



Absorbance-Based Evaluation of Black Grass Jelly and Chitosan Adsorption on Sand Under Different Formation-Water Salinities

Mohamad Obby Adiando^{1*}, Muhammad Agni Gustama¹, Nyimas Ulfatry Utami¹, Ferdian Budi Arrouf¹, Putri Dwi Afifah¹

¹ Mining Engineering Program Study, Faculty of Technology, Sriwijaya University, Palembang, Indonesia.

DOI: <https://doi.org/10.29303/goescienceed.v7i4.3524>

Article Info

Received: August, 12th 2026

Revised : August, 31st 2026

Accepted: October, 1st 2026

Correspondence:

Phone: +6285156338966

Abstract: Absorbance spectroscopy was used to estimate polymer concentrations and evaluate polymer adsorption onto sand. This study investigated black grass jelly, chitosan, polyacrylamide, black grass jelly-chitosan, and black grass jelly-polyacrylamide formulations in synthetic formation water with NaCl salinities of 10,000, 15,000, and 20,000 mg/L. Polymer concentrations of 500, 1,000, and 2,000 mg/L were tested using 50-mesh (0.355 mm) and 100-mesh (0.149 mm) sand. Calibration curves were developed for each formulation and salinity, and adsorption was estimated from the remaining polymer concentration after contact with sand. For black grass jelly at 10,000 mg/L salinity, absorbance increased from 0.066 to 0.091 as concentration increased from 500 to 2,000 mg/L. Maximum adsorption values ranged from 1.296 to 1.934 mg/g for 100-mesh sand and from 1.654 to 1.934 mg/g for 50-mesh sand. Chitosan exhibited the highest reported adsorption, reaching 1.934 mg/g on 50-mesh sand and 1.869 mg/g on 100-mesh sand at 10,000 mg/L salinity. Overall, adsorption generally increased with initial polymer concentration. These findings demonstrate the potential of absorbance-based calibration for evaluating polymer retention, although calibration quality and low absorbance values should be considered when interpreting the results.

Keywords: Absorbance, Enhanced Oil Recovery, Spektrophotometry, Mesona Palustris, Polymer.

Citation: Adiando, M. O., Gustama, M. A., Utami, N. U., Arrouf, F. B., & Afifah, P. D. (2026). Absorbance-Based Evaluation of Black Grass Jelly and Chitosan Adsorption on Sand Under Different Formation-Water Salinities. *Jurnal Pendidikan, Sains, Geologi, Dan Geofisika (GeoScienceEd Journal)*, 7(4), 6248–6254. <https://doi.org/10.29303/goescienceed.v7i4.3524>

Introduction

Polymer flooding is a chemical enhanced oil recovery (EOR) technique used to improve oil displacement by increasing the viscosity of injected water and controlling the mobility ratio between the displacing fluid and the displaced oil. The effectiveness of this technique depends not only on the rheological properties of the polymer solution but also on its interaction with reservoir rocks and the porous medium. During polymer injection, some polymer molecules may be retained through adsorption or other retention mechanisms, reducing the amount of polymer

available for transport through the reservoir. Polymer retention is therefore an important factor in evaluating injection performance, polymer consumption, and the potential reduction in formation permeability (S. Al-Hajri et al, 2018).

Polymer adsorption in porous media is influenced by several factors, including polymer concentration, solution salinity, rock properties, and the chemical characteristics of the polymer. Previous studies have investigated the effects of concentration and salinity on polymer adsorption at sandstone surfaces, as well as the relationship between adsorption

Email: obbyadianto2@gmail.com

and permeability reduction (M. Ali & Ben Mahmud, 2015). In addition, polymer retention behavior may vary depending on polymer type and experimental conditions. Understanding these interactions is particularly important when evaluating synthetic polymers and biopolymers as potential EOR agents (A. Agi et al, 2018).

Accurate determination of polymer concentration is necessary to quantify adsorption experimentally. Visible-light spectrophotometry provides a method for measuring the absorbance of a polymer solution and relating the measured signal to its concentration through a calibration curve. In an adsorption experiment, the initial polymer concentration is compared with the residual concentration measured after the solution has contacted the sand. The difference between these concentrations can then be used to estimate the amount of polymer adsorbed, provided that the calibration relationship is reliable and the experimental mass balance is properly established. Previous research on polymer adsorption in porous media provides a basis for investigating polymer retention under controlled laboratory conditions (S. Al-Hajri, 2018).

