa·s. However, the shear stress increased nonlinearly with the increase of the stirring rate. These indicated that the oily CRM sludge was a non-Newtonian fluid with significant shear-thinning behavior. The effect of temperature on viscosity was presented in Figure 3b. The viscosity of the oily CRM sludge decreased from 166.6 to 659.4 mPa·s when the temperature increased from 20 to 70 °C. This is due to the reduction of intermolecular cohesion by thermal motion, thus reducing the viscosity of oily CRM sludge.³⁰

3.2. Selection of Conditioning Agents for Oily CRM Sludge. Conditioning agents can be commonly divided into two types, minerals and carbon-based materials.³¹ For the consideration that the mineral particles are used as raw materials for steel production without a negative effect on the subsequent recycling process, coal powder, diatomite, and quicklime were selected as sludge conditioning agents. The influence of conditioning agents on the dewaterability of oily CRM sludge was investigated, and results are shown in Figure 4. Because of the high viscosity, fine particle size, and high SRF of oily CRM sludge, it was still not possible to dewater even if the filtration time was extended to 1 h. It still took a long time after being conditioned with coal powder and diatomite, while the filtration was rapid being conditioned with quicklime. The raw sludge cake and sludge conditioned with diatomite cake still contained high moisture after drying to a constant weight at 105 °C. The oily CRM sludge could not be dewatered by drying. The cake, obtained by being conditioned with coal powder, agglomerated to form small particles after drying, while the quicklime conditioned sludge cake was loose powder as well as iron ore. The oily CRM sludge filtrate was a turbid black solution when no conditioning agent was added. The filtrate could not be precipitated and clarified even after being left to stand. After adding coal powder and diatomite, the filtrate changed from black to light yellow but remained turbid. In particular, the filtrate conditioned with quicklime was a transparent light yellow liquid.

When the conditioning agent dosage was 10% of oily CRM sludge, the water dosage/oily CRM sludge (liquid/solid) ratio was 2:1, and the mixture was stirred at 20 and 40 °C for 30 min. The filter cake SRF of three kinds of conditioning agents was calculated to evaluate the effect of conditioning, as shown in Figure 5. The type of conditioning agent had limited influence on the viscosity of conditioning slurry. The effect of temperature on conditioning slurry viscosity was much higher than that of the type of conditioning agent. The SRF of oily CRM sludge without a conditioning agent was 96.57×10^{10} m/kg at 20 °C. The SRF decreased to 75.39×10^{10} m/kg after

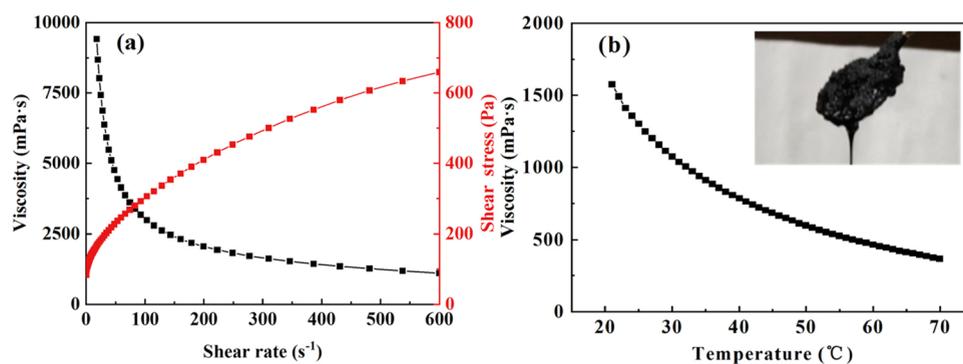


Figure 3. Rheological characteristics of oily CRM sludge.

