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Research paper

Micellar-polymer for enhanced oil recovery for Upper Assam Basin

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Abstract

One of the major enhanced oil recovery (EOR) processes is chemical flooding especially for the depleted reservoirs. Chemical flooding involves injection of various chemicals like surfactant, alkali, polymer etc. to the aqueous media. Bhogpara and Nahorkatiya are two depleted reservoirs of upper Assam basin where chemical flooding can be done to recover the trapped oil that cannot be recovered by conventional flooding process. Micellar-polymer (MP) flooding involves injection of micelle and polymer to the aqueous phase to reduce interfacial tension and polymer is added to control the mobility of the solution, which helps in increasing both displacement and volumetric sweep efficiency and thereby leads to enhanced oil recovery. This work represents the use of black liquor as micelle or surfactant that is a waste product of Nowgong Paper Mills, Jagiroad, Assam, which is more efficient than the synthetic surfactants. The present study examines the effect of MP flooding through the porous media of two depleted oil fields of upper Assam basin i.e. Bhogpara and Nahorkatiya for MP EOR. This work also compares the present MP flood with the earlier work done on surfactant (S) flooding. It was experimentally determined that the MP flood is more efficient EOR process for Bhogpara and Nahorkatiya reservoirs. The study will pertain to the comprehensive interfacial tension (IFT) study and the displacement mechanism in conventional core samples.

Keywords: Black liquor; Critical micelle concentration; Interfacial tension; Porous media; Enhanced oil recovery

1. Introduction

Enhanced oil recovery, commonly known as tertiary oil recovery, is an eminent method of maximizing oil recovery from the mature oil fields whose production has reached its peak and has started to decline. The planning for improving, maximizing or enhancing oil production strategies through EOR methods is one of the most critical challenges facing the oil industries today. EOR involves injection of more exotic and correspondingly more expensive fluids other than water and non-miscible gases. This method mobilizes and recovers the oil that has been left behind or cannot be produced economically by conventional means. Approximately 30–60% or more of the reservoirs' original oil can be extracted using EOR as compared to primary and secondary recovery methods with 20–40%. EOR includes so many methods such as thermal methods which incorporates conventional steam, cyclic injection, steam assisted gravity drainage and in-situ combustion, chemical injection which incorporates surfactant, polymer, alkaline, surfactant with foam, gas injection which involves N_2, CO_2, flue, NGL and injection of microbes which is also known as microbial enhanced oil recovery [1].

Basic mechanisms involved in chemical flooding are reduction in interfacial tension between oil and brine, solubilization of released oil, change in the wettability toward more water wet, reducing mobility contrast between crude oil and displacing fluid. Chemical flooding is found to be recovering more oil from the depleted reservoirs such as surfactant flooding, micellar-polymer, alkaline, polymer flooding etc. Among EOR techniques, micellar-polymer (MP) flooding process has the potential as it uses surfactant to reduce interfacial tension (IFT) and therefore, allow the oil to flow through porous media [2]. Beneficial synergistic effect by combining surfactant and alkali in a chemical flood has been reported in the literature [3–8]. The capillary forces reduce on addition of surfactants, which trap

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Nomenclature

EOR	enhanced oil recovery
IFT	interfacial tension
CMC	critical micelle concentration
S	surfactant
MP	micellar-polymer
g/ml	gram per milliliter
mPa.s.	millipascal.second
ppm	parts per million
mg/l	milligram per liter
k_{ro}	relative permeability of oil
S_{wi}	irreducible water saturation
k_{rw}	relative permeability of water
S_{or}	residual oil saturation
mN/m	millinewton per meter

