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SYNTHESIS AND APPLICATION OF AN EFFICIENT DEGREASING AGENT FOR OILY DRILLING CUTTINGS

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Abstract

Oil-based drilling fluids are widely used in oil and gas exploration and development. Large amounts of oily drilling cuttings are produced in the drilling process, and improper treatment can cause serious secondary pollution. Chemical cleaning is commonly used to treat oily drilling cuttings. However, most degreasing agents are not environmentally friendly and can cause secondary pollution. Thus, the processing requirements of oily cuttings are difficult to meet. In this study, an environmentally friendly degreasing agent CYJ-1 that is biodegradable and can efficiently treat oily drilling cuttings was designed and prepared using optimized treatment agents and conditions, achieving an oil removal rate of 93.02%. In addition, a harmless degreasing formula utilizing this environmentally friendly degreasing agent was developed and had a remarkable oil removal effect on oily drilling cuttings. Transition state theory was applied to explain the degreasing effect of oily drilling cuttings for the first time, and the mechanism of action of the degreasing agent was analyzed in conjunction with the interfacial tension and potential energy. The formula was applied at two wells in the Xinjiang oilfield in China. It could achieve a high oil removal rate, which efficiently solved the pollution and resource recovery problems associated with oily drilling cuttings.

Keywords: degreasing agent, degreasing mechanism, efficient, field application, oily drilling cuttings

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1. Introduction

With the industrial development of shale gas wells and the strategic development of shale gas in recent years, complex wells such as high-temperature deep wells, ultra-deep wells, high-angle wells, and horizontal wells have gradually increased, and oil-based drilling fluids have been used in a wide range of applications due to their excellent performance (He et al., 2012). In the oil and gas drilling process, a large amount of oily drilling cuttings will be produced (Leonard and Stegemann, 2010). If it cannot be effectively treated, it will cause serious environmental protection problems. The oily drilling cuttings will pollute the soil (including arable land) and water, and the heavy metals contained it will cause serious damage to animals, plants and even humans (Shan et al., 2013). Specifically, the impact of oily drilling cuttings on the environment is mainly manifested in: (1) Polluting surface water, destroying drinking water sources, affecting and damaging the normal growth of fish and other aquatic organisms in surface water, and may be ultimately affecting and endangering human health by the food chain; (2) Reducing permeability and wettability of soil, causing soil compaction, affecting plant growth, making plant roots difficult to absorb water, inhibiting seeds germination, and some plants can absorb heavy metal ions and possibly transmitted them to humans by food chain; (3) Some petroleum substances are volatile, and may make the

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total hydrocarbon concentration in the air to exceed the standard values. Among them, benzene series, polycyclic aromatic hydrocarbons, etc. are recognized as teratogenic, carcinogenic and mutagenic substances, and they are extremely harmful to humans (Li et al., 2016).

With the increasing stringent global laws and regulations and increasing emphasis on environmental protection (Li et al., 2013), research on waste of oil-based drilling fluid has gradually become an important research subject. Oily drilling cuttings are mainly derived from the use of oil-based drilling fluids and contain a large amount of mineral oil, heavy metals and other organic substances (Wang et al., 2017). It is a common drilling waste with a large amount of output and great harm, but it also contains a large amount of available resources which can achieve environmental protection and waste resource utilization after effective treatment (Taghiyev et al., 2015).