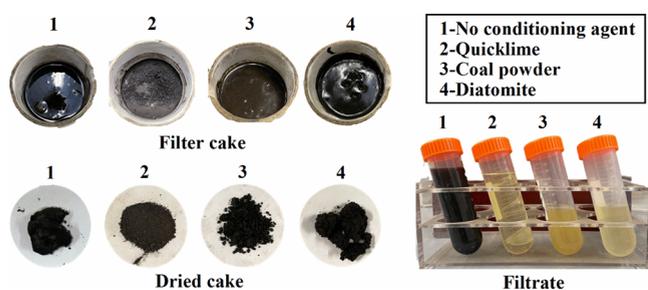


Figure 4. Filter cake and filtrate conditioned with different conditioning agents.

increasing the temperature, which indicated that the temperature would affect the conditioning effect. Compared with quicklime, the conditioning effects of coal powder and diatomic were poor even if the temperature was increased. Quicklime could make the suction filtration of oily CRM sludge smooth. Especially, the SRF of oily CRM sludge can be reduced to 33.76×10^{10} m/kg when conditioned with quicklime at 40 °C. From these results, it was clear that quicklime was the best conditioning agent for oily CRM sludge.

3.3. Effect of Conditioning on Slurry Viscosity of Oily CRM Sludge. The viscosity of conditioning slurry has a significant impact on the dewaterability of oily CRM sludge. The poor fluidity of the conditioning slurry was not conducive to the separation of solids and liquids, which resulted in a high SRF of the filter cake. Therefore, the influence of slurry viscosity on the conditioning condition was studied, and the results are shown in Figure 6. The viscosity decreased gradually with the increase of quicklime dosage. Conditioning slurry

viscosity decreased rapidly with increasing temperature, which is mainly due to the significant effect of temperature on sludge rheology.³⁰ High temperature could reduce the viscosity of the oil phase in oily CRM sludge, thus reducing the viscosity of the slurry. When quicklime dosage exceeded 10%, the viscosity decreased inconspicuously. With the liquid/solid ratio changed from 1:1 to 2.5:1, conditioning slurry viscosity decreased. This trend indicated that a high liquid/solid ratio was beneficial to reduce conditioning slurry viscosity. Adequate stirring time was also an advantage in reducing conditioning slurry viscosity.

3.4. Effect of Conditioning on Oily CRM Sludge Dewaterability. Figure 7 showed the effect of conditioning on the sludge filtration dewaterability. The controlled temperature was a single variable at the optimal dosage of quicklime. As the temperature rose from 20 to 80 °C, the sludge SRF decreased from 68.71×10^{10} to 2.65×10^{10} m/kg, and the moisture of the cake decreased from 40.22 to 19.89%. The reason was that the viscosity of conditioning slurry and the interfacial tension between oil and water would decrease greatly as the temperature increased.³² The improvement in sludge SRF and moisture of the cake was limited when the temperature exceeded 60 °C. Therefore, the optimal temperature was selected at 60 °C to save energy. With the quicklime addition at 60 °C, both the oily CRM sludge SRF and moisture content of the cake decreased. When the quicklime dosage was more than 10%, the sludge SRF and moisture content of the cake decreased inconspicuously. Considering the efficiency and economy of dewatering, the appropriate dosage of quicklime was 10%. The sludge SRF had decreased from 21.53×10^{10} to 2.35×10^{10} m/kg rapidly with the liquid/solid ratio changing from 1:1 to 2.5:1. This suggested that too low a liquid/solid ratio was unfavorable to dehydration. The sludge SRF and cake moisture gradually decreased with time extension from 15 to

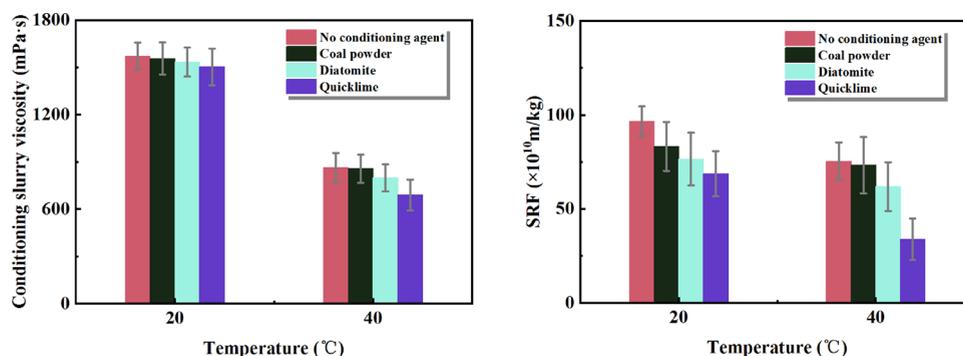


Figure 5. Conditioning effect of different conditioning agents on oily CRM sludge.