Salinity is another important variable in polymer flooding because dissolved salts can affect polymer behavior and polymer-rock interactions. Studies have examined polymer adsorption under different salinity conditions, including adsorption isotherms involving NaCl and CaCl₂, as well as polymer flooding using low-salinity preconditioning (A. Alfazazi et al, 2019). Consequently, investigating polymer concentration and absorbance at different formation-water salinities can help characterize the relationship between solution conditions and polymer retention. However, absorbance measurements must be interpreted using appropriate calibration curves for the polymer formulation and solution conditions being tested.

In this study, absorbance measurements were used to support the evaluation of polymer adsorption onto sand under different formation-water salinities. Five polymer formulations were considered: black grass jelly, chitosan, polyacrylamide, black grass jelly-chitosan, and black grass jelly-polyacrylamide. The experiments considered salinity levels of 10,000, 15,000, and 20,000 mg/L, polymer concentrations of 500, 1,000, and 2,000 mg/L, and two sand particle sizes. The absorbance calibration approach was used to relate the measured optical response to polymer concentration and to support the estimation of polymer adsorption after contact with sand.

The objective of this study was to evaluate the use of absorbance measurements for determining polymer concentration and to examine the reported polymer adsorption behavior under varying salinity

conditions and sand particle sizes. By comparing the absorbance responses and adsorption results of the five polymer formulations, this study aims to provide laboratory-based insight into the use of spectrophotometric measurements for characterizing polymer retention in porous media relevant to polymer flooding.

Method

System Design and Operational Flow

This study employed a laboratory experimental method to evaluate polymer adsorption onto sand under different formation-water salinities and polymer concentrations. The polymer formulations consisted of black grass jelly (*Mesona palustris*), chitosan, polyacrylamide, black grass jelly-chitosan, and black grass jelly-polyacrylamide. Sodium chloride (NaCl) was used to prepare synthetic formation water at salinities of 10,000, 15,000, and 20,000 mg/L. The polymer solutions were prepared at nominal concentrations of 500, 1,000, and 2,000 mg/L. The experimental equipment included a JK-VS-721N visible spectrophotometer, a magnetic stirrer, a digital balance, beakers, measuring cylinders, sample bottles, cuvettes, and filtration equipment. All adsorption experiments were conducted at room temperature, approximately 29 °C, in accordance with the procedures described in the original research methodology.

Synthetic formation water was prepared by dissolving the required amount of NaCl in distilled water. For a preparation volume of 250 mL, 2,500 mg, 3,750 mg, and 5,000 mg of NaCl were used to obtain nominal salinities of 10,000, 15,000, and 20,000 mg/L, respectively. The salt solution was stirred for approximately 15 minutes to promote complete dissolution. Polymer working solutions were subsequently prepared at concentrations of 500, 1,000, and 2,000 mg/L. For a final solution volume of 100 mL, the corresponding polymer masses were 50, 100, and 200 mg, respectively. The polymer was added to the prepared aqueous solution and mixed using a magnetic stirrer for approximately 12 hours to obtain a homogeneous solution. These preparation procedures followed the experimental methodology documented in the original study, which referenced the methodology documented in the original study and related polymer-retention literature (S. Al-Hajri et al, 2018).

Absorbance measurements were performed using a visible spectrophotometer at a wavelength of 600 nm. Before measuring the polymer solutions, the instrument was switched on and set to the specified wavelength. A cuvette containing distilled water was used as the blank to establish the baseline. The cuvette was placed in the spectrophotometer, and the

instrument's "0 Abs100 %" function was activated. Measurement proceeded after the display reached 0 absorbance. The polymer solution was then placed in the cuvette, and its absorbance was recorded. The use of visible spectrophotometry at 600 nm and the blank-setting procedure were based on the method described in the original study, with supporting references including Ali and Mahmud (M. Ali & Ben Mahmud, 2015), and the polymer-retention literature (A. Agi et al, 2018).

