International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

Research Article

Simulating Impact of Alkaline-Polymer Flooding in Sandstone Reservoirs of Lower Guru formation, A Case Study

Imtiaz Ahmed†*, Dr. Abdul Haque Tunio†, Engr. Habibullah†, Engr. Temoor Muther‡, and Engr. Zafarullah†

†Institute of Petroleum and Natural Gas Engineering Mehran University of Engineering and Technology, Jamshoro, Pakistan
‡ Institute of Petroleum and Natural Gas Engineering MUET, Shaheed Z.A. Bhutto Campus Khairpur Mir's, Sindh, Pakistan

Received 18 Dec 2020, Accepted 20 Feb 2021, Available online 22 Feb 2021, **Vol.11, No.1 (Jan/Feb 2021)**

Abstract

Hydrocarbon is the prominent in fulfilling the global energy requirement. It comprises almost sixty per cent of the world's energy consumption which demands further extraction of remaining oil. This residual oil can be extracted viably through the application of chemical methods. Additional oil recovery factor from the field performance is low while alkaline injection alone. Mobility control is very important; therefore, the alkaline flooding coupled with polymer flooding is good for controlling mobility. To provide a critical review of Alkaline-Polymer flooding, this paper presents a comprehensive study. This paper covers the following content: Interaction of Alkali-Polymer, technical screening criteria, simulation work and summary of field projects. Analysis was carried out to compare the different scenarios of polymer, alkaline, and alkaline & polymer of injected slugs and their performance in terms of corresponding oil recoveries. This study is aimed at observing comparative simulation study by using alkaline and polymer separately and in combination results maximum productivity of oil. The scope of this proposed work is that it brings about an optimized condition where various concentrations of alkaline and polymer can yield required properties and interfacial tension for its application as EOR in the sandstone reservoir. It was observed from the results that the combination of chemicals has increased the additional recovery more than 20%. It provides incremental oil production after primary and secondary recovery, as it is needed to fulfill the world's rising energy demand. In the contrast with the carried analysis the optimum combination of alkali-polymer system has been recommended in lower Goru formation for additional oil recovery.

Keywords: *Chemical EOR, Alkaline Flooding, EOR Simulation, Polymer Flooding AP Flooding.*

1. Introduction

Hydrocarbon fulfills wide range of the world's energy demand, and it is used as prominent source of energy in the world. Almost sixty per cent of the world's energy is obtained from oil and natural gas. Increased oil consumption worldwide demands residual oil to be produced. One way of extracting remaining oil is adopting the secondary recovery method. Both primary recovery & secondary recovery methods provides or able to recover almost thirty five (35) to fifty (50) percent of original oil in place from oil reservoirs. (Yugal Kishore Maheshwari, 2017).

With the passage of time the consumption and demand of energy is rising worldwide because of industrial revolution and population growth. Rising demand day by day made the petroleum industry to think of further recovery of hydrocarbons from a reservoir within economic limits. It can be done by revolutionary techniques for developing the mature fields and depleted reservoirs (Energy, 2014).

*Corresponding author's ORCID ID: 0000-0002-7147-4364
DOI: https://doi.org/10.14741/ijcet/v.11.1.8

At the primary depletion, generally one third quarter of the initial oil in place (OOIP) is left underground because the only drive energy which was there has been depleted (Ahmed, 2018). To overcome this menace, the depleted reservoir needs additional energy so that recoverable left behind can be extracted. It illustrates different types of oil recovery mechanisms. Very common method for having under saturated oil reservoirs recoveries and/ or pressure maintenance includes water flooding (Ahmed, 2018).

There are essential parameters required to design a field pilot project and many other elements are needed to be looked as such as geometry of the reservoir, reservoir fluid saturation, depth of the reservoir, properties of the fluids, petrology and lithology (Ahmed, 2018). Many research workers focused on minimum screening criteria including economical and technical for a successful water flood project since the past decades. Water flood projects are quite expensive as they require the surface facilities for handling water, additional flow lines, injection systems, and the injection and production flood pattern. In some conditions the location and size of the reservoir mismatched the conventional water flood project with in economic limits.