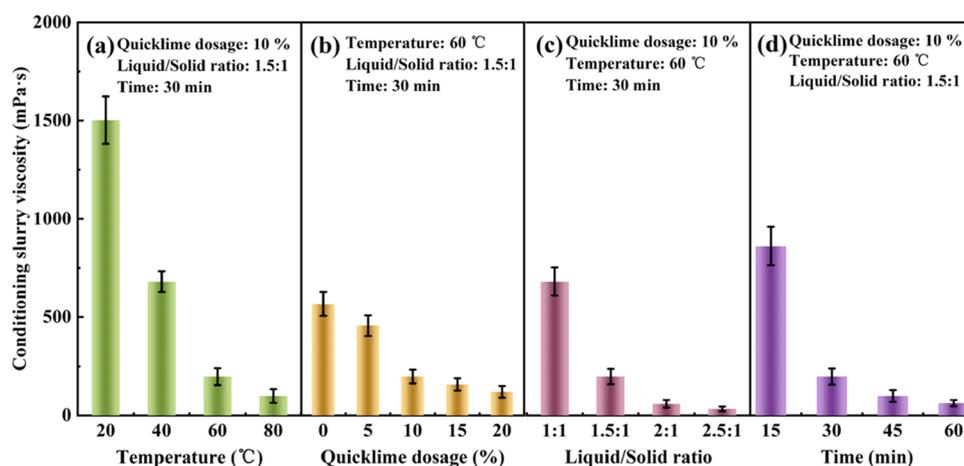


Figure 6. Effect of treatment conditions on conditioning slurry viscosity. (a) Temperature; (b) quicklime dosage; (c) liquid/solid ratio; (d) time.

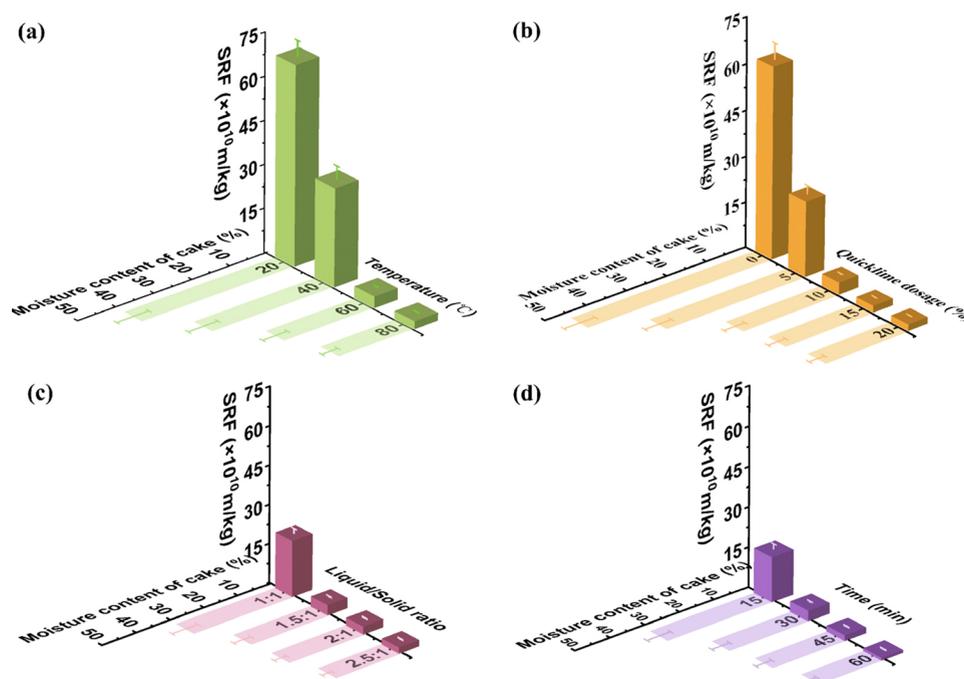


Figure 7. Effect of treatment conditions on filter cake dewaterability of oily CRM sludge (a) temperature; (b) quicklime dosage; (c) liquid/solid ratio; (d) time.