A calibration relationship between polymer concentration and absorbance was established using polymer solutions of known concentrations. Absorbance values were plotted against the corresponding polymer concentrations to obtain a calibration curve for estimating the concentration of the remaining polymer solution after the adsorption experiment. Where a linear relationship was appropriate, the calibration data could be represented by the equation (1), where (A) is absorbance, (C) is polymer concentration, (m) is the calibration slope, and (b) is the intercept. The residual polymer concentration was then estimated from (2). Calibration equations and coefficients of determination ((R²)) were evaluated for the relevant polymer formulation and salinity condition. This calibration approach follows the absorbance-concentration relationship discussed by the polymer concentration and retention literature (M. Alam, et al., 2025). The calibration equation and (R²) should be reported from the actual experimental data for each formulation and salinity; they should not be assumed to be identical across all samples.

$$A = m \times C + b \quad (1)$$

$$C = \frac{(A-b)}{m} \quad (2)$$

A =Absorbance

C =Polymer concentration

m =Calibration slope

b =Intercept. The residual polymer concentration

Polymer adsorption was evaluated using a static adsorption test. For each test, 40 g of sand with a particle-size fraction of either 50 mesh or 100 mesh was placed in a bottle containing 20 mL of polymer solution with a known initial concentration. The bottle was closed and maintained at room temperature (approximately 29 °C) for four hours to allow the polymer and sand to approach adsorption equilibrium. The bottle was shaken periodically to maintain contact between the polymer solution and the sand. After the contact period, the mixture was filtered to separate the sand from the remaining polymer solution. The

absorbance of the filtrate was measured using the visible spectrophotometer at 600 nm, and the residual polymer concentration was estimated from the corresponding calibration curve. The static adsorption procedure was based on the methodology described by Ali and Mahmud 2018, Al-Hajri et al. 2018, and Alajmi et al. 2025, as cited in the original study.

The amount of polymer adsorbed per unit mass of sand was determined from the difference between the initial and residual polymer concentrations. Adsorption capacity, (q), was calculated using (3), where (C₀) is the initial polymer concentration (mg/L), (C_e) is the residual polymer concentration after contact with sand (mg/L), (V) is the polymer-solution volume (L), and (m_s) is the mass of sand (g). In this experiment, the solution volume was 0.020 L and the sand mass was 40 g. The resulting adsorption capacity was expressed in mg/g. The calculation therefore depended on the reliability of the absorbance calibration curve, because the spectrophotometer measured absorbance rather than polymer concentration directly.

$$q = \frac{C_0 - C_e \times V}{m_s} \quad (3)$$

Data analysis compared the estimated adsorption capacities across the five polymer formulations, three formation-water salinities, three initial polymer concentrations, and two sand-size fractions. The absorbance-concentration calibration relationship was examined before residual concentrations were calculated. The initial and residual concentrations were then used to estimate adsorption capacity for each experimental condition. Calibration fit, represented by (R²), was considered when interpreting the estimated adsorption values. The experimental workflow consisted of preparing synthetic formation water, preparing polymer solutions, measuring standard-solution absorbance, establishing calibration curves, conducting static adsorption tests, filtering the mixtures, measuring filtrate absorbance, estimating residual polymer concentrations, and calculating adsorption capacity. The overall research procedure is presented schematically in Figure 1.

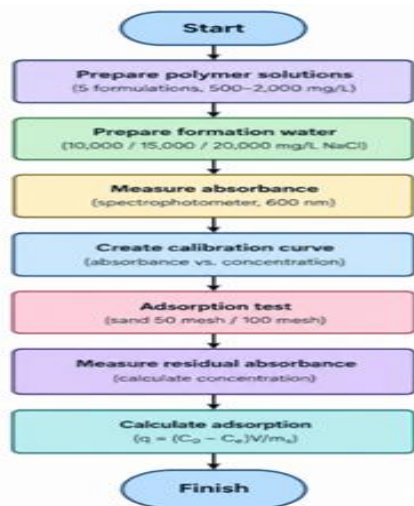


Figure 1. Research Flow Chart

Result and Discussion

Result

The reported absorbance values for black grass jelly increased with polymer concentration at each salinity. At 10,000 mg/L salinity, absorbance values were 0.066, 0.075, and 0.091 at concentrations of 500, 1,000, and 2,000 mg/L, respectively. At 15,000 mg/L salinity, the corresponding values were 0.103, 0.125, and 0.134; at 20,000 mg/L salinity, they were 0.110, 0.130, and 0.157. can be seen in Table 1.

