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The study of local polymers on enhance oil recovery

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ABSTRACT

The study of local polymer on enhance oil recovery is to fine outs the capacity of local material to enhance oil recovery. Locally sourced polymer from starch and Ogbono (irvingia gabonensis) seed were used to increase viscosity of brine, since it has been known for long that the efficiency of a water flood can be improved by lowering the water oil mobility ratio in the system, such a change leads to better sweep efficiency and also more efficient oil displacement in the swept zone. The required material for the mobility control has to be cheap and non-toxic because large volume are needed and later disposed of eventually to the environment. The experimental flow result show that viscosity range of 1.5(cp) to 3.0(cp) of the material used enhanced oil recovery and water breakthrough time retarded significantly while using local polymer. The maximum oil recovery recorded were 3.9cc, 2.8cc and 3.7cc for starch, ogbono and XCD polymer respectively at 2.0cp with corresponding breakthrough time of 44, 22 and 45 second respectively The good result may have resulted from the increase in the viscosity of the displacing fluid.

Key words: Oil Recovery, Polymer, Ogbono, Starch.

INTRODUCTION

Dependence of oil recovery on the displacing fluid-displaced oil mobility ratio during water injection operations has long been recognized. Displacement efficiency of the reservoir oil decreases with increasing mobility ratio. Therefore economic reduction of this parameter is an attractive approach to improving oil recovery. (Willhite and Green, 1998) stated that mobility ratio M is a universal guide to water-flood performance.

Mobility ratio M is defined as the ratio of mobility of displacing phase to that of displaced phase.

$$M = \frac{\lambda_{displacing}}{\lambda_{displaced}} \text{-- } 1$$

Mobility ratio M, for water flood can be defined as;

$$M = \frac{K_{rw}/\mu_w}{K_{ro}/\mu_o} \text{--} 2$$

Where K_{wr}, K_{ro}, is relative permeability to oil and water while μ_w, μ_o is viscosity of water and oil respectively

It is important in improved recovery techniques. Mobility is good in displacing oil when ($M < 1$), because low mobility increases sweep efficiency while high mobility ($M>1$) decreases sweep efficiency and result in early water breakthrough. Therefore controlling the viscosity of the fluid to give ($M< 1$) will depend on either increasing the displacing fluid viscosity or decreasing the viscosity of the displaced fluid.

Water flood mobility ratio can be controlled by dilute solutions of certain polymers, which provide a displacing fluid with considerably reduced mobility.(Ezeddin, 2000) reported that a number of other chemicals such as emulsion, biopolymers, foam and carbon dioxide activated silica gel, have the ability to increase the viscosity of water. Polymers particularly have the ability to lower mobility by reducing the relative permeability to water as well as increasing its viscosity (an index of mobility ratio improvement)

Addition of polymer increases the viscosity of the aqueous phase, which reduces the mobility of the phase, thus lowering. The presence of polymer does not reduce residual oil saturation except few polymers (Wang et al, 2000). However, it increases the sweep efficiency greatly. If the water flooding mobility ratio is high, the reservoir heterogeneity is serious, or combination of these two happens, polymer flooding will be useful (Lake, 1989). (Yang et al, 2006) observed that an incremental recovery over waterflooding of more than 20% original oil in place(OOIP) was obtained by injection of high molecular weight, high concentration polymer solution in Daqing field.

It has been established that an appreciable percentage of the original oil in place can never be recovered by the natural energy of the reservoir. (Craig, 1971) noted that at the completion of a water flood significant amount of oil still remains. Polymer augmented water flooding however stands the chance of improving recovery by mobilizing additional oil from reservoir pore spaces.

It is desired that in any water-flooding operations that the areal sweep efficiency be improved. (Pye,1964) pointed out that, if increased water viscosity could be economically realized, marked improvement in areal sweep efficiency would be realized in field operation. This reduction in mobility ratio is important because by properly controlling the mobility ratio between the oil and the displacing phase, important improvement in recovery can be achieved. The polymer for mobility control needs to be cheap because large volumes of water will be used, and it should be non-toxic because the water needs to be disposed of eventually as reported by (Onyekonwu, 2010).