The existing research on oily solid waste degreasing technology mainly focuses on drilling cuttings reinjection method (Gumarov et al., 2014), pyrolysis method (Wang et al., 2017), drilling cuttings cleaning method (Saphanuchart et al., 2012), centrifugation method (Ball et al., 2012), biological method (Kogbara et al., 2016), ultrasonic method (Pereira et al., 2013), water jet method (Mkpaoro et al., 2015) and the method of recycling the material for agricultural productivity (Kogbara et al., 2017). The process of the drilling cuttings reinjection method includes the collection, treatment and pumping of cuttings (Xia et al., 2014). The drilling cuttings reinjection method can achieve zero discharge of oily waste. It is a good method for handling oily waste in offshore drilling environment, remote areas and environmentally restricted areas. But this method is costly and is subject to formation conditions. The pyrolysis method uses heating method to desorb water, oil and solid waste, and then recovers the oil and collects the solid waste (Almeida and Medeiros, 2017). Pyrolysis is a good method for centralized treatment and commercial treatment of oily drilling cuttings. Oil treatment is thorough and recyclable. There have been cases of using pyrolysis to treat large quantities of oily drilling cuttings. However, there are also shortcomings such as small-scale treatment that is uneconomical, exhaust gas, dust and noise are generated during processing, which may cause secondary pollution (Sun et al., 2016). Drilling cuttings cleaning method include alkaline washing, surfactant washing, microemulsion cleaning, and extraction techniques. The main principle is to reduce the interfacial tension of the system, emulsify the oil in the drilling cuttings, change the wettability of the cuttings surface and similar compatibility principle (Wei et al., 2013). At present, the drilling cuttings cleaning method is considered to be a better method for treating oily solid waste (Khanpour et al., 2014), but its degreasing agent is highly targeted, and showing weak broad-spectrum activity. So it is difficult to meet the processing requirements of oily drilling cuttings (Deng et al., 2013). The principle of centrifugation method is simple. Because centrifugal equipment can produce very high angular velocity, the centrifugal force is much larger than gravity. Therefore, substances with different densities have different sedimentation speeds due to different centrifugal forces, so that substances with different specific gravity can be separated (Larsson and Purser, 2011). Biological method has the advantages of low cost, thorough treatment, environmental friendliness, and no secondary pollution (Alavi et al., 2014). Pretreatment methods such as oxidation or washing are considered to improve the biodegradability of oily drilling cuttings and shorten the degradation cycle (He et al., 2016). At present, petroleum-based degrading bacteria and related technologies have been studied with a degradation rate of more than 70% within 24 hours. The advantage of the ultrasonic method is that it can produce a higher reaction temperature and a stronger impact force in the shortest time (Wang, 2015). As the temperature increases, the viscosity between the petroleum substances decreases. And three phases of oil, water and slag produce displacement, it promotes the separation of petroleum substances from rock particles and the removal of experimental oils. The water jet method has also been developed as a new processing technology (Dhir et al., 2010), but the water consumption is higher during the process. The method of recycling the material for agricultural productivity is also applied. Stabilisation/solidification (S/S), which involves fixation and immobilisation of contaminants using cementitious materials, is one method of treating drill cuttings before final fate. This work considers the reuse of stabilised/solidified drill cuttings for forage production in acidic soils (Kogbara et al., 2017). The formula can turn the waste water-based drilling fluids into an environment friendly soil. The treated waste drilling fluids are favorable to the growth of the plants. The treatment process is easy to handle, low-cost and promote a new and sustainable way for landscaping (Zha et al., 2018).

Therefore, in view of the pollution characteristics of oily drilling cuttings (Okparanma et al., 2018), the influence of the molecular structure of degreasing agent on the degreasing performance is studied. The molecular structure design theory is adopted to develop a highly efficient oily drilling degreasing agent, and a harmless degreasing formula for oily cuttings utilizing CYJ-1 by chemical cleaning method is developed, which can promote the efficient recovery of oil in oily drilling cuttings, and also meet the needs of on-site environmental protection with great significance.

2. Material and methods

2.1. Material

The experimental materials are Tetrapropylene (analytical purity - as raw material for synthetic degreaser); propylene oxide (analytical purity - as raw material for synthetic degreaser); concentrated sulfuric acid (analytical purity - as raw material for synthetic degreaser); sodium hydroxide (analytical purity - as raw material for synthetic degreaser); Span-80 (Sorbitan monooleate) (analytical purity- one part of the harmless degreasing formula); OP-10 (alkylphenol polyoxyethylene ether 10) (analytical purity - one part of the harmless degreasing formula); octanol (analytical purity - one part of the harmless degreasing formula); EDTA–2Na (analytical purity - one part of the harmless degreasing formula); KOH (analytical purity - one part of the harmless degreasing formula), and oily drilling cuttings (sampling from the well in Xinjiang, for testing degreasing effects).

2.2. Instruments

The experimental instruments are Fourier transform infrared spectroscopy (to characterize product structure); ESI-MS High resolution mass spectrometer (to characterize product structure); Infrared oil measuring instrument (OIL480) (for evaluation of degreasing performance); BOD_5 measuring instrument (BSB/BOD 7400) (performance evaluation of degreasing formula), and COD rapid detector (TR-108) (performance evaluation of degreasing formula).

2.3. Design of the efficient degreasing agent

The attributes of the degreasing agent include emulsification, permeability, and wettability. This experiment focused on emulsification and wettability. First, the hydrophilic group was designed. Nonionic surfactants do not easily adsorb onto the solid surface in aqueous solution; thus, an anionic surfactant was selected to improve wettability. Secondly, the hydrophobic group was designed. In general, if the type and molecular size of the surfactant are the same, micelles cannot easily form when a surfactant has a branched chain structure. However, the surface tension can be reduced to a level lower than that of the surfactant with a linear structure. The longer the hydrophobic group is, the higher the surface activity is, and the greater the number of carbon atoms that the surfactant contains, the stronger the emulsifying ability and the smaller the solubility in water phase that the surfactant has. Third, because of the good wetting, emulsification, dispersion, and purification performance of an alkyl sulfate surfactant, $-OSO_3^-$ was selected as the hydrophilic group. Propylene tetramers were selected as the hydrophobic groups to improve emulsification and wetting. However, alkyl sulfates have two drawbacks: they are easily hydrolyzed by acid and have low solubility at room temperature, especially when the number of carbon atoms exceeds 14 (such as C_{16} and C_{18} alkyl sulfates). The first drawback can be solved by using a weakly acidic, neutral or alkaline medium. Alcohol from hydrolyzed surfactants can improve the surface activity under weakly acidic conditions. The second drawback can be solved by using compounds obtained from polyoxyethylene alkyl sulfate or oxyethylation, the latter of which exhibit better emulsifying ability, wetting ability, and solubility. The water solubility and surface activity of this surfactant are higher than those of other surfactants with the same carbon atom number. This surfactant demonstrates good calcium soap-dispersing ability, and salt resistance.