Tabel 1: Absorbance of black grass jelly standard solutions reported.

No.	Salinity (mg/L)	500 mg/L	1000 mg/L	2000 mg/L
1	10.000	0,066	0,075	0,091
2	15.000	0,103	0,125	0,134
3	20.000	0,110	0,130	0,157

The standard-curve examples in the thesis show that calibration quality differed among formulations and salinity conditions. For example, the reported black grass jelly curve at 10,000 mg/L had an R^2 of approximately 0.9991, whereas the black grass jelly-chitosan curve at 20,000 mg/L had an R^2 of approximately 0.9398; the analysis also reports lower R^2 values for some other curves. This variation indicates that each calibration curve should be assessed individually before using it to estimate residual concentration. Absorbance values around 0.2–0.8 are preferred for its measurement context. However, the listed black grass jelly standard absorbances are below 0.2. This is a methodological consideration: concentration estimates derived from these low signals may be more sensitive to baseline offsets, blank correction, and instrument noise. The values are

retained here as reported and should not be interpreted as having been remeasured.

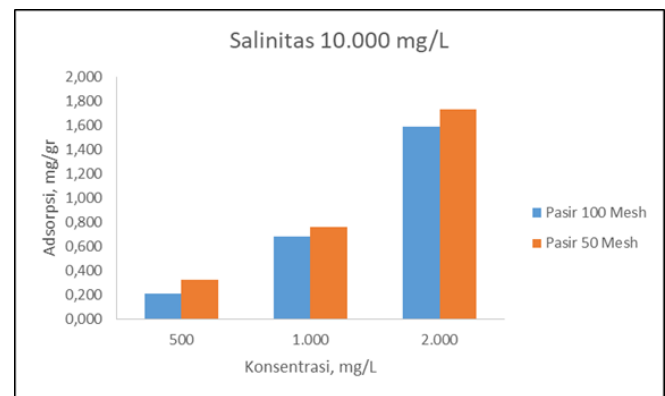


Figure 1. The effect of polymer solution adsorption on the size of 50 and 100 mesh sand at a salinity of 10.000 mg/L

From the figure.2 above, it can be seen that the effect of polymer solution adsorption on the size of 50 and 100 mesh sand at a salinity of 10.000 mg/L. Reports that adsorption generally increased as initial polymer concentration increased. This trend is consistent with a greater amount of polymer being available to interact with the sand surface. The analysis also states that adsorption increased with salinity in its overall interpretation; however, the reported maximum values for the individual polymers were identified at 10,000 mg/L salinity. Therefore, the salinity trend should be interpreted in relation to the particular formulation, concentration, and sand fraction rather than treated as universal for every sample maximum adsorption values reported in the analysis. The listed maxima were reported at a formation-water salinity of 10,000 mg/L can be seen in Table 2.

Tabel 2: Maximum adsorption values reported in the source thesis. The listed maxima were reported at a formation-water salinity of 10,000 mg/L

Polymer formulation	Maximum on 50 mesh sand (mg/g)	Maximum on 100 mesh sand (mg/g)
Black grass jelly	1,729	1,589
Chitosan	1,934	1,869
Polyacrylamide	1,679	1,296
Black grass jelly + Chitosan	1,654	1,574
Black grass jelly + Polyacrylamide	1,779	1,684

Based Table 2, The tested formulations, chitosan had the highest reported maximum adsorption

on both sand fractions: 1.934 mg/g on 50-mesh sand and 1.869 mg/g on 100-mesh sand. The lowest reported maximum in the comparison was for polyacrylamide on 100-mesh sand (1.296 mg/g). The analysis attributes adsorption to polymer molecules attaching to the rock or sand surface, thereby reducing the polymer concentration remaining in solution. The increase in absorbance with concentration is consistent with the general principle that the optical response of a solution can be related to the amount of absorbing material present. However, the absorbance values also differed between salinity conditions at the same nominal polymer concentration. For example, at 2,000 mg/L, the absorbance increased from 0.091 at 10,000 mg/L salinity to 0.157 at 20,000 mg/L salinity. This difference indicates that the calibration relationship should be established separately for each relevant salinity rather than assuming that a single calibration curve is suitable for all solution conditions.

