Resource recovery and harmless treatment of waste oil-in-water drilling fluid

Chao Tang^{1,2†}, Shui Xiang Xie³

¹Engineering and Technology College, Yangtze University, JingZhou 434000, China

²Petroleum Engineering College, Yangtze University, Wuhan 430000, China

³CNPC Research Institute of Safety & Environment Technology, Beijing 10000, China

ABSTRACT

Destabilization and demulsification is a difficult task for the treatment of waste oil-in-water drilling fluid because of its “three-high” characteristics: emulsification, stabilization and oiliness. At present, China is short for effective treating technology, which restricts cleaner production in oilfield. This paper focused on technical difficulties of waste oil-in-water drilling fluid treatment in JiDong oilfield of China, adopting physical-chemical collaboration demulsification technology to deal with waste oil-in-water drilling fluid. After oil-water-solid three-phase separation, the oil recovery rate is up to 90% and the recycled oil can be reused for preparation of new drilling fluid. Meanwhile, harmless treatment of wastewater and sludge from waste oil-in-water drilling fluid after oil recycling was studied. The results showed that wastewater after treated was clean, contents of chemical oxygen demand and oil decreased from 993 mg/L and 21,800 mg/L to 89 mg/L and 3.6 mg/L respectively, which can meet the requirements of grade one of “The National Integrated Wastewater Discharge Standard” (GB8978); The pollutants in the sludge after harmless treatment are decreased below the national standard, which achieved the goal of resource recovery and harmless treatment on waste oil-in-water drilling fluid.

Keywords: Collaboration demulsification, Harmless treatment, Oil recovery, Recycle, Waste oil-in-water drilling fluid

1. Introduction

Oil-in-water drilling fluid, a kind of low density underbalanced water-based drilling fluid with industrial mineral oil or diesel as dispersed phase, fresh water or saline water as continuous phase, has properties of both water-based and oil-based drilling fluid. Which is applied for mass promotion in oilfields of China [1-4]. Taking JiDong oilfield for example, according to monolithic deployment of oilfield exploration and development, annual drilling 200-210 wells, mud volume 170 thousand square meters per year (850 square meters per well calculation), usage of oil-in-water drilling fluid account for 10%, which is 17 thousand square meters per year. If not treated appropriately, it will cause great damage to ecological environment. Moreover, large amount of oil resources may be wasted (oil content in waste oil-in-water drilling fluid is about 20% - 40%), improvement of oilfield environment and sustainable economic development were restricted [5, 6].

For waste oil-based drilling fluid, the research in China is mainly focused on the field of oily cuttings treatment, such as

thermal desorption technology, high efficient oil removal agent for oily drilling cuttings, mechanical and biological treatment, etc. [7-10]. These technologies are tested and used in YiBin, SiChuan province and SuGeli gas field [11]. But China is lack of effective technical methods for dealing with waste oil-in-water drilling fluid at present. Cement anti-seepage pool or solidification technology are mainly methods adopted in oilfield [12], but as time goes on, it will be easy to cause secondary pollution and environmental risk cannot be eliminated thoroughly. So it is imperative to develop harmless and resource recycling technologies on waste oil-in-water drilling fluid [13].

2. Materials and Equipments

2.1. Main Materials

Waste oil-in-water drilling fluid was from well NP361 of JiDong oilfield; Demulsifier PR-10, ancillary demulsifier PR-15, Petroleum

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† Corresponding author

Email: 395450161@qq.com

Tel: +86-0716-8067503 Fax: +86-0716-8067507

ether, carbon tetrachloride, anhydrous sodium sulfate and sodium and sodium chloride, etc. were from Tian He Science and Technology Ltd., Jing Zhou.

2.2. Main Equipments

Oil 480 infrared oil content analyzers to measure oil was from Beijing Huaxia Instrument Tech. Co., Ltd.; DR200 COD digestion apparatus and DR 2800 UV-Vis Spectrophotometer to measure COD were from Hach Company, USA; AFS-830A Atomic fluorescence spectrometer to measure heavy metal was from Agilent Technologies; The six-speed rotational viscometer to measure property of drilling fluid was from HengTaiDa mechanical and electrical equipment Co., Ltd. in QingDao; Quadruple filtration apparatus to measure drilling fluid filter loss was from ShanDe Petroleum instrument Co., Ltd. in QingDao; some glass apparatuses, etc.