The molecular structure of the degreasing agent CYJ-1 is shown in Fig. 1.

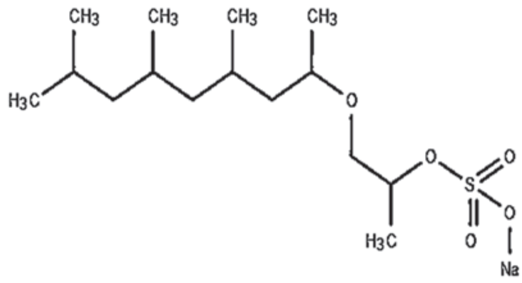


Fig. 1. Molecular formula of the degreasing agent

2.4. Synthetic route to the efficient degreasing agent

(1) A three-necked round bottom flask containing tetrapropylene was placed in a 0°C water bath. Concentrated sulfuric acid was added dropwise with stirring by electric mixer to make the esterification reaction occur.

(2) After stirring for 2 h the mixture was transferred to a pressure-equalized addition funnel and added dropwise at 10°C with stirring over 2 h to a three-necked flask containing 50% sodium hydroxide (aq). 4, 6, 8-trimethyl-2-nonanol was obtained as colorless transparent liquid.

(3) A three-necked round bottom flask containing 4, 6, 8-trimethyl-2-nonanol, propylene oxide and sodium hydroxide was placed in an electric heating jacket. The mixture was heated to 140°C, initially at reflux. Later reflux ceased. The alcohol ether product was obtained as a light yellow transparent viscous liquid.

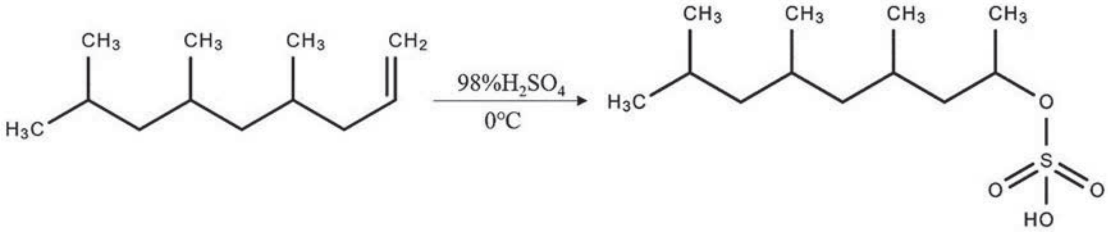
(4) A three-necked round bottom flask containing the alcohol ether was placed in a 50°C water bath. Sulfuric acid was added dropwise with stirring.

(5) After stirring for 3 h the mixture was transferred to a pressure-equalized addition funnel and added dropwise at 50°C with stirring over 1 h to a three-necked flask containing ethanol solution of 50% sodium hydroxide. After crystallization, the degreasing agent was obtained as a white powder.

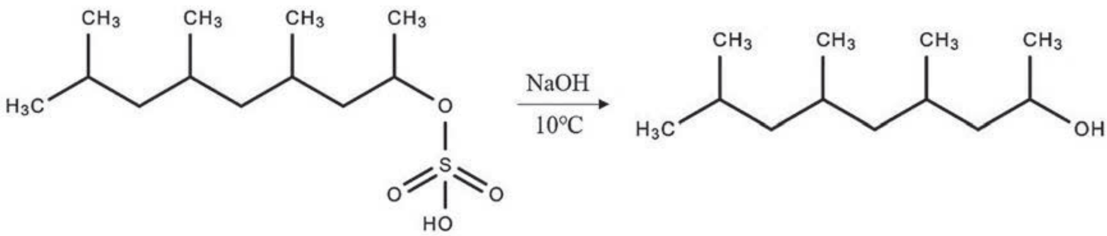
The principle reaction is illustrated in Eqs. (1-5).

2.5. Design of the harmless degreasing formula

A biodegradable and efficient degreasing agent is needed to remove oil in oily drilling cuttings. The following design requirements for this agent consider the difficulties in oil removal from oily drilling cuttings.