A similar concentration-dependent pattern was reported for the black grass jelly-chitosan formulation. Its absorbance values at 10,000 mg/L salinity were 0.047, 0.082, and 0.092 for concentrations of 500, 1,000, and 2,000 mg/L, respectively. At 15,000 mg/L salinity, the corresponding values were 0.078, 0.089, and 0.099, while at 20,000 mg/L salinity, they reached 0.104, 0.126, and 0.144. These results further demonstrate that absorbance response varied with both polymer concentration and salinity. The differences among formulations may reflect differences in their optical properties and solution composition; however, further measurements would be needed to establish the specific mechanisms responsible for these differences. The reported maximum adsorption capacity on 50-mesh sand was higher than that on 100-mesh sand for all five polymer formulations. The differences between the two fractions were 0.140 mg/g for black grass jelly, 0.065 mg/g for chitosan, 0.383 mg/g for polyacrylamide, 0.080 mg/g for black grass jelly-chitosan, and 0.095 mg/g for black grass jelly-polyacrylamide. The largest difference was observed for polyacrylamide, whereas the smallest difference occurred for chitosan. These results indicate that the reported adsorption capacity depended on the sand fraction used in the experiment. However, mesh number is inversely related to nominal particle size: 50-mesh sand is coarser than 100-mesh sand. Therefore, the higher adsorption values reported for 50-mesh sand should not be described as an effect of smaller particle size. Differences in particle-size distribution, surface characteristics, packing or experimental variability could potentially contribute to the observed pattern, but the present results do not identify which factor was responsible. Further investigation using measured particle-size distributions, controlled sand masses, and

replicate adsorption tests would be necessary to determine whether the difference between sand fractions is statistically significant and to clarify the relationship between sand characteristics and polymer retention.

Discussion

Implications for Absorbance-Based Adsorption Analysis demonstrate that visible spectrophotometry can provide an indirect method for comparing polymer concentration before and after contact with sand. The method relies on a calibration curve to convert the absorbance of the filtrate into a residual polymer concentration. The initial and residual concentrations can then be used to estimate the amount of polymer retained by the sand.

The main methodological limitation is that uncertainty in absorbance measurement and calibration propagates into the calculated adsorption capacity. Differences in (R^2) among the reported calibration curves, together with the relatively low absorbance values for several standards, indicate that calibration quality must be considered when comparing adsorption capacities. A strong linear fit is desirable, but it should be accompanied by appropriate blank correction, replicate measurements, and an assessment of whether the measured absorbance falls within a suitable working range.

Overall, the findings identify chitosan as the formulation with the highest reported maximum adsorption capacity under the tested conditions, while also showing that polymer formulation, salinity, and sand fraction should be considered when interpreting polymer retention. The results provide a basis for further laboratory evaluation of polymer adsorption relevant to enhanced oil recovery. Before quantitative conclusions are generalized, however, the calibration equations, residual-concentration data, experimental replicates, and statistical uncertainty should be verified against the original laboratory records.

Conclusion

This study demonstrated the application of visible spectrophotometry as an indirect method for estimating polymer concentration and evaluating polymer adsorption onto sand under different formation-water salinities. Absorbance measurements were conducted at a wavelength of 600 nm, and the measured absorbance values were related to polymer concentration through calibration curves. The resulting concentration estimates were used to determine the amount of polymer retained by the sand after a static adsorption period. This approach provides a practical framework for comparing the adsorption behavior of

different polymer formulations under controlled laboratory conditions.

For black grass jelly (*Mesona palustris*), absorbance increased with increasing polymer concentration at all three tested salinities. At a salinity of 10,000 mg/L, absorbance values were 0.066, 0.075, and 0.091 for polymer concentrations of 500, 1,000, and 2,000 mg/L, respectively. At 15,000 mg/L salinity, the corresponding absorbance values increased to 0.103, 0.125, and 0.134, while at 20,000 mg/L salinity, they reached 0.110, 0.130, and 0.157. These results indicate a positive relationship between polymer concentration and absorbance within the tested range. However, because the absorbance readings were relatively low, the reliability of the calculated concentrations depends on accurate blank correction, appropriate calibration, and sufficient instrument sensitivity.