2. Methodology

The purpose of a simulation study was to evaluate the effectiveness of the three scenarios, i.e. scenario 1: Water, scenario 2: Water-Polymer and scenario 3: Water, Alkaline-Polymer flooding with the intention to see which is the most suitable and cost-effective and efficient method in terms of production in the sandstone formation. Also, study will be carried out to compare both the scenarios with conventional water flooding. To collect data and model a reservoir, different research papers will be studied and analyzed. Finally, a simulator named Eclipse-(E-100) will be used to evaluate performance for the various scenarios. The reservoir model is simulated for heavy crude oil by simulator by Eclipse E-100 (2014.1) the base model is similar manner of a three dimensional model it includes the three directions or dimensions DX, DY and DZ having the cells 20, 20, and 9 respectively as model is shown in **Fig. 1**. The other simulation input parameters of reservoir model like porosity of 0.2 % and permeability X, Y & Z directions are 200, 150 & 20 mD respectively having the depth of reservoir 8020ft.

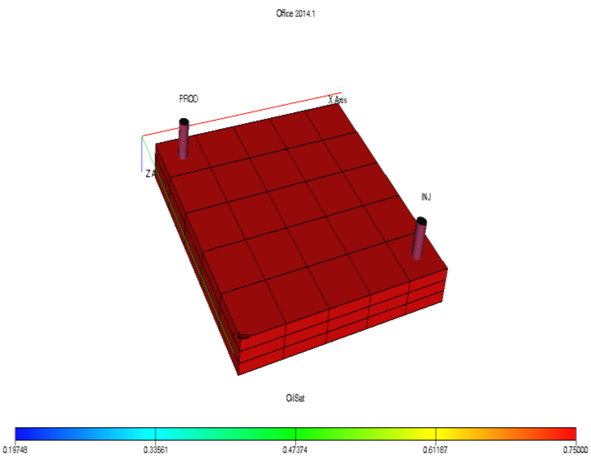

Fig. 1. Reservoir Model

Table 1: Reservoir parameters

Parameter	Range
Oil Viscosity, cp	0.318
API Gravity, API°	32.7
Oil density, Kg/m³	859.5
Oil FVF, Rm³/Sm³	1.038
Water density, Kg/m³	1033
Initial pressure, psia/bar	4800/ 330.95
Reservoir temperature, °C/°F	98/ 208.4

The base model was used for illustration of chemical injection behavior in terms of production enhancement especially polymer and alkaline with different combinations in lower goru formation

3. Results and Discussion

3.1 Production rate for all cases

The production rate remains stable at 10000 STB/D for initial 200 days and later it declines and stable with similar trend and it reaches to 2000 STB/D for total producing of 2000 days with scenario-1 as shown in **Fig. 2**. Similarly for scenario-2 the production rate remains stable at 10000 STB/D for initial 200 days and later it declines steady up to 6000 STB/D for 1000 days. Then for the next 400 days the production rate remains constant at 600 STB/D. After that it again declines. The final production rate at 2000 days is 3200 STB/day as it could be clearly shown in **Fig. 2**. On other hand for scenario-3 production rate also remains stable at 10000 STB/D for initial 200 days and later it declines frequently up to 6000 STB/D for 1000 days then for the next 400 days the production rate remains constant. After that it again declines. But final production rate at 2000 days is observed greater to scenario-2 3800 STB/day with polymer and alkaline flooding as shown in **Fig. 2**.

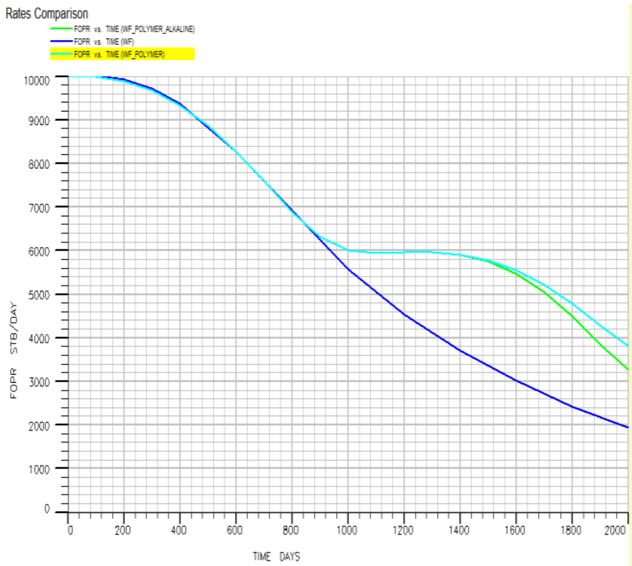

Fig.2 Production rate response for Water-Alkaline-Polymer

3.2 Cumulative oil production for all cases

The total oil production denoted by keyword FOPT known as cumulative oil production. The total amount of oil that has been extracted for 2000 days is 1.16 billion STB for scenario-1. For scenario-2 the cumulative oil production is 1.37 billion STB for total producing days as shown in figure 4.2. While the cumulative oil production of scenario-3 for 2000 days have been observed to be 1.38 billion STB as shown in **Fig.3**.