the oil inside the pores of the rock. The surfactant slug helps to displace the majority of the oil from the contacted reservoir, by reduction of the interfacial tension between oleic phase and aqueous phase. The surfactant flooding in petroleum reservoirs is an effective way of recovering a fraction of remaining oil and widely recognizable for providing an ultra low IFT ($\approx 10^{-3}$ mN/m) between the oil and the aqueous solution containing surfactant. Several surfactants have been investigated in the literatures [9–13]. Babakhani et al. (2011) from his investigations found that around 60% of the reserves were recovered with the help of chemical flooding. Surfactant reduces the IFT value and polymer solution controls mobility and increases the volumetric sweep efficiency, thereby enhanced oil recovery [14]. Gurgel et al. also highlighted the use of various chemical methods for further oil displacement from the depleted reservoirs which can be achieved by attaining ultra-low interfacial tensions and reduced fluid viscosity in the oil reservoirs. He mentioned the importance of interfacial science, physico-chemical properties of chemical systems and geological characteristics of the rock matrices to plan and obtain a high yield processes through optimization and modeling techniques [15]. Mandal (2015) from his analysis also found that chemical flooding mainly operates on two basic mechanisms, increase of macroscopic and microscopic displacement efficiencies. The increase in macroscopic efficiency can be obtained by polymer injection which increases the viscosity of displacing fluid and improves the mobility ratio whereas the increase in microscopic efficiency can be obtained by alkali/surfactant injection through reduction of IFT, emulsification of oil and water, solubilization of interfacial films, wettability reversal, etc. [16].

Reduction of IFT is a major contributor for increasing the oil recovery from the depleted reservoirs. If IFT is reduced, the emulsification of residual oil will be easier and EOR will prove to be more efficient. Many literatures have supported the particular phenomenon [17,18]. Surfactant plays an important role in reducing the IFT by getting adsorbed into the liquid–liquid interface and alters the wetting properties of reservoir rock and fluid. Howard (1927) reported, for the first time, a patent on surfactant-based chemical EOR where surface tension between reservoir rock and crude oil was reduced using soap or any other aqueous solutions [19]. De Groote (1929) granted a patent where he claimed that water soluble surfactants help to improve oil recovery [20]. Johnson et al. (1982) invented black liquor (BL) that can be able to inject into an oil-bearing subterranean formation before or simultaneously with the emulsion of chemical flood that gets adsorbed on the active mineral surfaces of the matrix formation and efficaciously reduces the surfactant adsorption in the chemical flood. The effluent or BL is used alternatively to displace the surfactant from the mineral surfaces that eventually helps in increasing the recovery of crude oil [21]. Novosad (1983) claimed that the advantages of lignosulfonates have not come from the activity as a sacrificial agents [22]. With addition of lignosulfonate, the lowering of IFT can be achieved, which was quantitatively similar to that observed by the addition of NaCl, which was provided in the solution when it was below the optimum salinity level. However, the quantity of lignosulfonate required was much smaller for lowering IFT [23]. Several surfactants of petroleum sulfonate have been examined to produce such low interfacial tensions. However, this petroleum sulfonate is high in cost and one of the major issues in surfactant flooding processes. The possibilities of using lignosulfonates, which were almost four times cheaper as compared with petroleum sulfonates for EOR operations, have been reported [24–28]. About 10% of the total spent liquors in Canada were processed to recover useful products such as lignosulfonates [29] for various applications that involves EOR.

The main objective of this work is to use a locally available surfactant for an effective chemical flood. Especially, we will investigate the use of inexpensive black liquor (BL), where the main constituent is sodium lignosulfonate, which is readily available from Nagoan Paper Mill at Jagiroad, Assam as a substitute for the more expensive or commercial surfactant [30]. This work also examines the comparison between MP and surfactant flooding on the two depleted oil fields of upper Assam basin i.e. Bhogpara and Nahorkatiya. The experiments are conducted on the description of multiphase flow in porous media based on Darcy's law and JBN method for unsteady-state displacements. JBN [31] method is a direct calculation method derived from the simplified theory and formulation of immiscible displacement through porous media according to Buckley and Leverett [9].

2. Experimental analysis

2.1. Materials

The materials used for the preparation of emulsion were distilled water and paraffin oil with a density of 0.5742 g/ml and viscosity 220 mPa.s. The brine solution used is 3000 ppm of NaCl in DW having viscosity (μ_w) of 1 mPa.s. The surfactant used is BL whose main constituent is Na-lignosulfonate, which is cheap and locally available as waste from Nagoan Paper Mill, Jagiroad. The polymer used is polyacrylamide with a density of 1.02 g/ml and viscosity 1.5 mPa.s.

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