The adsorption results showed differences among the five tested polymer formulations and the two sand fractions. At a formation-water salinity of 10,000 mg/L, chitosan exhibited the highest reported maximum adsorption capacity, reaching 1.934 mg/g on 50-mesh sand and 1.869 mg/g on 100-mesh sand. Black grass jelly exhibited maximum adsorption capacities of 1.729 and 1.589 mg/g on 50- and 100-mesh sand, respectively. Polyacrylamide reached 1.679 mg/g on 50-mesh sand and 1.296 mg/g on 100-mesh sand. The black grass jelly-chitosan formulation reached 1.654 and 1.574 mg/g, whereas the black grass jelly-polyacrylamide formulation reached 1.779 and 1.684 mg/g on 50- and 100-mesh sand, respectively. These comparisons identify chitosan as the formulation with the highest reported adsorption capacity under the stated conditions, while the black grass jelly-polyacrylamide formulation showed the second-highest maximum values among the tested formulations.

The results also indicated that adsorption generally increased with increasing initial polymer concentration, suggesting that the amount of polymer available for interaction with the sand surface influenced the quantity retained. Nevertheless, adsorption behavior should not be interpreted as being controlled by concentration alone. Polymer composition, solution salinity, and sand characteristics may also affect polymer-surface interactions. Although the thesis discusses the influence of salinity on adsorption, the reported maximum values for the individual formulations occurred at 10,000 mg/L salinity. Therefore, the effect of salinity should be evaluated separately for each polymer formulation and sand fraction rather than generalized as a uniform trend across all experimental conditions.

The comparison between 50-mesh and 100-mesh sand further showed that the reported maximum

adsorption capacities were higher on 50-mesh sand for all five formulations. This pattern suggests that the measured adsorption capacity differed between the two sand fractions. However, mesh number and particle size are inversely related: a higher mesh number generally corresponds to a smaller particle size. Consequently, the interpretation of this difference should be supported by verification of the sand-size classification and experimental records before a definitive explanation is proposed.

An important methodological finding is that the reliability of adsorption calculations depends directly on the quality of the absorbance-concentration calibration. The reported coefficients of determination varied between polymer formulations and salinity conditions, indicating that calibration performance was not uniform. For example, the black grass jelly calibration at 10,000 mg/L salinity had a reported (R^2) of approximately 0.9991, whereas the black grass jelly-chitosan calibration at 20,000 mg/L salinity had an (R^2) of approximately 0.9398. Because absorbance was used to estimate the residual polymer concentration, any uncertainty in the calibration equation could affect the calculated adsorption capacity. The calibration equations, replicate measurements, and associated statistical uncertainty should therefore be reported for each formulation and salinity condition to strengthen the validity and reproducibility of the results.

Overall, the findings support the use of absorbance-based concentration estimation as a practical approach for investigating polymer adsorption onto sand. Among the tested formulations, chitosan demonstrated the highest reported adsorption capacity at 10,000 mg/L salinity. The results also emphasize the importance of considering polymer formulation, initial concentration, salinity, and sand fraction when interpreting adsorption behavior. Before the method is adopted for broader evaluation in enhanced oil recovery (EOR) applications, further validation is recommended through replicate experiments, complete reporting of calibration equations and (R^2) values, assessment of measurement uncertainty, and verification of the relationship between absorbance and polymer concentration in each solution matrix. These improvements would provide a more reliable basis for comparing polymer retention and assessing the potential suitability of different polymer formulations for polymer-flooding applications.

Acknowledgements

The authors are particularly grateful to All Author and Sriwijaya University, for their invaluable guidance and support throughout this research.