60 min. A popular explanation is that more conditioning agents could penetrate the oil film and adsorb on the solid surface with the extension of time. Therefore, after comprehensive consideration of effectiveness and economy, the optimal conditions were as follows: the quicklime dosage was 10%, the temperature was 60 °C, the liquid/solid ratio was 1.5:1, and the time was 30 min. Under the optimal conditions, sludge SRF was 3.98×10^{10} m/kg, the moisture of the cake was 23.76% and the reductions were 95.9 and 52.6% respectively. After being conditioned with quicklime, the oily CRM sludge was more dispersed, which reduced the sludge SRF and improved the dewaterability of the cake.³³ At the same time, the lower moisture content of dewatered oily CRM sludge would benefit the final disposal.

3.5. Microstructure Changes of the Oily CRM Sludge Cake. For the oily sludge conditioned by conditioning agents, many reports only speculated on the changes of the sludge cake without any visible results. To study the mechanism of

oily CRM sludge conditioned with quicklime, the microstructural changes of oily sludge cake before and after conditioning were investigated by ESEM as shown in Figure 8. The surface and longitudinal section of the oily sludge cake indicated that it was dense and nonporous. After being conditioned with quicklime, the microstructure of the oily sludge cake changed significantly. The surface and longitudinal sections of the oily sludge cake were no longer dense. At the same time, there were obvious cracks on the longitudinal section of the cake. The loose and porous structure made it easy for water to flow through the filter cake.

Compressibility is a critical factor for rapid and effective dewatering of oily CRM sludge, and the sludge dewatering rate could be further improved by reducing compressibility. The coefficient of compressibility of filter cake was shown in Figure 9. Quicklime reacted with water to form hydrated lime, which could improve the compressibility of the filter cake as the skeleton structure. The coefficient of compressibility of the oily