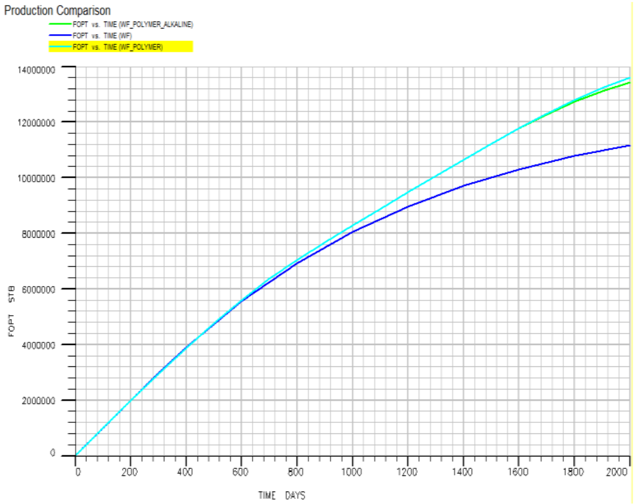

Fig.3 Cumulative oil production response for water-Alkaline and Polymer

3.3 Water production rate for all cases

The water production rate for initial 200 days is negligible and later it starts producing with constant rise with similar trend. The ultimate water production rate at for total producing days reaches at 8000 STB/D for scenario-1. Then for scenario-2 the water production rate initially 200 days was negligible and later it starts producing with constant rise with similar trend up to 4000 STB/D for next 800 days then for the next 400 days the production rate remains almost stable as shown in **Fig.4**. Later on it again starts rising. The final water production rate at 2000 days reaches at 6200 STB/D. As of **Fig.4** for scenario-3 the water production rate was insignificant for initial 200 days. Later it starts producing with constant rise with similar trend up to 4000 STB/D for next 800 days then for the next 400 days the production rate remains almost stable as shown in **Fig.4**. Later on it again starts rising. The final water production rate for remaining 600 days reaches to 6750 STB/D with water-polymer-alkaline flooding.

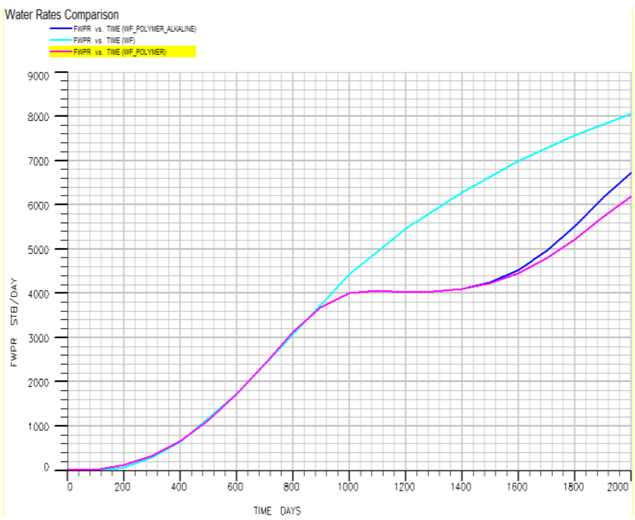

Fig.4 Water production rate response for Water-Alkaline-Polymer

3.5 Comparative analysis

The comparative analysis were carried out for the major production performance parameters i.e. oil production rate, cumulative oil production, water production rate, cumulative water production and water cut with the help of excel generated graphs as given below for all scenarios.

3.5.1 Oil production rate

The oil production rates were found to be similar and stable at 10.0 MSTB/day during 200 days of production for all scenarios. It was observed from the simulation results that for scenario-1 oil production rate was reduced continuously and reached to 2000 STB/day up to total producing time of 2 thousands days. But for both scenarios 2 & 3 rate was declined with slower and steady and reached to 3200, 3800 STB/day for scenario-2 & scenario-3 respectively as shown in **Fig.5.**