3. Methods

3.1. Determination of Waste Oil-in-water Drilling Fluid Composition

A moisture determination device was used to determine the water content of the waste oil-in-water drilling fluid. In this device, the moisture was first extracted with petroleum ether, and then condensed and collected. The water content in the sample was calculated by reading the extracted water volume. The residual content was determined by weighing the dried residue after pumping and filtering the liquid inside. Finally, the oil content was calculated by the dispersion method.

3.2. Determination of Oil Content

Determination of oil content in wastewater is based on “Determination of petroleum oils and animal and vegetable oils-Infrared spectrophotometry” (HJ/T 637-2012). Determination of oil content in solid is based on “Determination method for municipi-

pal sludge in wastewater treatment plant” (CJ/T 221-2005).

3.3. Determination of Chemical Oxygen Demand (COD)

Determination of COD is based on “Determination of the chemical oxygen demand- Fast digestion- spectrophotometric method” (HJ/T 339-2007).

3.4. Determination of Drilling Fluid Properties

Determination of drilling fluid properties is based on “Field testing of drilling fluids- Part 1: Water-based fluids” (GB/T 16783.1-2006).

4. Results and Discussion

4.1. Composition Analysis of Waste Oil-in-water Drilling Fluid

The composition of waste oil-in-water drilling fluid from well NP361 of JiDong oilfield was analyzed. The results were shown in Table 1 indicating that water content was 51.83%; oil content was up to 38%. Because of its high oil content, it gives a good value to be recycled.

4.2. Oil Recovery Test of Waste Oil-in-water Drilling Fluid

Certain content of waste oil-in-water drilling fluid was put into erlenmeyer flask, when stirred in magnetic stirrer, a certain amount of demulsifier PR-10 and PR-15 were added in order to make demulsifier and fluid mixed thoroughly. The reaction lasted for 15mins and the temperature was controlled at 60°C. After that, the emulsion was separated into three phases (water, oil and solids) as shown in Fig. 1. The upper liquid was poured into glass separating funnel, standing for 20-30 min. Recycled the upper oil and collected the lower water and sludge. The analysis results for the composition of oil, water and solid after three-phase separation were shown in Table 2.

Table 2 indicated that good oil-water-solid three-phase separation effects can be achieved by the method of physical-chemical

Table 1. Contents of Waste Oil-in-water Drilling Fluid (w, %)

No.	Types	Water content	Oil content	Solid content
1207-1	Diesel-in-water	51.83	38.14	10.03

Fig. 1. Before and after oil recovery of waste oil-in-water drilling fluid: (a) waste drilling fluid; (b1), (b2) three-phase separation; (c) oil-water separation.

Table 2. Contents of Waste Oil-in-water Drilling Fluid Components after Treated (w, %)

Phases after disposal	Water content	Oil content	Solid content
oil phase	0.00	99.94	0.06
water phase	97.52	2.18	0.30
solid phase	63.09	4.77	32.14

Table 3. Properties Evaluation and Comparison of Drilling Fluid Prepared by Recycled Oil

Type of oil	Properties of drilling fluid					
	AV, mPa.s	PV, mPa.s	YP, Pa	ρ , g/cm ³	APL.FL, mL	Filtrate pH
0# diesel	33.5	22	11.5	0.93	6.8	9-10
reclaimed oil	35.0	23	12.0	0.97	7.4	9-10
NP36-P3002 well drilling fluid design (5,957-6,470 m)	/	20-22	10-12	0.96-0.98	≤ 5	10-12

AV: Apparent Viscosity

PV: Plastic Viscosity

YP: Yield Point

APL.FL: American Petroleum Institute Filtration Loss

Table 4. The Main Pollutants in Middle Layer Wastewater (mg/L)

Samples	pH	COD	Cr	Pb	As	Hg	Cd	Oil
wastewater before disposal	7	993	0.19	0.08	/	/	0.01	21,800
wastewater after disposal	7	89	0.13	0.05	/	/	0.01	3.6
GB8978 (grade one)	6-9	100	1.5	1	0.5	0.05	0.1	5

collaboration demulsification technology. Oil content in water and solid was 2.18% and 4.77% respectively, which was convenient to later treated, while the oil recovery rate is more than 90% with no water and high purity. The goal of resource recovery on waste oil-in-water drilling fluid can be achieved.

