**The Effect of Polymers on Permeability During Polymer Flooding**

**ABSTRACT**

Polymer adsorption onto rock surfaces is likely one of the causes of disproportionate permeability reduction. Polymers are used for conformance control to block or reduce the fluid transmissibility of high permeability channel without causing formation damage to the less permeable channel which could result in complete shut off the displacing fluid from entering and displacing oil from such zones. This research used convectional polymers such as hydrolyzed polyacrylamide, xanthan gum and a local polymer obtained from caladium bicolor tuber to compare the permeability alteration of this polymer and its oil recovery ability using four core samples obtained from a Niger delta reservoir. The result after flooding the core samples with the different polymer showed permeability reduction; hydrolyzed polyacrylamide, reduced the permeability by 25.4%, Xanthan gum and caladium bicolor starch reduced by 9.76%, caladium bicolor starch by 6.92% and gum guar and caladium bicolor starch by 4.39% respectively. The oil recovery rate for each core sample was at a close range as hydrolyzed polyacrylamide had a recovery of 46.6%, Xanthan and caladium bicolor starch, had a recovery of 42.7%, caladium bicolor starch, 46.9% and guar gum and caladium bicolor starch, 47.1% oil recovery. The results obtained indicated permeability reduction from each of the polymers after flooding.

**Keywords:** Polymer flooding, Biopolymer, Permeability alteration,

**INTRODUCTION**

Polymers are large molecular compounds in the form of long chains. [10]Nasiru *et al*.,2020. Polymer is made up of a combination of smaller subunits. Polymers are classified in two forms, synthetic polymers and biopolymers. Synthetic polymers are produced in the laboratory, examples includes nylon, polyethylene, polyproppylene, polyacrylamide (PAM), hydrolized polyacrylamide (HPAM), teflon and epoxy. The most popular polymers used for enhanced oil recovery in the industry is hydrolysed polyacrylamides (HPAM) and they are straight chain polymers made up of acrylamide monomers. HPAMs are often referred to as partially hydrolysed polyacrylamides, as the degree of hydrolysis – a chemical reaction in which the oxygen double bond reacts with a water molecule – varies and alters the characteristics of the polymer, such as shear degradation and thermal stability.

Permeability of a porous medium is the ability to transmit fluid flow. This means that a high permeability reservoir implies high production of hydrocarbon and vice versa for a low permeability reservoir. Hence proper understanding of permeability variations is vital across the reservoir zone in the selection of production wells [3]Amirhossein et al, 2023). Permeability depends on porosity, pore geometry and structure, Pore geometry is a function of the effective confining stress that causes permeability alteration around the near – well zone of the resevoir. Permeability reduction has an adverse effect on flood productivity most especially naturally low permeability reservoirs. The consequence of this is irreversible damage to the reservoir and hence poor produvtivity efficiency and higher cost of production [8]Manichand and [13]Seright,2014.

According to [11]Ogunkunle et al, 2022 in their research that the level of polymer retention is directly connected to the degree of permeability alteration.

[7]Liu et al,2023 in their study revealed that high pore volume displacement has an effect on enhanced oil recovery. They concluded that high pore volume may result in high permeability of the reservoir.Research as shown that the pore structure of oil reservoir is altered during flooding which leads to varying porosity and permeability and impacts on oil recovery efficiencies [2]Afrough et al.,2017.

Polymer flooding is a method of chemical enhanced oil recovery technique that involves the injection of polymer into a heterogeneous reservoirs with the aim of decreasing the mobility ratio of oil to improve oil production. However, the injection of polymer also have some disadvantage effect that results in severe polymer induced permeability reduction due to the reaction between the injected polymer and the rock near the well bore of the reservoir [6]Khaled,2022. Polymer flooding is majorly adopted in enhanced oil recovery in cases of unfavorable mobility ratio during water flooding. This is a likely condition for highly viscous reservoiirs with high degree of areal or vertical heterogeneity. Polymer flooding is one of the most used chemical enhanced oil recovery globally because it is the most successfully applied EOR at commercial scale in light , medium and heavy viscosity oil where thermal enhanced oil recovery is uneconomical [4]Delamaide et al, 2014. Polymer flooding comprises of the following mechanism; rheology, salinity, variation, permeability reduction, retention and adsorption [5]Francisco et al., 2022.