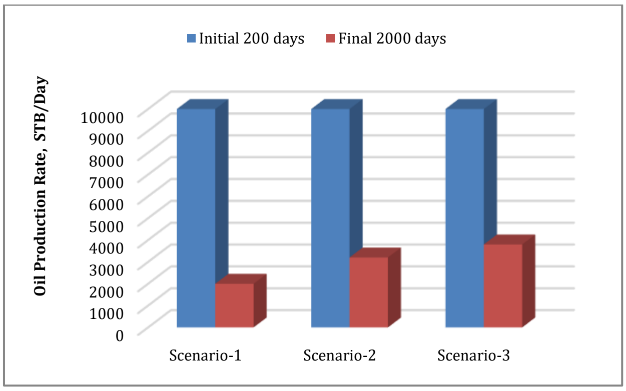

Fig.5 Oil production rate for all scenarios

3.5.2 Cumulative oil production

The cumulative oil production was found to be 1.16 billion STB from simulation of water flooding (scenario-1) for production span of 2000 days. While for scenario-2 and scenario-3 the cumulative oil production was enhanced to 1.37 billion STB and 1.38 billion STB respectively as shown in **Fig.6**.

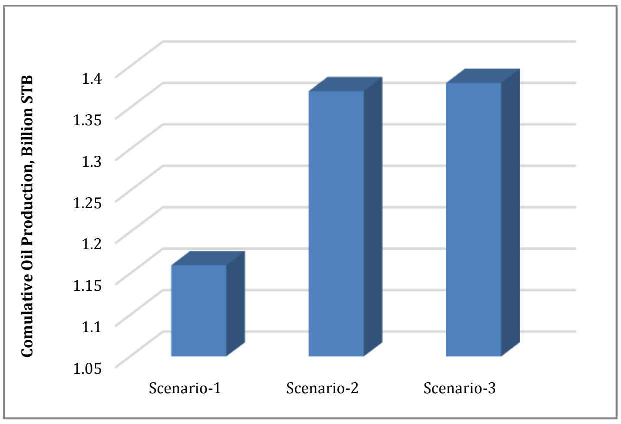

Fig.6 : Cumulative oil production for all scenarios

3.5.3 Water production rate

The water production rates were found to be negligible during 200 days of production for all scenarios. It was observed from the simulation results that for scenario-1 the ultimate water production rate increased continuously and reached to 8000 STB/day for 2 thousand days of production. For scenario-2 initially it was insignificant which later rose to 4000 STB/day for 800 days then it remained stable for next 400 days and it again started rising and reached at 6200 STB/day at the end of production time. For scenario-3 the water production rate was similar to that of scenario-2. But for last 600 days it rose sharply and reached to 6750 STB/day as show in **Fig.7**.

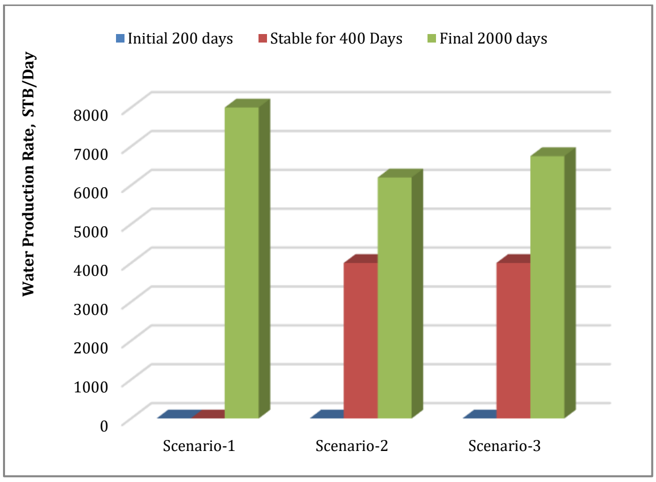

Fig.7 Water production rate for all scenarios

3.5.4 Cumulative water production

The cumulative water production was found to be 8.8 million STB from simulation of water flooding (scenario-1) for production span of 2000 days. While for scenario-2 and scenario-3 the cumulative water production was reduced to 6.4 million STB and 6.6 million STB respectively as shown in **Fig.8.**