(Ikeagwu et al, 2013) reported that mixture of alcohol and starch (ratio of 1:1) recovered the most oil compared to other mixtures. They attributed the result to low interracial tension between oil and water by alcohol and high viscosity of the displacing fluid by the starch which ensures good sweep efficiency.

This study involving experimental work, seeks to determine the suitability of locally sourced polymer as enhanced oil recovery agents and also find out to what extent increasing water viscosity by the addition of the local polymers can recover oil through control of mobility ratio. The economic merit of the study will be evaluated by laboratory test result.

MATERIALS AND METHODS

The experimental apparatus is comprised of the following components: Core flooding equipment, a physical model, crude oil, brine, polymer solutions obtained from XCD polymer, ogbono seeds and cassava starch, porous media, injection and production systems, and pressure monitoring system. Figure 1 shows the system assembly for the experiment. It consists of core holder, pressure gauge and the constant rate injection pump. The pump is a chem-tech series 100 pump, model X030, rated 220volts 50 Hz while the relevant properties of all fluids are presented in Table 1.

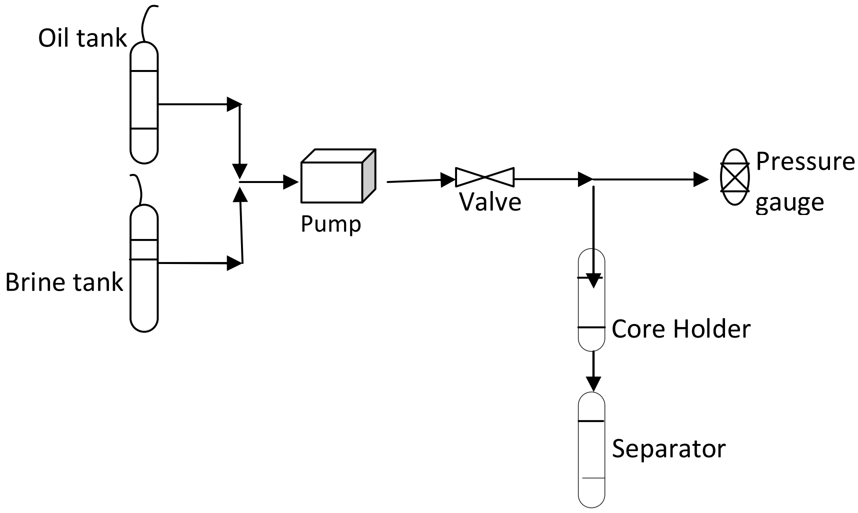

Fig 1 Schematic of core flood equipment

Table 1 - Properties of the cores and fluids

Type of sand	Sand stone
Core type	Unconsolidated
Average porosity ϕ	24.12%
Oil viscosity	4.0 cp
Oil density	0.86 g/cm^3
Oil API gravity	33.3 ^{0} API
Brine composition	30g/l NaCl
Brine viscosity	1.1 cp
Brine density	1.01 g/cm^3
Polymer used	XCD polymer, ogbono, cassava starch
Polymer viscosity range	1.5 -3.0 cp
Temperature	27 ^{0}C

Experimental procedure

Fourteen unconsolidated core samples were used for the experiment two as control sample for brine flooding while four each for starch, ogbono and XCD polymer flooding. The core samples were weighed and the pre-saturated dry weight recorded. The cores were carefully arranged in a saturator. Vacuum was connected and air evacuation carried out for 12 hours. The pore volumes of the cores were determined after saturation.

During this experiment, polymer solution of specific concentration was injected at a constant rate into a cylindrical core mounted in such a way that brine/polymer can be injected into the central axis. Pressure drops were measured across the entire length of the core. A constant injection rate of 1 cubic centimeter per minute (cc/min) was maintained until the pressure drop reached a steady state. Measurement of pressure drops were taken for all the core samples to determine the flow properties of the local polymers used for the core flooding. The principal objectives were to study the effect of each polymer type on water breakthrough time and oil recovery. Table 2 shows the result of weight and viscosity measurement.