Field results from Shuanghe oilfield have shown that successful polymer flooding have remarkable reduction effect on reservoir permeability [15]Standnes,2014. Permeability reduction was noticed following the injection of a polymer solution into the reservoir as a result of polymer adsorption by the rock surface anv via mechanical entrapment of polymer molecule that causes formation damage [1]Abdelaziz et al.,2023. [9]Manichand and Seright (2014) in their studies stated that about half of Xanthan (biopolymer) retention was as a result of adsorption and the other half as a result of mechanical entrapment whereas, for hydrolized polyacrylamide 35.2% of retention is attributed adsorption and 64.8% to mechanical entrapment.[13]Seright and Wang,2023. Experimental analysis indicated that the impact of viscosity on relative permeabilities is remarkably insignificant. Sheng in his findings reported that relative permeability curve for polymer solution is lower compared to corresponding relative permeability curve to water before polymer transport as a result of pemeability reduction due to polymer adsorption mechanism.

Research some decades ago, expressed concerns on polymer adsorption in porous medium and its effect on permeability reduction. It was concluded that polymer treatment reduces permeabbility by adsorption of polymer and reduction in pore radii , this reduction is known as residual resistance factor [18]Zheng et al.,2000.[17] Zaitoun et al.,1998 reported that oil and water can be altered by wall effects as a result of polymer adsorption.

Polymer flooding plays a vital role in mobility ratio control aiding sweep efficiency but also have the risk of severe polymer induced permeability due to polyer/rock interaction near the wellbore or in-depth or the reservoir. Various factors affects the extent of polymer induced permeability reduction such as mineralogy, oil saturation, temperature, formation water salinity, rock pore structure, polymer type, polymer molecular weight, shear rates in porous medium [6]Khaled, 2022.

In recent times the use of biopolymer is becoming more popular due to its enviroment frienldy properties. Some biopolymers used for EOR includes xanthan gum, welan gum, guar gum, acacia gum, gum arabic and starch has been in use instead of synthetic polymers.These biopolymers improves the mobility ratio by alters the viscosity of the displacing fluid and aids in permeability reduction [12]Samah et al., 2023. This is crucial in producing oil in more pocket friendly and environment friendly way.[9] Matovanni et al.,2023 discussed the use of different biopolymers (Xanthan gum, guar gum and starch) and modification of their properties to enhance oil recovery.

**MATERIALS AND EQUIPMENT**

Three different polymers were used; Hydrolyzed polyacrylamide, Xanthan gum, Guar gum and polymer obtained from caladium bicolour tuber. Crude oil, distilled water, industrial sodium chloride, 4 core samples obtained from a Niger delta resevoir and crude oil sample from a flow station in Niger Delt.The equipment used include; Core flooding equipment, permeameter, porosimeter pycnometer, electric weighing balance, measuring cylinder, receiver tubes, viscomter, knife, Electric blender and sieve.

This experiment was conducted at Corefluid Energy Service, Port Harcourt, Rivers State, Nigeria.

Table 1, shows the petrophysical properties of the crude oil uesd in the experiment.

**Table 1: Petrophysical property of the Crude oil**

|  |  |  |  |
| --- | --- | --- | --- |
| Crude Oil Sample | Density | Specific gravity | API gravity |
| Medium crude | 0.9346 | 0.92 | 22.1 |

**Sample Preparation**

The polymers used in this work was gotten from chemical and oil field services Laboratory, University of Port Harcourt.

Caladium tuber was freshly harvested from a bush in Emohua local government area of Rivers state. The tubers of caladium bicolor were washed properly to remove debris of soil contamination with s distilled water. The tubers were peeled and sliced into smaller pieces with sterilized knife. They were air-dried at room temperature to remove moisture. It was blended to fine powders using electronic grinder. The blended samples were screened through a fine mesh sieve (sorting) to ensure uniform fine powder. 10000ppm of the caladium bicolor was prepared.

The polymers used was prepared to a concentration of 10000ppm solutions.

The hydrolyzed polyacrylamide and the caladium bicolor starch were flooded individually while the Xanthan gum and Guar gum were used in combination with the starch from caladium bicolor.

**Core sample Characterization**

Five core samples obtained from Niger delta reservoir were taken to the laboratory, cleaned with toluene and methanol to remove salts and hydrocarbon contaminants.

The porosity and permeability of each of the core samples were ascertained using the porosimeter and permeameter respectively. The permeabilities of the core samples were evaluated before and after flooding with the different polymers..