(1)



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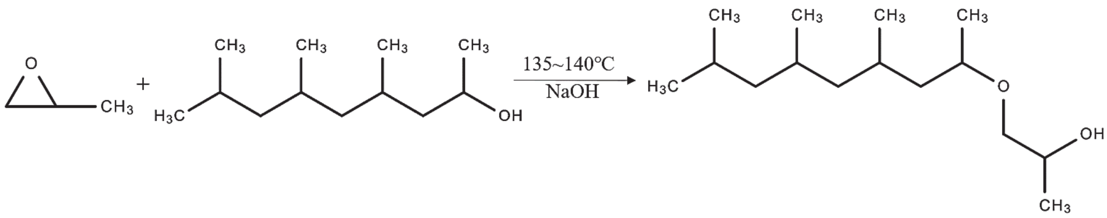

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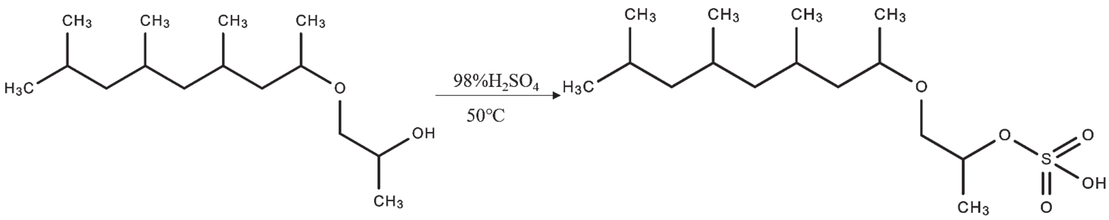

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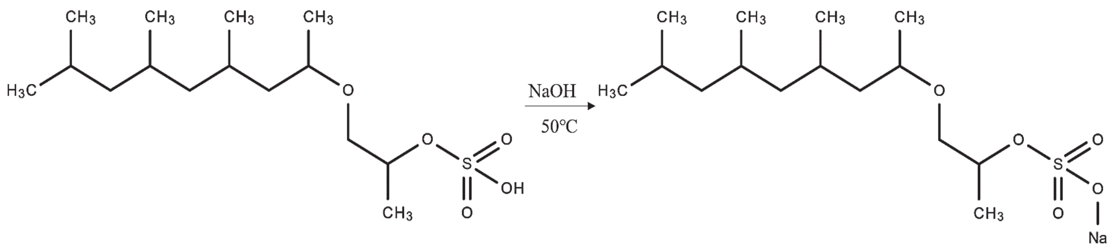


(5)

The degreasing agent should function similar to an emulsifying agent and possess a structure similar to that of soap salt.

Since emulsification is the formation of small droplets of oil in water, the metal ions should be monovalent metal ions.

The degreasing agent should function similar to a penetrating agent with a polyoxyethylene chain polyether structure and should exhibit strong adsorption at the oil–water interface to promote oil emulsion and stripping. The degreasing agent should exert a reverse wetting effect and contain an anionic surfactant. As a reverse wetting agent, the degreasing agent removes oil from the surface of the solid as much as possible via reversible adsorption substitution.

However, a single surfactant cannot meet all the oil removal requirements because of the multiple and complex interfacial phenomena that occur during the oil removal from oily drilling cuttings through surfactant cleaning. Therefore, the degreasing agent was designed and synthesized, and a few auxiliary surfactants were added to prepare the harmless degreasing formula that meets the aforementioned requirements.

2.6. Preparation of the harmless degreasing formula

A preliminary experiment in the laboratory was conducted to evaluate the treatment agents containing CYJ-1. Compared with the oil removal agent in the market, the use concentration of CYJ-1 is lower, the oil removal rate is higher and the cost is lower. Moreover, because the oil droplets from the surface of the debris in the degreasing solution are difficult to remove, an emulsifier must be added; to avoid the secondary attachment of oil droplets on the cuttings, a wetting agent should be added to the oily cuttings. The initial determination of the oil removal formula for oily drilling cuttings resulted in the following: degreasing agent CYJ-1 + wetting agent + emulsifier.

(1) A round-bottom flask containing water (50 mL) was placed in a 60°C water bath. EDTA–2Na (2.0 g) was slowly added and dissolved in the water. The degreasing agent CYJ-1 (3.4g) was added with stirring. OP-10 (2.5 g) was added slowly with mixing. A small amount of octanol was added if foam was present.

(2) Another round-bottom flask containing water (50 mL) was placed in a 60°C water bath. Span-80 (3.5 g) was added with stirring.

(3) The first mixture was slowly added to the second round-bottom flask, and the resulting mixture was stirred for 0.5 h.

(4) After the aqueous solution became transparent, a suitable amount of KOH was added to shift the pH to 7 and stirring was continued for 5 min. The efficient degreasing agent was obtained as colorless transparent viscous liquid.

2.7. Performance evaluation of the harmless degreasing formula

The oil removal performance of the degreasing agent was evaluated in three stages: the initial determination of the oil content of the oily drilling cuttings, the actual oil removal from the oily drilling cuttings, and the final determination of the oil present in the oily drilling cuttings. Experimental conditions: degreasing temperature: 30°C, centrifugal speed: 4000 r/min, centrifugal time: 10 min.

The moisture content of the oily drilling cuttings was measured in accordance with GB/T 260-77 oil product moisture measurements. The solid content of the oily drilling cuttings was measured by drying the oily drilling cuttings to constant weight. Then, the oil content was calculated. The final oil content of the oily drilling cuttings was measured through infrared spectrophotometry in accordance with HJ 637-2012 (Infrared spectrophotometric method for the determination of water quality oil and animal and vegetable oils).