In order to establish irreducible water saturation for each core sample, an oil flood was conducted by injecting crude oil into the cores until no more mobile water was observed at the outlet. Subsequently, the permeability to oil at irreducible water saturation**.**

In all cases, polymers (powder) of different concentrations were dissolved in heated 3% brine solution at about 40^{o}C. Polymer was added slowly while stirring to allow for quick dispersion of polymer particles. The solution was allowed to cool down to laboratory temperature. The viscosity was measured with Ostwald glass viscometer at a laboratory temperature of 27^{o}C. Polymer concentration and viscosity values are shown in Table 2.

Table 2 – Concentration and Viscosity of polymer solution

Core samples	Starch concentration C (g/L)	Ogbono concentration C (g/L)	XCD Polymer concentration C (g/L)	Viscosity in 3% NaCl brine (cp)
C, G, K	3.8	2.0	0.9	1.5
D, H, L	5.0	4.0	1.7	2.0
E, I, M	6.3	6.0	2.3	2.5
F, J, N	7.5	8.0	3.2	3.0

RESULTS AND DISCUSSION

In this study, four different polymer concentrations that yielded four different viscosity values for each polymer were used. Recovery of oil and water was done in a 20 ml graduated cylinder from the core holder. Flow test was run until water breakthrough was observed from the outer port of the core holder

In all cases, recovery of oil and water was carried out in a 20ml graduated cylinder. The recovery and mobility ratio was computed from the fourteen independent runs.

The oil resulting from the use of polymer was computed by comparing the average brine flood recovery value in the control samples (core A and B) with recoveries from other cores flooded with starch, ogbono and XCD polymer. These incremental oil recoveries were used to evaluate the polymer flood efficiency.

Tables 3, 4, 5 and 6 shows the recoveries from the cores after flooding with brine, starch, ogbono and XCD respectively, while Figures 2, 3, 4, and 5 are Chart of breakthrough time verses polymer viscosity, Graph of breakthrough time verses polymer viscosity, Chart of oil recoveries verses polymer viscosity and Graph of oil recoveries verses polymer viscosity respectively.

Table 3 - Oil recovery from control sample A and B

Core sample	Pore volume	Brine concentration g/L	viscosity μ (cp)	Volume of brine displaced (cc)(Oil in place)	Breakthrough time (min)	Oil recovered at breakthrough (cc)
A	15.33	30	1.1	3.8	20	0.8
B	17.33	30	1.1	4.4	17	0.8

Table 4 - Oil recovery during starch flood

Core sample	Pore volume	Starch concentration g/L	viscosity μ (cp)	Volume of brine displaced (cc)(Oil in place)	Breakthrough time (sec)	Oil recovered at breakthrough (cc)
C	15.90	3.8	1.5	5.6	27	3.0
D	11.63	5.0	2.0	5.7	44	3.9
E	16.08	6.3	2.5	5.6	48	2.0
F	15.77	7.5	3.0	4.5	50	1.0

Table 5 - Oil recovery during ogbono flood

Core sample	Pore volume	Ogbono concentration g/L	viscosity μ (cp)	Volume of brine displaced (Oil in place)	Breakthrough time (sec)	Oil recovered at breakthrough (cc)
G	17.37	2.0	1.5	5.0	25	2.2
H	12.45	4.0	2.0	4.8	22	2.8
I	16.48	6.0	2.5	4.9	11	1.6
J	14.16	8.0	3.0	4.0	11	1.6

Table 6 - Oil recovery during XCD polymer flood

Core sample	Pore volume	XCD polymer concentration g/L	viscosity μ (cp)	Volume of brine displaced (Oil in place)	Breakthrough time (sec)	Oil recovered at breakthrough (cc)
K	13.09	0.9	1.5	5.0	40	2.6
L	17.23	1.7	2.0	7.0	45	3.7
M	12.97	2.3	2.5	6.2	46	4
N	13.98	3.2	3.0	7.5	50	4.9