**RESULTS AND DISCUSSION**

Table 2 shows the lithlogical properties of 4 core samples obtained from a Niger delta reservoir with varying depths ranging from 8767.20ft to 8784.20ft and porosity range of 22.1% to 24.2%. The porosity result indicates that this is an heterogeneous formation having variarations in porosity with depths.

**Table 2: Core Sample Properties**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Sample ID | Depth, ft | Length of core,cm | Diameter of core, cm | Grain density,g/cc | Pore volume of core,cc | Porosity of core, % |
| S1 | 8776.20 | 6.516 | 3.742 | 2.64 | 17.9 | 25.5 |
| S2 | 8775.10 | 5.630 | 3.760 | 2.64 | 15.6 | 22.1 |
| S3 | 8784.20 | 6.821 | 3.782 | 2.65 | 19.2 | 24.2 |
| S4 | 8767.20 | 6.830 | 3.761 | 2.63 | 19.0 | 24.7 |

Table 3 describes permeabilities of the individual core samples that were evaluated before and after flooding. A remarkable alterations in core sample permeabilities were observed . All the core samples permeabilities reduced after flooding with the various polymers used for flooding.

Table 3 : Permeabilities of Core Samples Before and After Flooding.

|  |  |  |  |
| --- | --- | --- | --- |
| Sample ID | Permeability before(4500psig NOB), md | Permeability after (4500psig NOB), md | % Permeability Reduction |
| S1 | 4600.50 | 3434.00 | 25.4 |
| S2 | 4410.40 | 3980.00 | 9.8 |
| S3 | 4300.50 | 4002.80 | 6.9 |
| S4 | 5209.00 | 4980.20 | 4.4 |

The volume of oil recovered before and after flooding was recorded as shown in Table 4.

Table 4: Volume of Oil Recovered Before and After Flooding

|  |  |  |  |
| --- | --- | --- | --- |
| Sample ID | Oil Recovery before, cc | Oil Recovery After, cc | % Oil Recovery |
| S1 | 22.1 | 11.8 | 46.6 |
| S2 | 17.1 | 9.8 | 42.7 |
| S3 | 19.2 | 10.2 | 46.9 |
| S4 | 22.1 | 11.7 | 47.1 |

Table 4 shows varying degree of oil production before and after flooding at a close range of 46.6% to 47.1%, the least percentage oil recovery of 42.7% was obtained from the caladium bicolor starch and the maximum from the combination of caladium bicolour starch and guar gum polymer flooding.

Figure 1 shows the effect of the various polymers used for flooding on permeability and percentage oil recovery.

Figure 1.Effect on percentage permeability reduction on percentage oil recovery

From the result obtained, there were variations in the degree of permeabilty alteration from each polymer due the various level of polymer retention as confirmed in the research conducted by [11]Ogunkunle et al., 2022.HPAM permeability reduced by 25.4%, Xanthan gum and Caladium bicolor combination altered the permeability by 9.8%, Caladium bicolor starch by 6.9% while the combination of Cladium bicolor starch and guar gum had 4.4% alteration.

Figure 2 shows the effect of pore volume on percentage oil recovery after flooding each of the core sample with different polymers.

Figure 2: Pore volume on Percentage Oil Recovery

Pore volume is vital in oil recovery since oil flows via pores. The variation in the pore volumes led to variations in percentage oil recovery. Higher pore volume produced more oil becouse there is a higher contact between the polymer and the oil resulting in enhanced oil recovery. This is at par with [9]Liu et al.,2023 in their confirmed that high pore volume has an influence in oil recovery.

**CONCLUSION**

From the results obtained polymer flooding alters the permeability of the reservoir as observed from experimental analysis ,there was significant reduction in permeabilities of the core samples.Varying degree of reduction was reported as a result of the adsorption and retention properties of the different polymers. Even though, there was reduction in oil recovery after flooding, the reduction is not a function of permeability reduction alone, it could also be due depletion of the reservoir and other factors. The result showed that maximum permeability alteration was obtained from HPAM and the least permeability change was from the combination of Caladium bicolor starch and guar gum.

Abbreviations

EOR: Enhanced Oil Recovery

HPAM : Hydrolzed polyacrylamide

S1: Hydrolyzed polyacrylamide

S2: Xanthan gum and Caladium bicolor starch

S3: Caladium bicolor starch

S4: Caladium bicolor starch and Guar gum

NOB: Net overburden

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