Biodegradability refers to the degradation ability of materials under natural conditions. The equation of international BC value (%) (i.e., the five-day biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD)) is shown below (Eq. 6) (Cossu et al., 2017; Lalwani and Devadasan, 2013).

$$BC\ value(\%) = BOD_5 / COD \tag{6}$$

The BC value determines material biodegradability and is classified as Table 1.

Table 1. The level distribution of degradability

BC value (%)	*Degradability*
≥25	easy degradation
15~25	biodegradable
5~15	difficult degradation
< 5	refractory

The COD determination method was in accordance with GB 11914-89 "Water quality determination of the COD using the dichromate method." In addition, the BOD_5 determination method was in accordance with HJ 505-2009 "Water quality determination of the five-day biochemical oxygen demand (BOD_5) using the dilution and inoculation method". The BOD_5 and COD values of the aqueous solution of the degreasing agent at 1000 mg/L were obtained by using a BOD_5 measuring instrument (BSB/BOD 7400,) with constant cultivate temperature of 20°C and a COD rapid detector (TR-108), respectively.

3. Results and discussion

3.1. Structural characterization of the efficient degreasing agent

(1) Infrared spectral analysis

The molecular structure of the efficient degreasing agent CYJ-1 was characterized using Fourier transform infrared spectroscopy. As shown in Fig. 2, the functional groups that can be found in the infrared spectrum are: C-O, -OH, $-SO_4^{2-}$, $-CH_2$, $-CH_3$, -CH, which may have ethers, alcohols, and sulfates. It was found to match the infrared absorption peak of the functional group of tetrapropyl propyl ether sulfate, indicating that the sample may contain a large amount of sodium tetrapropyl propyl ether sulfate. The functional groups corresponding to the molecular structure of the efficient degreasing agent CYJ-1 indicate that the designed degreasing agent was successfully synthesized.

(2) Mass spectrometry

The molecular structure of the efficient degreasing agent CYJ-1 was characterized using ESI-MS, and the results are shown in Fig. 3. As seen from the figure, the highest molecular weight of the fragment in the sample has a molar molecular mass of 245.1, which coincides with the tetra-propyl propyl ether fragment. The fragment having a molar molecular mass of 345.2 is consistent with tetrapropyl propyl sulphate. It is indicated that the sample may contain a large amount of sodium tetrapropyl propyl acrylate. Thus, the synthesis of the designed degreasing agent was successful.

3.2. Performance evaluation of the harmless degreasing formula

The experimental results are shown in Table 2. After using an aqueous solution of the degreasing agent at 1000 mg/L to treat the oily drilling cuttings under optimal processing conditions, the oil removal rate from the oily drilling cuttings was 93.02%.

The degreasing agent showed good oil removal ability. The oil removal rates from the oily drilling cuttings exceeded 90%, which is consistent with the design.

The results are shown in Table 3. The COD and BOD_5 values of the aqueous degreasing agent solution (1000 mg/L) were 1157 mg/L and 208 mg/L, respectively. The BC ratio was 17.91%, which indicates that the degreasing agent is efficient, consistent with the design.