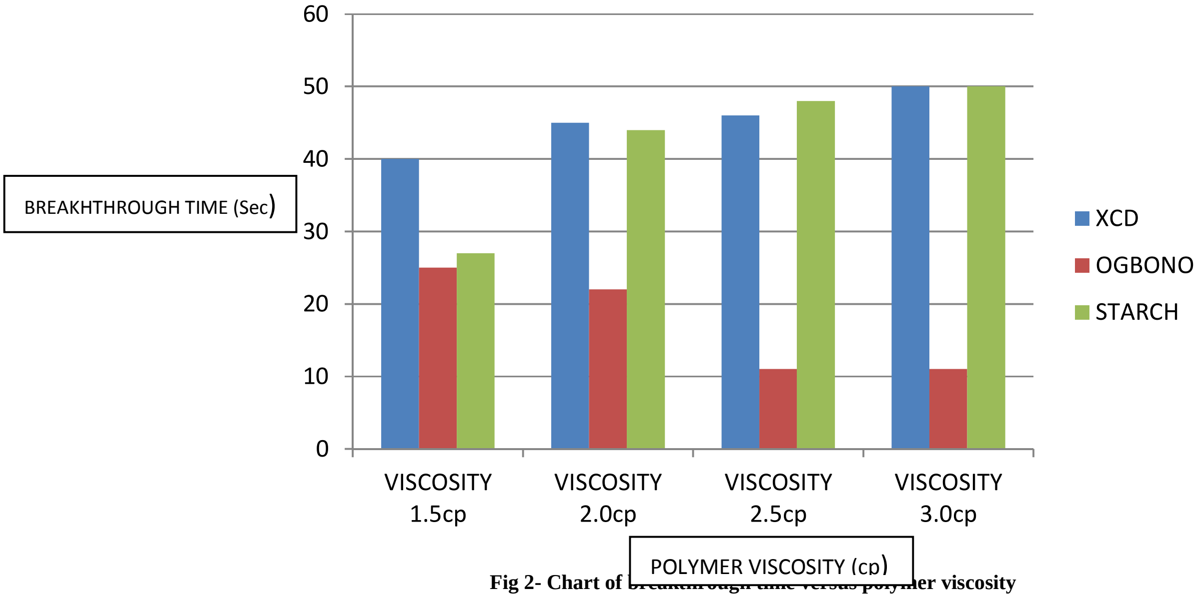

Fig 2- Chart of breakthrough time versus polymer viscosity

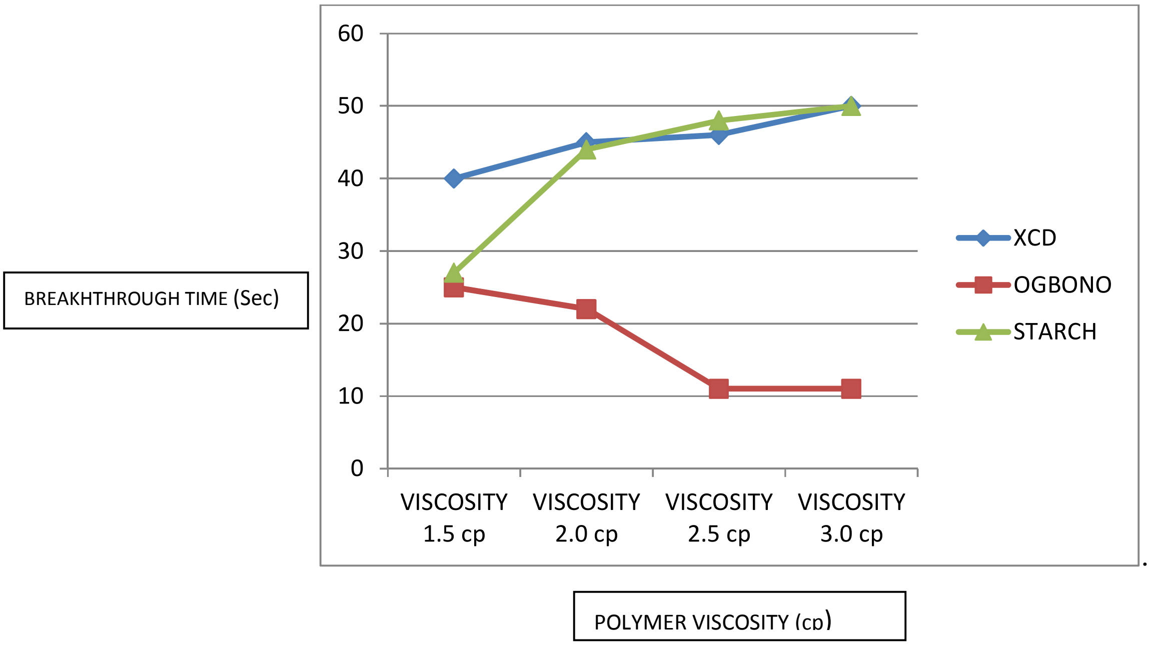

Fig 3 - Graph of breakthrough time versus polymer viscosity

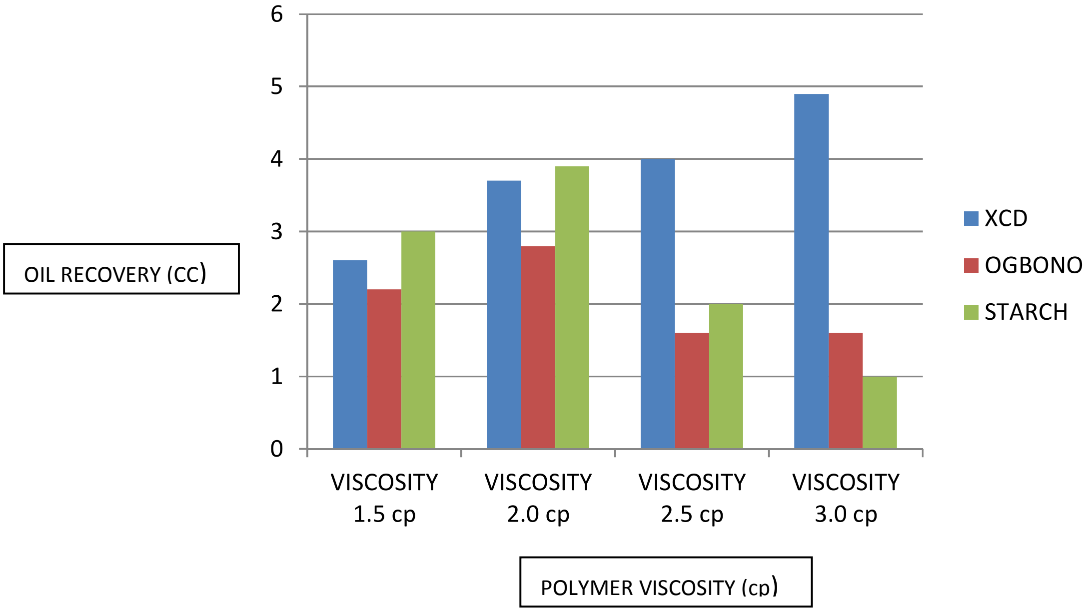

Fig 4 - Chart of Oil recovery versus polymer viscosity

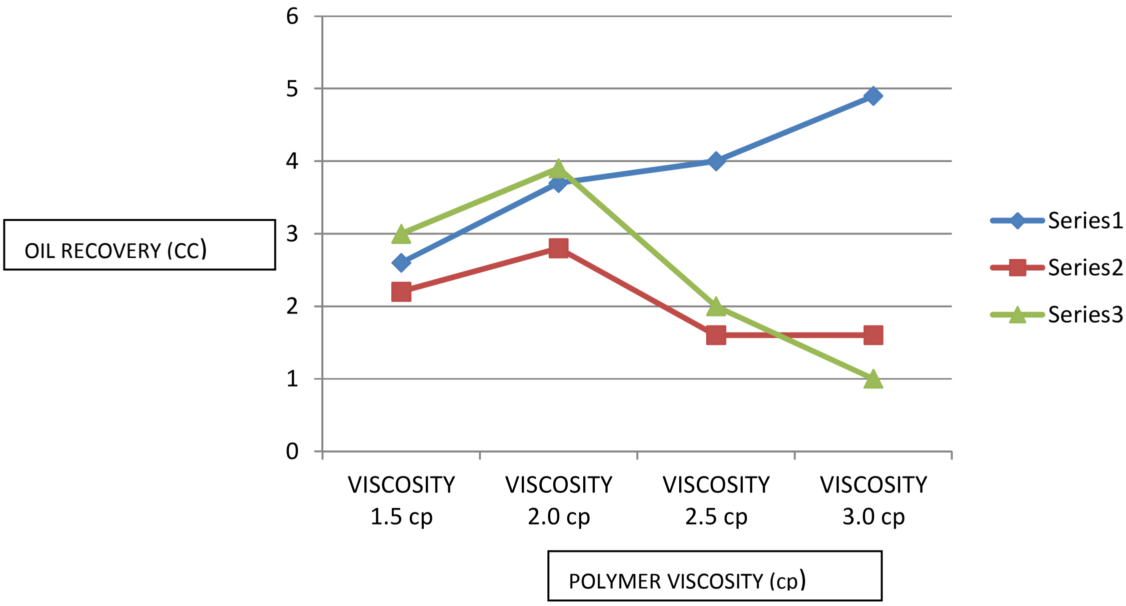

Fig 5 - Graph of Oil recovery versus polymer viscosity

Polymer concentration was found to play an important role in oil recovery. The effect of polymer solution concentration is more understandable because the higher concentration polymer has a larger apparent viscosity.

Table 4 shows the amount of oil recovered and the breakthrough time for starch solution in the cores that were used. The role of viscosity is clearly demonstrated in cores C, D, E, and F compared with the control sample cores A and B. The performance of all the polymer solutions is better than 1.1 cp brine flood in the control samples.

For starch and ogbono solution, viscosity increase resulted in steady increase in recovery up to 2.5 cp after which recovery began to drop. At oil recovery of 1 ml from core F, the core stopped responding to flooding as no more oil or water came out. This suggested an indication that polymer must have blocked the pore spaces in the core.