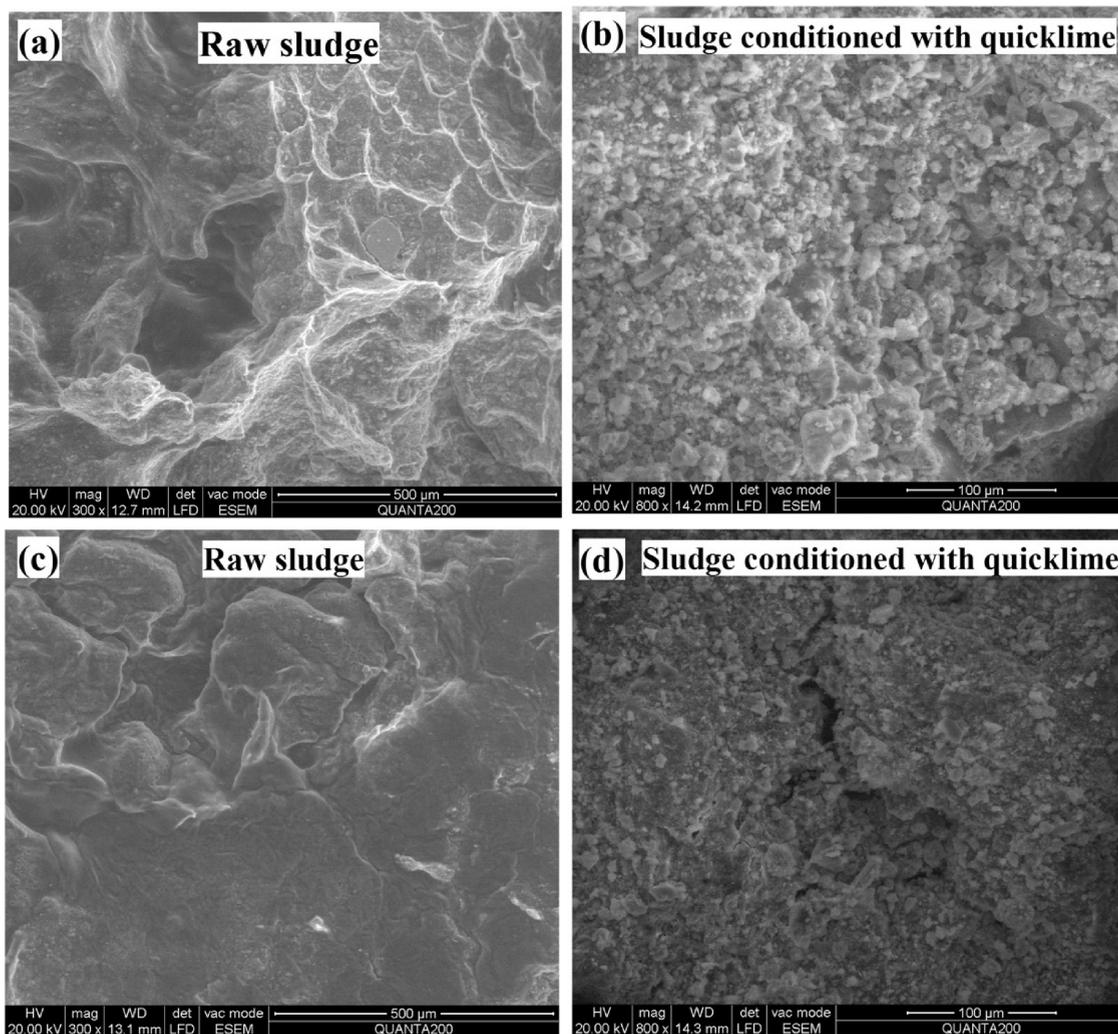


Figure 8. Microstructure of sludge cakes. (a) and (b) Surface of filter cakes; (c) and (d) Longitudinal section of the sludge filter cakes.

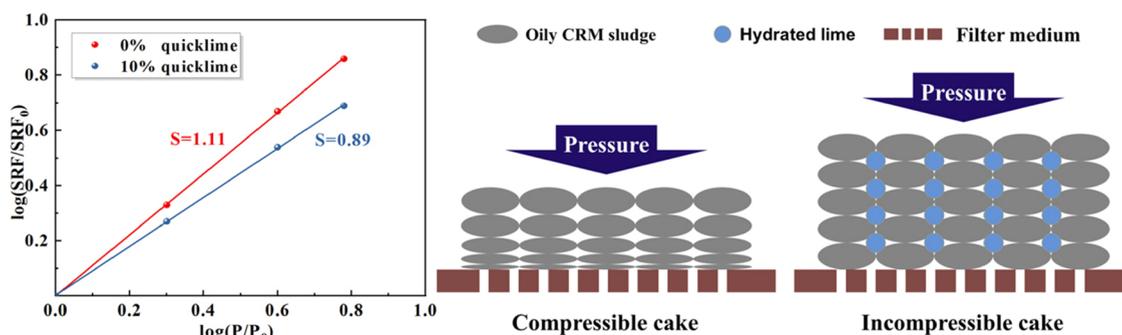


Figure 9. Coefficient of compressibility of the filter cake and structure diagram.

CRM sludge cake was 1.11. After the quicklime was added, the coefficient of compressibility decreased to 0.89. This might be the reason why conditioning agents could significantly improve dewatering capacity by producing more incompressible and permeable sludge cakes.²² For the oily CRM sludge cake, during the filtration, the cake became denser and denser due to the high compressibility of the sludge, which hindered the removal of moisture. This is the reason for the long filtration time and low dewatering rate of oily CRM sludge. However, the water in the sludge could easily pass through the conditioned sludge cake because the cake not only formed a

skeletal structure with some rigidity but also maintained a large number of pores as permeable channels for water passage.