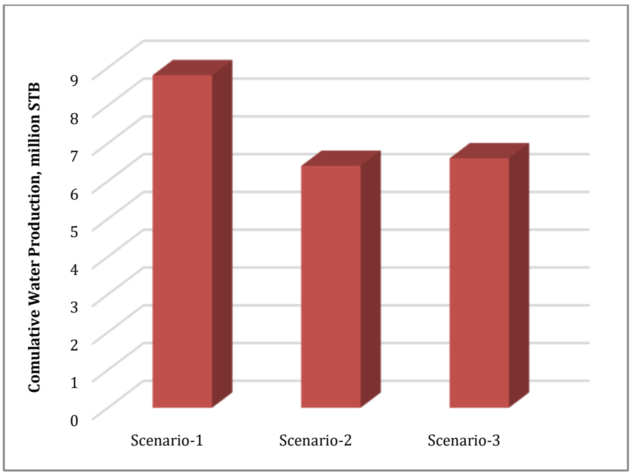

Fig.8 Cumulative water production for all scenarios

3.5.5 Water cut

Initially the water cut was found insignificant for initial 200 days for all scenarios. While for scenario-1 it increased to 0.8 but for scenario-2 after 200 days of production it increased to 0.4 for 1000 days then for next 400 days it remains stable and it again rose to 0.62. Whereas for scenario-3 it increased to 0.4 for 800 days after that it remained stable for next 400 days and it again rose to 0.68 as shown in **Fig.9**.

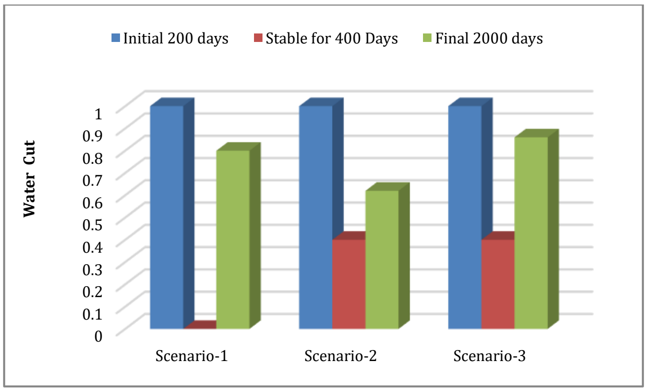

Fig.9 Water cut for all scenarios

3.5.6 Recovery factor

Recovery factor for scenario-1 was found to be 52%, which is lower than the scenario-2 and scenario-3. Whereas for scenario-2 and scenario-3 the recovery factor is almost same as 62.5% and 63.2% respectively as shown in **Fig.10**. The recovery factor for last two scenarios is significant that shows the viability for implementation of polymer and polymer-alkaline flooding in sandstone reservoirs.

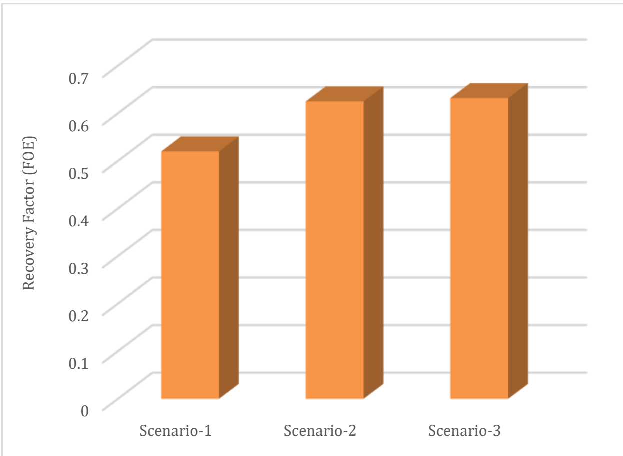

Fig. 10 Recovery factor for all scenarios

Conclusion

The cumulative oil production and water production of polymer and polymer-alkaline flooding is greater and lower than that of the water flooding respectively.

It was observed from the results that the combination of chemicals has increased the additional recovery more than 20%.

It provides incremental oil production after primary and secondary recovery, as it is needed to fulfill the world's rising energy demand.

The recovery factor for polymer and polymer-alkaline flooding methods are significant that shows the viability for implementation of polymer and polymer-alkaline flooding in sandstone reservoirs.

Simulation technique is the prominent tool for reservoir modeling and future performance prediction of recovery. It enables the reservoir engineer to adopt optimal technology and suitable operational parameters for enhancement of recovery. Alkaline polymer flooding has the potential to boost the fluid recovery. It also provides the best solution to maintain the reservoir pressure for the long period of recovery.

Recommendation

This paper suggests the AP synergy need to be further studied with more experimental measurement and theoretical analysis.

Further the comparative simulation study for vertical and horizontal well could be carried out for production enhancement and their economical comparison.

References

Ahmed, T. (2018) Reservoir engineering handbook, Reservoir Engineering Handbook. doi: 10.1016/C2016-0-04718-6.

Al-Hashim, H. S. et al. (2007) 'Alkaline Surfactant Polymer Formulation for Saudi Arabian Carbonate Reservoirs'. doi: 10.2118/35353-ms.