4.3. Reusing of Recycled Oil

To verify the feasibility of preparing drilling fluid from recycled oil of waste oil (diesel)-in-water drilling fluid, the experiment of preparing drilling fluid from recycled oil was made. The results were shown in Table 3 indicating that (1) The properties of drilling fluid prepared by recycled oil is closed to 0# diesel, which verified recycled oil can be used for the preparation of drilling fluid; (2) Compared with NP36-P3002 well drilling fluid design, except for the water loss of the drilling fluid prepared from recycled oil was a little higher than the requirements of the design (which is associated with the dosage of filtrate reducer), the other properties can meet the demand of the design. The water loss of the drilling fluid can be reduced by adjusting filtrate reducer dosage in oilfield.

4.4. Treatment of Middle Layer Wastewater

Main pollutants in waste oil-in-water drilling fluid of middle layer wastewater after oil-water-solid three-phase separation were analyzed. The results were shown in Table 4 indicating that the heavy metal content and the pH value in the wastewater produced by waste oil-in-water drilling fluid after oil recovery can meet the requirements of grade one of "The National Integrated Wastewater Discharge Standard" (GB8978), but COD and oil is

higher than standard limited value, which need further treated.

The method of flocculation oxidation can be used for the treatment of wastewater. First adding flocculant to reduce COD, then the Fenton reagent oxidation was used to further reduce the COD. Therefore, the treated water can reach national discharge standard.

The proper operation conditions for wastewater treatment were as follows: Polyaluminium chloride (PAC) dosage 1%, room temperature, stirring time for 15 min; $\text{H}_2\text{O}_2/\text{Fe}^{2+} = 3.5:1$, stirring time for 30 min. Wastewater after treatment was analyzed. The results were shown in Table 4, which indicated that the COD and oil can meet the first grade of national standard (GB8978).

4.5. Harmless Treatment of Sludge

The sludge in waste oil-in-water drilling fluid after oil-water-solid three-phase separation was analyzed and the results were shown in Table 5, indicating that the heavy metal in the sludge can meet the requirements of "Control Standards for Pollutants in Sludge from Agricultural Use" (GB4284), while the oil content is up to 47,700 mg/kg, higher than standard limit: 3,000 mg/kg, which need further treated.

Harmless treatment experiment of sludge was performed adopting new harmless treating agent composed of curing agent and reinforcing agent. The proper indoor conditions for the treatment of sludge were as follows: curing agent concentration 3% w/w, reinforcing agent concentration 10% w/w. At room temperature, the sludge was solidified for 7 d, then the lixivium of sludge cured product was measured. The results were shown in Fig. 2 and Table 6 indicating that the lixivium was colorless and trans

Table 5. The Main Pollutants in the Sludge (mg/kg, mg/L)

Items	Oil	Cr	Cd	Pb	As	Hg
testing value	47,700	12.9	2.04	0.52	6.2	0.12
GB4284 (grade one)	3,000	75	20	15	1,000	1,000

Table 6. The main pollutants in the lixivium of sludge cured product (mg/L)

Items	pH	COD	Oil	Cr	Cd	Pb	As	Hg
testing value	8	76.0	4.2	0.69	0.023	0.81	0.017	0.0093
GB8978 (grade one)	6-9	≤ 100	≤ 5	≤ 1.5	≤ 0.1	≤ 1.0	≤ 0.5	≤ 0.05

Fig. 2. Sludge after solidification and its lixivium.

parent after solidification treatment. pH value, COD, oil and heavy metals can meet the requirements of grade one of “The National Integrated Wastewater Discharge Standard” (GB8978). So good effects of harmless treatment on sludge can be achieved. will not be caused.

5. Conclusions

The Composition of waste oil-in-water drilling fluid from well NP361 in JiDong oilfield was analyzed, water content was 51.83%; oil content was 38.14%; sludge content was 10.03%, high oil content gives a value to be recycled.

Physical-chemical collaboration demulsification technology was used for treatment of waste oil-in-water drilling fluid. The oil recovery rate was more than 90% after oil-water-solid three-phase separation. The water loss in the drilling fluid prepared by recycled oil was a little higher than the design criteria, the other properties index can meet the demand of the design.

Harmless treatment technology of middle layer wastewater and sludge in waste oil-in-water drilling fluid after oil recovery was studied. The wastewater after treated was clean, COD and oil can meet the first grade of national standard (GB8978); the lixivium in the sludge after solidification was colorless and transparent, pH value, COD, oil and heavy metals can meet the requirements of grade one of “The National Integrated Wastewater Discharge Standard” (GB8978).

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