3.6. Zeta Potential of Oily CRM Sludge Conditioned with Quicklime. Zeta potential is an important indicator of the stability of colloidal dispersion, which characterizes the strength of repulsion or attraction between particles. The smaller the absolute value of the zeta potential, that is, the attraction is greater than the repulsion, the more the system tends to condense or aggregate. Therefore, the effect of quicklime on the surface charge of oily CRM sludge was investigated by measuring the zeta potential of the filtrate

obtained from filtering the sludge at different quicklime dosages. The results are shown in Figure 10. The surface oily

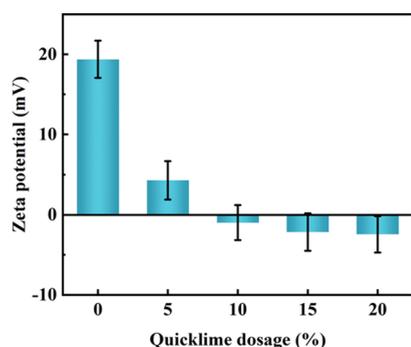


Figure 10. Zeta potential of oily CRM sludge at various quicklime dosages.

CRM sludge particles were positive which was mainly related to the process of its generation. The sludge was produced after the acids washing process in cold rolling mill, thus there were positive charges attached to the particles' surface. The zeta potential of the raw sludge was 19.37 mV, indicating that there was a strong repulsion between particles to keep the system stable and prevented flocculation. The zeta potential of conditioned sludge progressively decreased with increasing quicklime dosage. The addition of quicklime provided negative electrons, which could be adsorbed by oily sludge particles to make the system appear electrically neutral. When the quicklime dosage was 10%, the zeta potential of oily sludge particle was -0.98 mV, which was almost neutral.

3.7. Other Benefits of Oily CRM Sludge Conditioned with Quicklime. Changes in OC and COD of the oily CRM sludge filtrate were investigated to reveal other benefits of sludge conditioned with quicklime, and the consequences were proven in Figure 11. The filtrate OC and COD of raw sludge were 511.6 and 1420 mg/L respectively. With the addition of quicklime, the OC and COD of the filtrate decreased rapidly. The COD was reduced to as low as 397.7 mg/L at 20% of the quicklime dosage. Similarly, when the conditioning temper-

ature increased, the OC and COD of the filtrate also decreased to a certain extent. Under the optimal conditions in section 3.3, the OC and COD of the filtrate are 246.65 and 481.8 mg/L, respectively. It could be seen from the filtrate photos that the filtrate of raw sludge was brown, turbid, and opaque, while the filtrate conditioned with quicklime was a light yellow transparent liquid. Conditioning with quicklime effectively reduced the OC, COD, and turbidity of sludge filtrate, because quicklime also had the function of adsorbent.³⁴ The low OC, COD, and turbidity were conducive to the further treatment of the sludge filtrate, which could significantly reduce the difficulty and cost of subsequent wastewater treatment.

Chemical compositions of dewatering oily CRM sludge obtained under the optimum conditions were detected as shown in Table 3. The iron content of oily CRM sludge was 56.50%, the calcium content was 4.28%, and the organic components' content was 25.04%. Although the iron content was reduced, it could still be reused in the steel production process as a raw material for the sintering plant. Organic components can be effectively removed during the sintering process without affecting the performance of the sintered ore. Using oily CRM sludge as a production raw material not only realized the resource utilization of solid waste but also meets the current policy requirements of solid waste not leaving the factory.

3.8. Discussion of the Technical and Economy of the Quicklime Conditioned Oily CRM Sludge Process. It is well known that the solid phase volume of oily CRM sludge increases after the addition of quicklime, leading to an increase in the subsequent treatment volume and treatment cost. However, some studies have shown that a 20% reduction in sludge WC could reduce the total volume of sludge by 50%.³⁵ Therefore, the total volume reduction of the sludge was more significant compared to the small increase in the solid phase volume of the oily CRM sludge. The quicklime conditioning treatment of oily CRM sludge could reduce the viscosity and SRF of oil sludge, which is conducive to water removal, material dispersion, and granulation. The solid phase of the sludge obtained had a high iron grade and contained a certain amount of calcium hydroxide. The use of iron-containing solid waste as a raw material for sintering could not only achieve