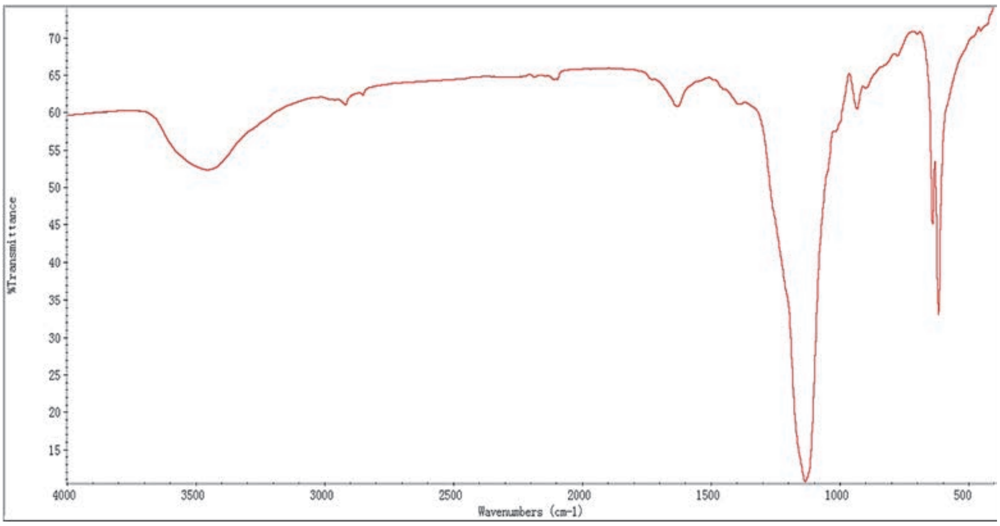


Fig. 2. Infrared spectrum of degreasing agent CYJ-1

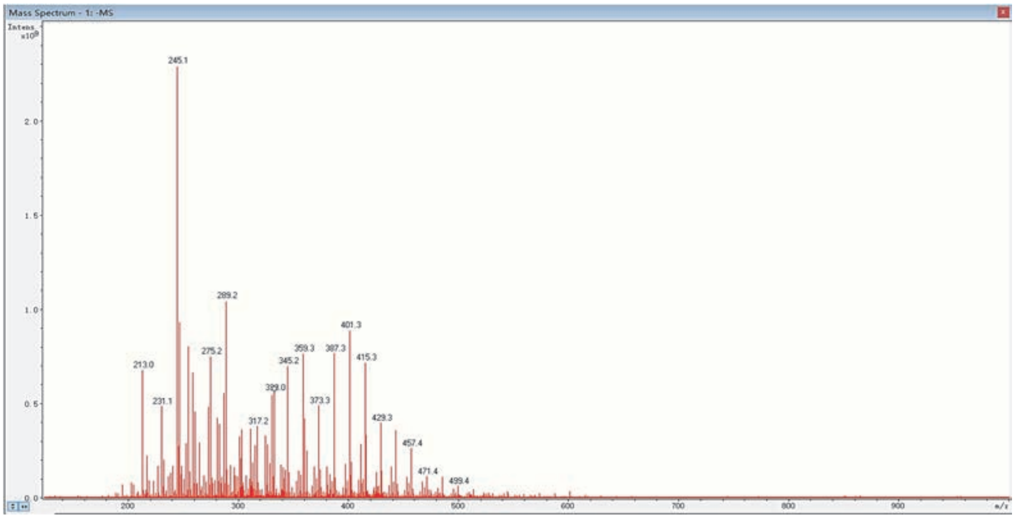


Fig. 3. Mass spectrum of degreasing agent CYJ-1

Table 2. Performance evaluation of the oil removal by the efficient biodegradable degreasing agent

Item	*Concentration (mg/L)*	*Oil content before oil removal (mg/kg)*	*Oil content after oil removal (mg/kg)*	*Oil removal rate (%)*
Oily drilling cuttings	1000	144 000	10 050	93.02

Table 3. Biodegradation experimental results for the aqueous degreasing agent solution

Item	*Concentration (mg/L)*	*COD (mg/L)*	*BOD_5 (mg/L)*	*BC ratio (%)*	*Biodegradability*
1	1000	1125	210	18.65	Biodegradable
2	1000	1106	197	17.78	Biodegradable
3	1000	1247	216	17.32	Biodegradable
Average value	1000	1157	208	17.91	Biodegradable

3.3. Study of the mechanism of oil removal for oily drilling cuttings

The mechanism of oil removal was investigated to describe and explain the feasibility of oil removal on a mesoscopic scale based on transition state theory. In chemistry, transition state theory is used to explain the reaction rate of elementary chemical reactions. During the conversion of the reactants to the product, the reaction must pass through a transition state with a higher energy level. The potential energy of the transition state is the potential energy barrier that the reaction product must pass through. The lower the potential energy barrier is, the faster the chemical reaction rate. The function and mechanism of the degreasing agent in degreasing the oily drilling cuttings were also determined.

Using the transition state theory to analyze the process of oil removal. The initial state of the oil droplet is analogized to the reactant in the transition state theory. The transition state of the oil is similar to the activated complex in the transition state theory. The final state of the oil is similar to the product of transition state theory. The structure diagram of the three states is shown in Fig. 4, where the small circles are oils and the black circles are research objects-small oil droplets. The black block in Fig. 4 (a) is the surface of the cuttings. And the horizontal dotted line indicates water phase. Take a small amount of small oil droplets for analysis, and the results are as follows:

(a) In the initial state, the oil droplets are attached to the surface of the oily solid waste. The surrounding environment is other oil droplets, and the interaction between them is the intermolecular force between non-polar oils.

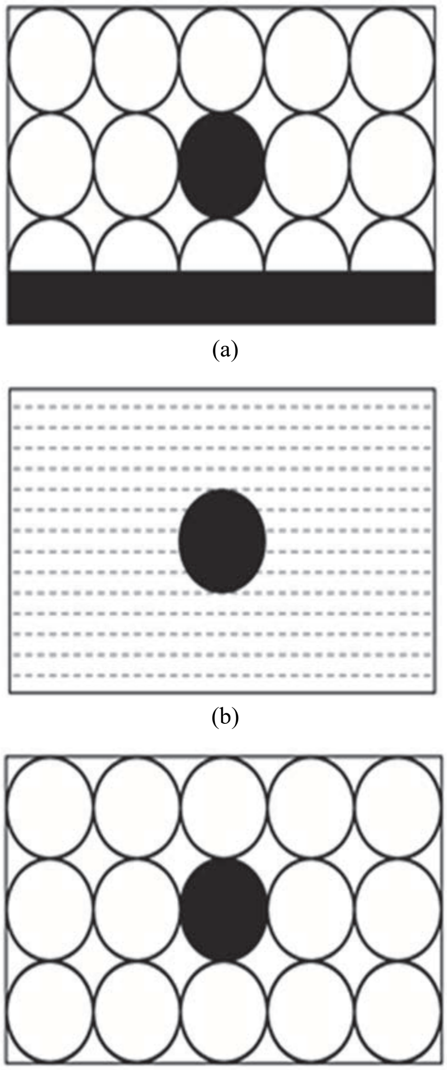
(b) In the transient state, oil droplets exist in water, and the surrounding environment is water. The force between the oil droplets and the surrounding environment is the oil-water interfacial tension. Because the oil-water interfacial tension is higher, the oil droplet potential energy is higher at this time, which is the saddle point of oil removal process.

