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Destabilization of oil droplets in produced water from ASP flooding

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Abstract

Produced water from alkali/surfactant/polymer (ASP) flooding was more difficult to treat than that from water flooding due to large quantities of residual chemicals (alkali, surfactant and polymer) in the produced water. Surfactant was mainly responsible for the stability of oil droplets, decreasing oil–water interfacial tension and zeta potential on the surface of the oil droplets. Flocculation and demulsification were conducted to remove the stable oil droplets in the produced water. Due to the large dose of the flocculants and some viscous sediment formed, flocculation was not suitable for the wastewater treatment. Demulsification was an effective method to accelerate oil–water separation for the produced water. Of the numerous demulsifiers screened, DODY68 was found to be the most effective in treating the wastewater. The zeta potential of oil droplets increased after addition of the demulsifier to the produced water from ASP flooding, which indicated that the approach and coalescence of small oil droplets became easier due to the decrease in electrostatic repulsion between oil droplets.

Keywords: Alkali/surfactant/polymer flooding; Produced water; Destabilization; Oil–water separation; Demulsifier

1. Introduction

During the process of oil extraction, produced water (oily wastewater) is generated after dehydration of the produced liquid, which is a mixture of oil and water and pumped directly from oil wells in oilfields. Produced water requires treatment before being injected into the stratum for reuse [1–3]. In Daqing oilfield in China, the amount of produced water is up to about 3×10^8 tonnes per year. Therefore, the treatment of produced water plays an important role in oil production.

In recent years, technologies for tertiary oil extraction have been relatively well developed. Alkali/surfactant/polymer (ASP) flooding technology is an important technology in tertiary oil extraction, which has been found to enhance oil recovery by over 20%. Hence, it has been used on an industrial scale in Daqing oilfield, which is the only oilfield in the world to use ASP flooding technology [4–6]. However, due to the use of alkali, surfactant and polymer in the injected water in ASP flooding technology, produced water from this process contains residual chemicals and is more difficult to treat than that from water flooding [7].

Fig. 1 shows the conventional produced water treatment system in Daqing oilfield including the settling and filtration processes used. Although the settling tanks may be replaced by some effective separation equipment such as hydroclone, floatation tank and coalescer they are popular in the oilfield due to its ease in management, steady operation and lower cost. However, the existing systems for the treatment of produced water from water flooding cannot meet the requirement needed for produced water treatment from ASP flooding in Daqing oilfield. Industrial experiments have shown that with an oil concentration of less than 100 mg/L, the settling time required was up to 26 h in the settling tanks for the produced water from ASP flooding, which was considerably longer than the 4 h needed in water flooding system. Moreover, the

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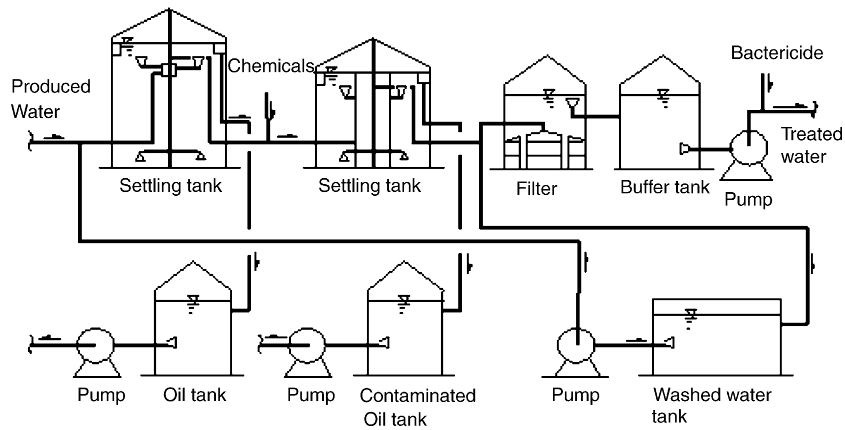

Fig. 1. Schematic diagram of produced water treatment in Daqing oilfield.

subsequent filters could not work normally for the large quantities of residual chemicals in the produced water from ASP flooding. Even though the gravity filters were replaced by pressure filters, some problems including too high a pressure drop and a short filtration period would take place.

Although various conventional processes such as gravity settling, floatation, de-emulsification, and membrane separation have been used to treat the produced water from water flooding in some oilfield [8–14], there has been no report on the treatment of produced water from ASP flooding in literature. In Daqing oilfield, the treatment system shown in Fig. 1 has been used to treat the produced water from water flooding for many years. It has been shown that the most applicable and cost-effective method for the treatment of produced water from ASP flooding is to add chemicals to the settling tanks in the existing system to accelerate oil–water separation.

In this study, based on the characteristics of oil droplets in the produced water from ASP flooding, flocculation and demulsification experiments were conducted to destabilize the oil droplets in the produced water. Demulsification was studied in detail, which was shown to be an effective method in the treatment of the produced water from ASP flooding.

2. Materials and methods

2.1. Materials

The crude oil obtained from the local oilfield in Daqing has water content of less than 0.5%, and density and viscosity of 850 kg m^{-3} and 60.89 mPa s (at 45 °C), respectively. The polymer (partly hydrolyzed polyacrylamide, HPAM) from SNF Company (France) has an average molecular weight (MW) of 2.72×10^6 and a degree of hydrolysis of about 25–30%. A commercial surfactant ORS-41 with a major component of alkylbenzene sulphonate was purchased from Witco Company (USA). The alkali used in this study was NaOH. About 200 demulsifiers were provided by Shandong Binzhou Chemical Company and Nanjing Jinling Chemical Company in China. The flocculants poly aluminium chloride (PAC), cationic polyacrylamide (MW = 3.2×10^6) and nonionic polyacrylamide (MW = 4.0×10^6) were commercial products.

2.2. Size determination of oil droplets

A laser particle size analyzer 1064 (CILAS Company, France) was used to determine the size of the oil droplets. Five hundred milliliter of deionized water was added to a beaker, and heated up to 45 °C in a water bath. An appropriate amount of produced water containing oil droplets was then added to the beaker and stirred gently with a glass rod, and transferred to a cuvette. The median diameter of oil droplets was then measured.

2.3. Micrographs observation

A drop of oily wastewater was placed on a glass holder, held on the platform of an optical microscope (Leica Microsystems, Germany), and observed and recorded on a camera. The magnification used was 20 × 10.

2.4. Oil–water interfacial tension measurement

One hundred grams of the simulated produced water with/without demulsifier and 30 g of the crude oil were added to a 150 mL jar and maintained at 45 °C in a constant temperature device for 24 h. The partitioned oil and water were tested. A K12 tensiometer (Kruss Company, Germany) was used to determine the oil–water interfacial tension at an operating temperature of 45 °C.

2.5. Determination of zeta potential of oil droplets

The zeta potential measurement was conducted on a Zetaplus zeta apparatus (Brookhaven Company, USA). One hundred milliliter of 1000 mg/L produced water with/without demulsifier was allowed to settle for 2 h at 45 °C, and then 5–10 mL sample was taken out from the bottom of the jar