References

- A. Agi, R. Junin, J. Gbonhinbor, and M. Onyekonwu, "Natural polymer flow behaviour in porous media for enhanced oil recovery applications: a review," *Journal of Petroleum Exploration and Production Technology*, vol. 8, no. 4, pp. 1349–1362, 2018, doi: 10.1007/s13202-018-0434-7.
- M. Alam, S. Kaur, B. N. Dar, and V. Nanda, "Classification, techno-functional properties, and applications of diverse hydrocolloids in fruits-based products: A concise review," *Journal of Food Science*, vol. 90, no. 3, Art. no. e70119, 2025, doi: 10.1111/1750-3841.70119.
- M. Ali and H. Ben Mahmud, "The effects of concentration and salinity on polymer adsorption isotherm at sandstone rock surface," *IOP Conference Series: Materials Science and Engineering*, vol. 78, no. 1, 2015, doi: 10.1088/1757-899X/78/1/012038.
- A. Alajmi, M. Algharaib, and M. Ali, "Experimental study on the injectivity, adsorption, and in-situ rheology of HPAM polymer in intact and fractured sandstone," *Journal of Petroleum Exploration and Production Technology*, vol. 15, no. 3, Art. no. 58, 2025, doi: 10.1007/s13202-025-01962-4.
- A. Alfazazi et al., "Experimental investigation of polymer flooding with low-salinity preconditioning of high temperature-high salinity carbonate reservoir," *Journal of Petroleum Exploration and Production Technology*, vol. 9, no. 2, pp. 1517–1530, 2019.
- S. Al-Hajri, S. M. Mahmood, H. Abdulelah, and S. Akbari, "An Overview on Polymer Retention in Porous Media," *Energies*, vol. 11, no. 10, Art. no. 2751, 2018, doi: 10.3390/en1102751.
- A. E. Chalykh, "Supramolecular structure of epoxy oligomers," *Polymer Engineering & Science*, vol. 64, no. 11, pp. 5289–5303, 2024, doi: 10.1002/pen.26942.
- A. Chauveteau, K. Denys, and A. Zaitoun, "New insight on polymer adsorption under high flow rates," in *Proceedings of the SPE/DOE Improved Oil Recovery Symposium*, 2002.
- M. M. El Sayed, "Production of Polymer Hydrogel Composites and Their Applications," *Journal of Polymers and the Environment*, vol. 31, no. 7, pp. 2855–2879, 2023, doi: 10.1007/s10924-023-02796-z.
- O. Falode and E. Manuel, "Wettability Effects on Capillary Pressure, Relative Permeability, and Irreducible Saturation Using Porous Plate," *Journal of Petroleum Engineering*, vol. 2014, Art. no. 465418, 2014, doi: 10.1155/2014/465418.
- R. Hu, S. Tang, M. Mpelwa, Z. Jiang, and S. Feng, "Research progress of viscoelastic surfactants for enhanced oil recovery," *Energy Exploration & Exploitation*, vol. 39, no. 4, pp. 1324–1348, 2021, doi: 10.1177/0144598720980209.
- W. Lei, T. Liu, C. Xie, H. Yang, T. Wu, and M. Wang, "Enhanced oil recovery mechanism and recovery performance of micro-gel particle suspensions by microfluidic experiments," *Energy Science & Engineering*, vol. 8, no. 4, pp. 986–998, 2020, doi: 10.1002/ese3.563.
- S. M. Rajabi, R. Moradi, and M. Mehrizadeh, "Experimental investigation of chemical solutions effects on wettability alteration and interfacial tension reduction using nano-alkaline-surfactant fluid: an EOR application in carbonate reservoirs," *Journal of Petroleum Exploration and Production Technology*, vol. 11, no. 4, pp. 1925–1941, 2021, doi: 10.1007/s13202-021-01155-9.
- W. Tang, X. Chen, D. Liu, and J. Xie, "Bioactive Components of Mesona Blume and Their Potential Health Benefits," *Food Reviews International*, vol. 38, no. sup1, pp. 70–85, 2022, doi: 10.1080/87559129.2020.1849271.
- B. Wei, L. Romero-Zerón, and D. Rodrigue, "Oil displacement mechanisms of viscoelastic polymers in enhanced oil recovery (EOR): a review," *Journal of Petroleum Exploration and Production Technology*, vol. 4, no. 2, pp. 113–121, 2014, doi: 10.1007/s13202-013-0087-5.
- Z. Wang, C. Xu, L. Qi, and C. Chen, "Chemical modification of polysaccharides for sustainable bioplastics," *Trends in Chemistry*, vol. 6, no. 6, pp. 314–331, 2024, doi: 10.1016/j.trechm.2024.04.009.