(c) In the final state, the entire system is separated into three phases. The oil droplets exist in the oil phase, and the surrounding environment is other oil droplets, which is similar to the state before treatment.

The internal state of the oil droplets is basically the same in all three states. Thus, the potential energy level of the oil droplets is mainly caused by different interface statuses.

The potential energy of the oil droplets under the three states was analyzed, and the potential energy surface of the oil removal process without degreasing agent was obtained. The potential energy of the (a) and (c) states is zero; therefore, the potential energy of the (b) state is the surface free energy of oil and water.

At room temperature, the water–diesel oil interfacial tension is 30 mN/m, the surface area of a small droplet is A (m^2), and the potential energy of the (b) (W_b') state is given by Eq. (7).



(a)

(b)

(c)

Fig. 4. Change in the oil droplet environment during oil removal from oily drilling cuttings: (a) Oil droplet before treatment; (b) Oil droplet during treatment; (c) Oil droplet after treatment

$$W_b = 30\,(mN/m) \times A\,(m^2) = 0.03A\,(J) \qquad (7)$$

Therefore, the chemical potential of oil droplets is optimally reduced by adding the surfactant. The surfactant possesses hydrophilic and lipophilic properties; thus, it can adsorb on the water–oil interface, which greatly reduces the water–oil interfacial tension in the transition state and the potential energy barrier of the transition state when degreasing oily drilling cuttings. This phenomenon allows oil degreasing.

According to the test and analysis in the laboratory, the water–oil interfacial tension was 2.3 mN·m^{-1}, and the surface area of the small droplets was A (m^2) after adding 1000 mg/L degreasing agent at room temperature. Then, the potential energy of the (b) (W_b') state is given by Eq. (8):

$$W_b' = 2.3\,(mN/m) \times A\,(m^2) = 0.0023A\,(J) \qquad (8)$$

The change in potential energy of the oil drops before and after adding the degreasing agent was studied. The comparison chart is shown in Fig. 5.

After adding the degreasing agent, the potential energy of the (b) state oil drops is reduced by 92.3% from 0.03A (J) to 0.0023A (J), significantly reducing the potential energy barrier in oily drilling cutting removal. Oil droplets easily cross the potential energy barrier for successful degreasing of oily drilling cuttings.

3.4. Application of the efficient degreasing agent

A harmless degreasing formula for oily drilling cuttings was developed. This formula includes oil removal from oil drilling cuttings by surfactant cleaning and the treatment of oily wastewater and waste residue. A flow chart of the process is shown in Fig. 6. The formula was applied at two wells in Xinjiang during July of 2013. The related test results are depicted in Tables 4-6. After treatment, the oil from the oily drilling cuttings at the well site was recycled and reused, and the wastewater and waste residues were properly dealt with. The original ecological landscape was restored at the well site, and the oil removal rate from the oily drilling cuttings exceed 90%. The main indexes of the leach liquor of oily wastewater and waste residue after curing met the integrated wastewater discharge standard GB 8978-1996 secondary standards. The proposed method in this study enables harmless treatment and resource recovery from oily drilling cuttings.

Table 4. Field application results for oil removal from oily drilling cuttings at two wells in Xinjiang

Item	*Oil content before processing (mg/kg)*	*Oil content after processing (mg/kg)*	*Oil removal rate (%)*
Oily cuttings from the well 1	143 000	12 441	91.3
Oily cuttings from the well 2	122 000	12 088	90.1

Table 5. Wastewater test results for oil removal from oily drilling cuttings at two wells in Xinjiang

Item	*Main indicators of wastewater after treatment*		
	COD (mg/L)	*Oil (mg/L)*	*Suspended solids in water (mg/L)*
Wastewater from the well 1	93	6.4	10
Wastewater from the well 2	47	4.2	12
GB8978-1996	150	10	200

Table 6. Liquid slag leaching test results for oil removal from oily drilling cuttings at two wells in Xinjiang

Item	*Leaching residues after curing, liquid detection index*							
	pH	*COD (mg/L)*	*Oil (mg/L)*	*As (mg/L)*	*Hg (mg/L)*	*Cr (mg/L)*	*Pb (mg/L)*	*Cd (mg/L)*
Leach liquor from the well 1	6	37	4.3	-	-	0.13	0.12	-
Leach liquor from the well 2	6	24	3.7	-	-	0.07	0.18	-
GB8978-1996	6~9	100	10	0.5	0.05	0.5	1.0	0.1