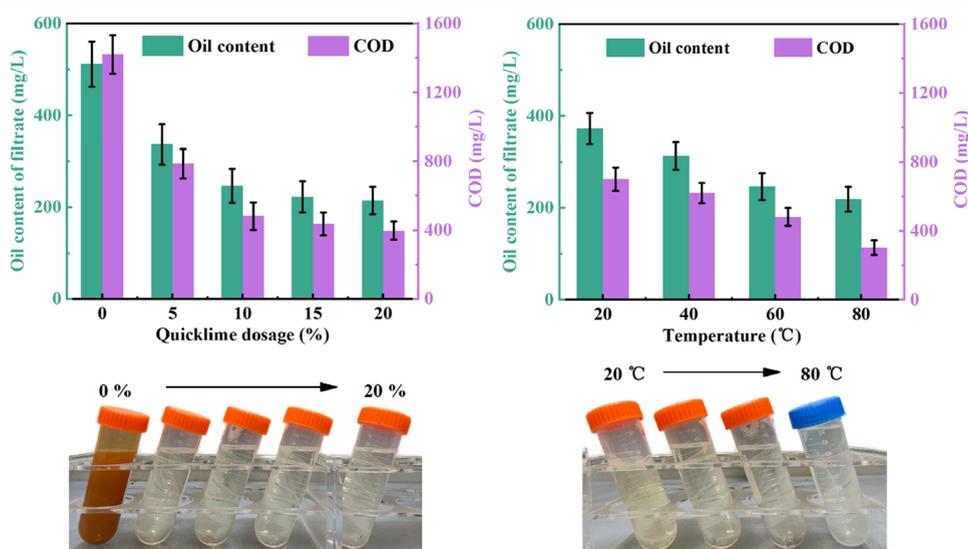


Figure 11. Effect of quicklime dosage and temperature on OC and COD of the sludge filtrate.

Table 3. Chemical Compositions of Dewatering Oily CRM Sludge (wt %)

Fe	Si	Ca	Mg	Al	Cr	Cu	Mn	Zn	P	S	organic components
56.50	0.08	4.28	0.06	0.13	0.05	0.06	0.13	0.01	0.01	0.16	25.04

waste utilization and protect the environment, but also reduce sintering production costs. Therefore, it is generally considered that solid waste with iron content above 50% could be used as a raw material for sintering production. The iron grade of the sludge solid phase has met this requirement. At the same time, it was necessary to add a certain amount of quicklime as flux to improve the strength and reducibility of sintered ore in the sintering process, and calcium hydroxide in the solid phase of the sludge could be used as flux for sintering production after conditioning and dewatering. Thus the efficiency of quicklime utilization increased while the cost decreased. Therefore, quicklime conditioning and dewatering treatment could realize the resource utilization of oily CRM sludge.

4. CONCLUSIONS

The results of the experiment indicated that quicklime as a conditioning agent could effectively reduce the viscosity of oily CRM sludge and improve the dewaterability of the oil sludge filter cake. The optimal conditioning effect was obtained when the quicklime dosage was 10%, the temperature was 60 °C, the liquid/solid ratio was 1.5:1, and the time was 30 min. The reduction of oily CRM sludge SRF and moisture was 95.9%, and the dewatering rate increased from 9.0 to 52.6%. The coefficient of compressibility of the oily CRM sludge filter cake decreased from 1.11 to 0.89, and the zeta potential decreased from 19.37 to -0.98 mV. The oily CRM sludge cake formed an incompressible rigid porous structure due to conditioning with quicklime which not only increased filter cake incompressibility but also neutralized the charge of the sludge particles resulting in increased agglomeration of the oily sludge. In addition, after conditioning with quicklime, the OC, COD, and turbidity of the filtrate decreased and the composition of the dried filter cake met the requirements of ironmaking raw materials and reduced the amount of flux in the sintering process. Therefore, quicklime conditioning and dewatering treatment of oily CRM sludge could realize its harmless disposal and resource utilization.

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Notes

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ABBREVIATIONS

Oily CRM Sludge oily cold rolling mill sludge
SRF specific resistance to filtration
COD chemical oxygen demand

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