UGC MINOR RESEARCH PROJECT

EXECUTIVE SUMMARY
ON THE TOPIC

A Study on Micellar Flooding with special reference to natural porous media of Bhogpara Oil Field

Submitted by

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Executive Summary of UGC Sponsored Minor Research Project

Topic

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Enhanced Oil Recovery (EOR) is an attractive option for the coming years when the production from mature fields would be declining and it will compete with new developments in more hostile environments. The main objective of the project was to use a locally available surfactant for an effective chemical flood. In the study, the use of inexpensive Black Liquor (BL), the main constituent of which is sodium lignosulfonate, as a substitute for the more expensive surfactant which was readily available from Nagoan Paper Mill at Jagiroad, Assam, have been investigated. For the analysis, the site and porous media selected was from Bhogpara oil field of the eastern part of Upper Assam Basin. Various conventional and sidewall cores were taken from well no. BH(A) of Bhogpara from a depth of 3827 - 3837 m.

Rock Characterization

Rock characterization was done by observing the thin section slides under a microscope, known as Petrography study. This is the study of mineral composition of rocks which gives us clues about the source rock, environment of deposition, digenetic history, tectonic setup of the source area, etc. and thus helps us in understanding the geologic history of the study area. Rock characterization was further done by Scanning Electron Microscope (SEM) which is used to provide accurate description of the reservoir rock surface topography. The SEM is used to attain the pore size distribution of the rock, besides three-dimensional views of the minerals. The grain size distribution analyses were done in sieves to examine the coarseness and fineness of the grains present in the reservoir core samples. The porosity of various samples of Bhogpara porous media was obtained using TPI-219 Teaching Helium Porosimeter, Coretest systems. The Air permeability of various samples was calculated by Gas Permeameter, Vinci Technologies.

Thin section slides of BH(A) core samples shows the presence of minerals like feldspar, quartz, mica and rock fragments. While chlorides and cherts were also present in BH(A). Feldspars ($KAlSi_3O_8 - NaAlSi_3O_8 - CaAl_2Si_2O_8$) are a group of rock-forming tecto-silicate minerals that make up as much as 60% of the Earth's crust. Quartz is the second most abundant mineral in the Earth's continental crust, after feldspar. It is made up of a continuous framework of SiO_4 silicon–oxygen tetrahedra and oxygen being shared between two

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tetrahedra, giving an overall formula SiO_2. The mica group of sheet silicate (phyllo-silicate) minerals includes several closely related materials having close to perfect basal cleavage. All are monoclinic, with a tendency towards pseudo-hexagonal crystals, and are similar in chemical composition. The nearly perfect cleavage, which is the most prominent characteristic of mica, is explained by the hexagonal sheet-like arrangement of its atoms. The chloride ion is the anion (negatively charged ion) Cl^-. It is formed when the element chlorine (a halogen) gains an electron or when a compound such as hydrogen chloride is dissolved in water or other polar solvents. Chert is a fine-grained silica-rich microcrystalline, cryptocrystalline or micro-fibrous sedimentary rock that may contain small fossils. It varies greatly in color (from white to black), but most often manifests as gray, brown, grayish brown and light green to rusty red; its color is an expression of trace elements present in the rock, and both red and green are most often related to traces of iron (in its oxidized and reduced forms respectively). Certain bended mica was also observed, which is also known as diagenetic mica. Plagioclase feldspar was also seen in some slides which are often identified by its polysynthetic twinning which shows the presence of sodium and calcium atoms and observed as oblique fractures under cross polarized light. Some slides also shows the presence of clay in BH(A) core samples. Clay is a fine-grained soil that combines one or more clay minerals with traces of metal oxides and organic matter. Geologic clay deposits are mostly composed of phyllosilicate minerals containing variable amounts of water trapped in the mineral structure. The framework silica minerals quartz was mainly subangular to subrounded in nature, although anhedral crystals were also present which are opposite to euhedral crystals, a rock with an anhedral texture composed of mineral grains that have no well formed crystal faces or cross-section shape in thin section.