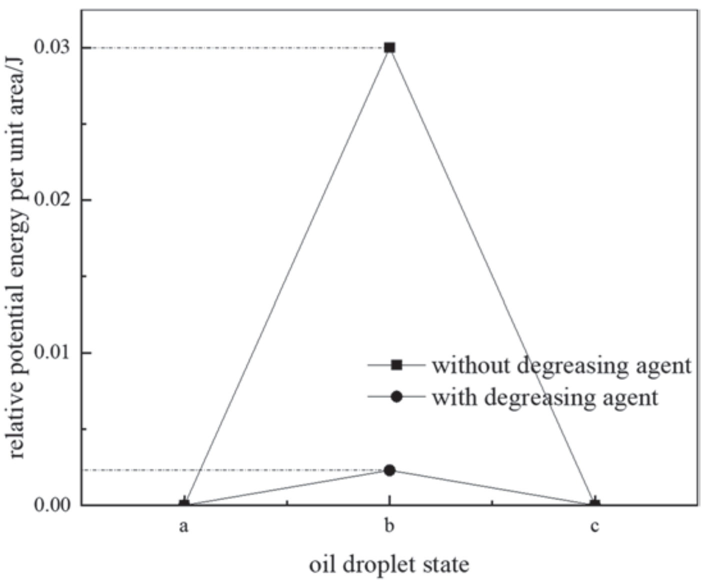


Fig. 5. Potential energy variation of oil drops with or without degreasing agent

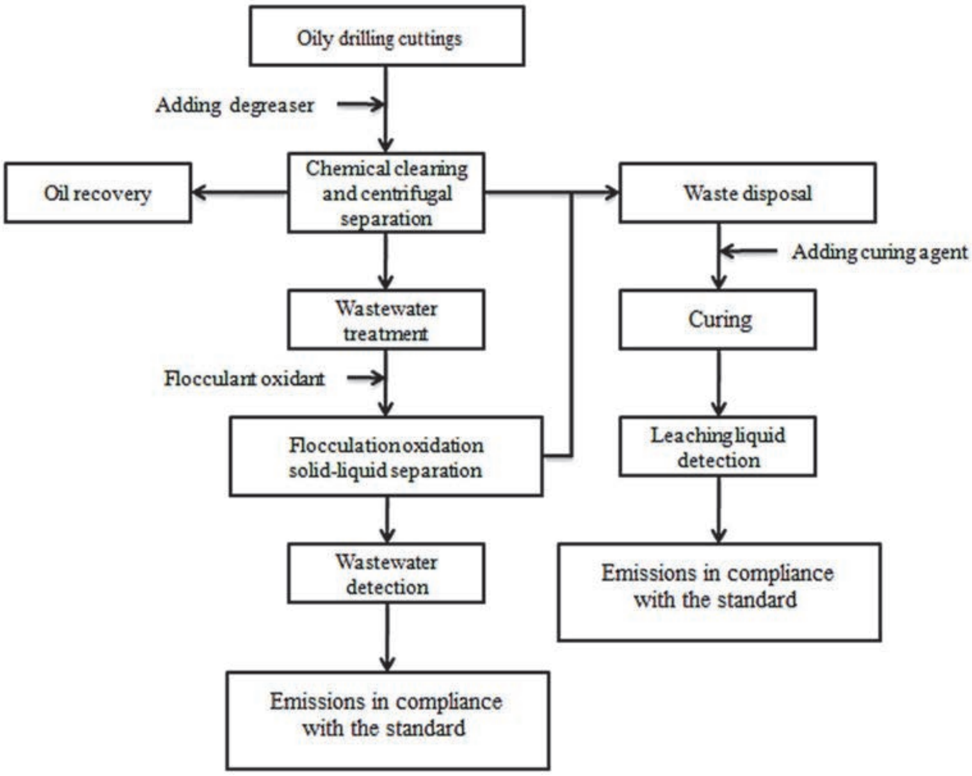


Fig. 6. Process flow diagram of oily drilling cutting treatment

4. Conclusions

(1) Aiming at the pollution characteristics of oily cuttings, the efficient degreasing agent CYJ-1 used for the oily drilling cuttings was designed and synthesized in the laboratory.

(2) The harmless degreasing formula for oily drilling cuttings was developed based on the efficient degreasing agent CYJ-1. The harmless degreasing formula was biodegradable and efficient, and it demonstrated good oil removal performance with the oil removal rate of 93.02%.

(3) Transition state theory was used to explain the mechanism of action of the degreasing agent for the first time. Combined with the data of interfacial tension and potential energy, the degreasing mechanism of oily cuttings was revealed. The research results showed that the harmless degreasing formula could reduce the potential energy barrier of oily cuttings in the process of oil removal by 92.3%, which made the oil removal difficulty of oily cuttings greatly reduced, and provided theoretical support for the chemical cleaning treatment of oily cuttings.

(4) The formula could achieve a high oil removal rate when using efficient degreasing agent CYJ-1 in field application, demonstrating the successful facilitation of the resource recovery and harmless treatment of oily drilling cuttings.

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