Alsahid, Y. A. et al. (2017) 'Alkaline Surfactant Polymer Flooding: What Happens at the Pore Scale?', 79th EAGE Conference and Exhibition 2017 - SPE EUROPEC. doi: 10.3997/2214-4609.201701591.

Awolola, K. A. (2012) 'Enhanced Oil Recovery for Norne Field (Statoil) C-Segment Using Flooding', (July).

Ehsan, M., Gu, H., Akhtar, Malik M., et al. (2018) 'A geological study of reservoir formations and exploratory well depths statistical analysis in sindh province, southern lower indus basin, Pakistan', Kuwait Journal of Science, 45(2), pp. 84–93.

Ehsan, M., Gu, H., Akhtar, Malik Muhammad, et al. (2018) 'Identification of Hydrocarbon Potential of Talhar Shale: Member of Lower Goru Formation Using Well Logs Derived Parameters, Southern Lower Indus Basin, Pakistan', Journal of Earth Science, 29(3), pp. 587–593. doi: 10.1007/s12583-016-0910-2.

Energy, B. (2014) 'BP Energy Outlook 2035', [Energy Outlook 2035]], (January).

Gbadamosi, A. O. et al. (2019) An overview of chemical enhanced oil recovery: recent advances and prospects, International Nano Letters. Springer Berlin Heidelberg. doi: 10.1007/s40089-019-0272-8.

Ghosh, P., Sharma, H. and Mohanty, K. K. (2017) 'SPE-187274-MS Chemical Flooding in Low Permeability Carbonate Rocks', (October), pp. 9–11.

Kon, W., Pitts, M. and Harry, S. (2007) 'Mature Waterfloods Renew Oil Production by Alkaline-Surfactant-Polymer Flooding'. doi: 10.2523/78711-ms.

Liu, S. et al. (2008) 'Favorable Attributes of Alkaline-Surfactant-Polymer Flooding', SPE Journal, 13(01), pp. 5–16. doi: 10.2118/99744-PA.

Mohan, K. (2014) 'Alkaline Surfactant Flooding for Tight Carbonate Reservoirs', (October), pp. 4–7. doi: 10.2118/129516-stu.

Nisar, U. Bin et al. (2016) 'Structural and reservoir interpretation of cretaceous lower goru formation, sanghar area, lower Indus Basin, Pakistan', Journal of Himalayan Earth Sciences, 49(1), pp. 41–49.

Qi, Q. et al. (2000) 'SPE 129164 Alkaline-Surfactant-Polymer Flood : From the Laboratory to the Field', SPE Reservoir Engineering, 12(4), pp. 1–15. doi: 10.2523/35354-MS.

Sahito, A. G. et al. (2013) 'Sedimentologic studies of Upper sands of Lower Goru Formation based on well cuttings and wireline logs from wells of X Field in the subsurface of Sindh Monocline, Southern Indus Basin, Pakistan', (July 2014).

Samanta, A. et al. (2012) 'Comparative studies on enhanced oil recovery by alkali-surfactant and polymer flooding', Journal of Petroleum Exploration and Production Technology, 2(2), pp. 67–74. doi: 10.1007/s13202-012-0021-2.

Sheng, J. J. (2017) 'Critical review of alkaline-polymer flooding', Journal of Petroleum Exploration and Production Technology, 7(1), pp. 147–153. doi: 10.1007/s13202-016-0239-5.

Sheng, J. J. (2019) 'Status of Alkaline Flooding Technology', Journal of Petroleum Engineering & Technology, 5(1), pp. 44–50. Available at: http://engineeringjournals.stmjournals.in/index.php/JoPET/article/view/2073.

Uzoho, C. U., Onyekonwu, M. O. and Akaranta, O. (2020) 'Comparative analysis of local and conventional eor agents', Society of Petroleum Engineers - SPE Nigeria Annual International Conference and Exhibition 2020, NAIC 2020.

Voroniak, A. et al. (2016) 'SPE-181640-MS Two-Dimensional Visualization of Heavy Oil Displacement Mechanism During Chemical Flooding', pp. 1–18.

Yang, H. et al. (2018) 'Alkaline-Surfactant-Polymer Flooding: Where is the Enhanced Oil Exactly?', (1), pp. 1–22. doi: 10.2118/190340-ms.

Yin, D. and Zhao, D. (2017) 'Main Controlling Factor of Polymer-Surfactant Flooding to Improve Recovery in Heterogeneous Reservoir', Advances in Materials Science and Engineering, 2017, pp. 1–8. doi: 10.1155/2017/5247305.