SEM images of sandstone recovered from BH(A) shows the presence of Kaolinite and quartz overgrowth. Kaolinite is a clay mineral, part of the group of industrial minerals, with the chemical composition $Al_2Si_2O_5(OH)_4$. Rocks that are rich in kaolinite are known as kaolin or china clay. The kaolinite in the book form and quartz overgrowths can disintegrate in the pore filling spaces causing a reduction in porosity and permeability. Grain size distribution of conventional core samples of BH(A) appeared very fine and the value of porosities ranges from 17 to 25%.

Fluid formulation by IFT determination for Enhanced Oil Recovery

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Fluid formulation was done using 3000 ppm of NaCl in DW having viscosity (μ_w) of 1 mPa.s. and the surfactant used is Black Liquor. Density and Viscosity were measured by U-tube viscometer also known as glass capillary viscometer or Ostwald viscometers and Hygrometer respectively. The IFT test was conducted in KRUSS Easy Dyne Tensiometer, which is intended only for measurements of the surface tension of liquids, the interfacial tensions between two liquids and measurements of the density of a liquid.

The reduction of IFT plays an important role in additional oil recovery. The efficiency of the chemical EOR is a function of liquid viscosities, relative permeabilities, interfacial tensions, wettabilities, and capillary pressures. Even if all the oil is contacted by the injected chemicals, some oil would still remain in the reservoir. This is due to the trapping of oil droplets by capillary forces due to high IFT between water and oil. Surfactant systems, as used in EOR, adsorb at the oil/water interface and can be designed to generate an interface that is flexible and that has a low IFT. Very low IFT between oil and water is the primary requirement for emulsion formation. Lowering of IFT recovers additional oil by reducing the capillary forces that leave the oil behind any immiscible displacement. This trapping is best expressed as a competition between viscous forces which mobilize the oil, and capillary forces which trap the oil. Therefore, low IFT implies a significant increase in the capillary number for a given flow velocity and viscous forces generated during a flood can mobilize additional oil.

Oil recovery from porous media when flooded by 0.34% BL in DW is determined. The oil recovery by 3000 ppm brine solution is compared with the oil recovery by surfactant i.e. BL, the main constituent of which is Sodium lignosulphonate. After brine flooding through the core sample, it is flooded with surfactant, the breakeven point is recorded and datas are taken from the instant when the breakeven point is reached. Breakeven point is the point when the surfactant starts coming out from the core sample.

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The IFT experiment was conducted using Liquid Paraffin (H) as the oleic phase and the aqueous phase was chosen as BL in DW. The experiment shows that with addition of surfactant, the IFT between the aqueous & oleic phase decreases. The concentration of BL is increased slowly to check for more appropriate CMC & IFT value. With increase in the concentration of BL in DW, four different values of IFT at CMC were obtained. Initially, IFT was 12.8 mN/m at 0.03 CMC, then by increasing the concentration of BL in DW, IFT value becomes 9.5 mN/m at 0.111 CMC, then further IFT equals 6.5 mN/m at 0.22 CMC and finally at 0.335 CMC, the IFT value is 4.8 mN/m.

When the oleic phase was chosen as Liquid Paraffin (L) and the aqueous phase was chosen as BL in DW, the experimental results shows four different values of IFT at CMC. Initially, IFT was 19.5 mN/m at 0.04 CMC, then by increasing the concentration of BL in DW, IFT value becomes 17 mN/m at 0.09 CMC, then further IFT equals 12.5 mN/m at 0.175 CMC and finally at 0.225 CMC, the IFT value is 6 mN/m. Compared to the petroleum based surfactants for EOR, lignin based surfactant systems combine the advantage of low cost and high brine tolerance. Since Lignin is produced from a source unrelated from petroleum, the price of lignin is not tied directly to the price of crude oil. And this decoupling is a significant advantage for EOR formulations.