This loss was viewed as detrimental because more oil would have been recovered. This loss probably resulted from plugging by high viscosity polymer.

However, oil recovery increased steadily with increase in XCD polymer concentration.

It was also observed during ogbono flooding, that at high viscosity values, recovery was almost the same.

Comparatively, starch solution performed more than ogbono solution because more recovery was obtained from starch using solution of the same viscosity.

In the case of water flood in the control samples, the water breakthrough time occurred after 0.8 ml of oil had been produced at 20^{th} and 17^{th} minutes respectively. Water cut then rose rapidly to a high value.

At high viscosity values, the breakthrough time was retarded in the cores flooded with starch solution. It was observed that at viscosity values above 2.0cp, even though water breakthrough time was retarded, this did not result into more oil recovery.

In cores flooded with ogbono solution, breakthrough time was retarded up to viscosity value of 2.0cp, but this breakthrough time declined rapidly thereafter. This was suspected to be as a result of the slimming characteristics of ogbono solution which increases as polymer concentration increases. However, ogbono polymer mobilized more oil than brine solution.

In all cases, except for ogbono solution at high concentration, experiment results showed that breakthrough time improved with increasing polymer concentration.

CONCLUSION

Based on the experimental results obtained from this study, the following conclusions are reached:

- Injection of starch and ogbono solutions into core samples produced more oil than did brine injection. Oil recovery increases significantly when the mobility ratio is reduced.
- During starch and ogbono flooding, low amount of polymer concentration was required to effectively improve mobility control and also oil recovery
- Oil recovery improvement was achieved with starch polymer than with ogbono polymer.
- Result showed that there existed a viscosity value for the local polymer solution at which oil is best recovered which is 2.0cp.

Nomenclature

S_w = Water saturation
qt = injection rate,
Kw = permeability of rock to water,
Ko = permeability of rock to oil,
λ = Mobility
μ_w = viscosity of water,
μ_o = viscosity of oil and F_w is dimensionless
N_p = oil recovery,
A = area,
U = Darcy's velocity in cm/s
K = permeability in Darcy
ΔP = pressure drop in atmosphere
L = length of core cm
cc = cubic centimeter
μ = viscosity in cp

Subscripts

$_{O, p, w}$ = oil, polymer solution and water.

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