Oil Recovery

The absolute permeability values for two selected BH(A) core samples are shown in Table 1 along with the porosity values, as obtained by TPI-219 Teaching Helium Porosimeter, Coretest systems and grain size distribution by sieve analysis method.

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Table 1: Parameters of Porous media

Sample No.	Depth (m)	Absolute Permeability Kw (md)	Pore Volume (cc)	Porosity (%)	Grain size
BH(A)#1	3827.2	50.14 md	17.3084	17.24	very fine sand
BH(A)#4	3837	53.32 md	19.30241	20.25	very fine sand

Table 2: Fluid saturation results of Permeability Experiment

Flooding Medium	Sample No.	Parameters	Saturation % PV
1. Paraffin oil	BH(A)#1 BH(A)#4	Irreducible water saturation = Swc	8.95 9.23
	BH(A)#1 BH(A)#4	Initial oil Saturation = Soi	91.05 90.77
2. Brine	BH(A)#1 BH(A)#4	Residual oil saturation = Sor	40.19 30.27
	BH(A)#1 BH(A)#4	Recovered oil Saturation	50.18 60.50
3. Surfactant	BH(A)#1 BH(A)#4	Residual oil saturation = Sors	28.92 16.79
	BH(A)#1 BH(A)#4	Recovered oil Saturation	11.27 13.48

The fluid saturation results of the permeability experiment are shown in Table 2 and the parameters of the porous media are in Table 1. The Table 2 shows that the irreducible water saturation (Swc) of BH(A)#1 & BH(A)#4 were 8.95 & 9.23 %, which can approximately be considered as 9% for each core sample and initial oil saturations (S_{oi}) were 91.05 & 90.77 %, which again can be considered as 90% for each porous media. When brine flooding was done, the oil recoveries were 50.18 & 60.50% in BH(A)#1 & BH(A)#4 test samples respectively.

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This shows that with increase in depth, oil recovery is increasing which may be because of increasing absolute permeability and increase porosity with depth.

The Sor for BH(A)#1 & BH(A)#4 were 40.19 & 30.27 % respectively. This means that residual oil saturation decreases with increase in depth, which again may be because of increasing absolute permeability & porosity with depth. When surfactant (0.335% BL in DW) flooding was done, the residual oil saturation further decreases to 28.92 &16.79 % for BH(A)#1 & BH(A)#4 respectively and the Enhanced oil recovery from the two core sample was 11.27 &13.48 % respectively (Table 2), which can be considered as average of 13.48% for each porous media. This increase in oil recovery shows that with the addition of surfactant to the aqueous phase, the IFT between oleic and aqueous phase decreases thereby enhancing the recovery from the porous media. Table 3 below shows the percentage of surfactants injected with enhancement in oil recovery for different porous media of Bhogpara oil field of Upper Assam basin.

Table 3: Results of Oil Recovery from different Porous Media after Miceller flooding

% of surfactant injected in BH(A)#1	oil flow (%Sor) out from BH(A)#1	% of surfactant injected in BH(A)#4	oil flow (%Sor) out from BH(A)#4
2.46	0.00	2.46	0.00
3.81	0.00	3.81	0.00
4.79	0.00	4.79	0.00
5.58	0.00	5.58	1.71
6.8	0.67	6.8	2.13
7.39	0.92	7.39	4.41
8.71	1.78	8.71	4.72
9.86	2.12	9.86	4.97
10.43	2.42	10.43	5.29
11.09	2.52	11.09	5.41
12.32	2.52	12.32	5.5
13.59	2.54	13.59	5.5
14.79	2.54	14.79	5.5
15.29	2.54	15.29	5.5
16.02	2.54	16.02	5.5

The project finally concluded that use of Black liquor proves to be an effective surfactant for Micellar flooding in the depleted Bhogpara oil field of Upper Assam Basin by enhancing the oil recovery and reducing the residual oil saturation.

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