International Journal of Petroleum and Gas Exploration Management
Vol.8, No.1, pp.11-22, 2025
Print ISSN: 2515-0863 (Print)
Online ISSN: 2515-0871 (Online)
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

Highlighting the Influencing Variables of Recovery from Oil Rim Reservoir under Water Flooding Technique through Correlation Coefficients

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doi: https://doi.org/10.37745/ ijpgem.15/vol8n11122 Published: February 23, 2025

Citation: Ndem D. (2025) Highlighting the Influencing Variables of Recovery from Oil Rim Reservoir under Water Flooding Technique through Correlation Coefficients, *International Journal of Petroleum and Gas Exploration Management*, Vol.8, No.1, pp.11-22

Abstract: *This study examined the influence of eleven reservoir variables on the recovery factor of an oil rim reservoir under water flooding. Data was collected from various oil rim reservoirs in the Niger Delta to obtain a range of values for these variables. The extent to which these reservoir variables affect recovery under water flooding was evaluated using Design Expert (DOE++), which facilitated the planning of fourteen different experiments. A linear screening of these variables, employing Placket-Burman Design of Experiment, helped identify the significant ones. The Eclipse dynamic simulator was then used to run simulations, initially creating a generic oil rim model that was subsequently refined to align with the specific simulation runs, from which recovery factors for water flooding processes were obtained. Correlation analysis was conducted on these parameters to determine the most significant factor affecting recovery, utilizing the Pearson Correlation, the analysis of these eleven parameters revealed that Height below Gas Oil Contact (HGOC) is the principal variable influencing recovery in oil rims subjected to water flooding, followed by the oil rim thickness.*

Keywords: oil rim, waterflooding, influencing parameters, recovery factor, Pearson correlation coefficient

INTRODUCTION

An oil rim reservoir represents a unique challenge in the field of petroleum engineering, characterized by a saturated reservoir that features a limited thickness of oil, crowned by a gas cap and resting above an aquifer. Razak, et al., (2011) highlight that maximizing oil recovery from these reservoirs hinges on maintaining consistent contact between the oil rim and production wells. This objective can be effectively achieved through the strategic management of water over the oil contact (WOC) and gas over the oil contact (GOC) via innovative peripheral and fencing water injection techniques. However, in thin oil rim reservoirs accompanied by extensive gas caps and vigorous aquifers, this goal becomes particularly formidable (Razak, et al., 2011; Vijay K. S. et al., 1998). Masoudi, et al., (2013) underscores the myriad technical challenges confronting oil rim reservoirs, which include issues such as water/gas coning, breakthrough phenomena, uneven resource distribution, intricate production mechanisms, the presence of transition and invasion zones, oil smearing, and alarmingly low recovery factors often below 18%. Addressing these challenges is vital for enhancing oil extraction efficiency and maximizing the value derived from these complex reservoirs.

A good knowledge of this reservoir type is essential to combat these technical challenges. Also, an investigation into the viability of water injection for secondary production of thin oil columns is crucial for decision making on their exploration and production. Many oil reservoirs have gas-cap and/or water support (Kromah and Dave, 2008). The structure of the reservoir may be dome shaped with the oil sandwiched between the gas cap and the bottom water, sloping with the edge water (Jill M. and Richard A., 2009) or in a linear geometry (Ahmad T., 2006). Understanding these structural characteristics is vital for optimizing recovery strategies and enhancing overall production efficiency.

Extensive research has established effective methods to enhance oil recovery from thin oil columns located between a bottom aquifer and a substantial gas cap. According to Masoudi, et al., (2013), key strategies for the development and depletion of thin oil columns include gas cap blowdown, sequential and concurrent development, and swing development. Furthermore, the implementation of smart wells equipped with inflow control devices (ICDs), meticulous placement of horizontal wells, and the application of water alternating gas (WAG) techniques are crucial. The adoption of gravity-assisted water alternating gas (GASWAG) methods alongside idle well rejuvenation and infill drilling plays a pivotal role in maximizing recovery, (Razak, et al., 2011). Masoudi, et al., (2011) firmly asserts that the success of the Field Development Program (FDP), well design and philosophy, and the Reservoir Management Plan (RMP) is heavily reliant on the selected strategies.

Kabir., Agamini., and Holguin (2004) implemented a depletion strategy aimed at enhancing oil recovery from remaining reserves. Their approach involved initiating development with a conventional horizontal well completed below the Gas-Oil Contact (GOC). Once the well began to water out, it was re-completed in the gas zone, either at the crest for smaller gas-cap reservoirs or at the GOC, thereby inducing a reverse cone effect for reservoirs with thicker gas columns. Similarly, Sascha and Marc (2008) conducted a focused study on conventional strategies for oil rim development. Their proposed development plan involves an initial oil development phase featuring two dedicated oil rim wells, followed by a gas development phase with two dedicated gas wells, amounting to a total of four wells with four drainage points. This phased production strategy is specifically designed to limit pressure decline in the reservoir by strategically constraining well operations, which effectively minimizes the movement of the oil rim.

In this strategy, oil production is initially set aside while the gas cap is depleted. However, this approach results in a low oil recovery factor (Masoudi, et al., 2011), primarily due to the energy loss linked to gas cap production. Furthermore, Behrenbruch and Mason demonstrated that oil recovery can be optimized in an oil rim reservoir with a small gas cap (m<0.2) by depleting the gas cap during the early production phase, assuming a robust aquifer is present.

Optimizing oil rim reservoir management poses significant challenges due to uncertainties in predicting fluid movements. These uncertainties can lead to production losses, increased gas-to-oil ratios, and elevated water cuts, ultimately jeopardizing the integrity of the oil rim. Amir, et al., (2024). To mitigate these issues, Amir, et al., (2024) developed a novel proof-of-concept early warning system, leveraging advanced data analytics techniques and integrating well data, such as pressure and temperature measurements. This system aims to detect changes in water cut, serving as an indicator of oil rim movement. The proposed workflow encompasses data extraction, pre-processing, regime detection, trend analysis, and exception-based surveillance with alerts. A case study was conducted using a selected oil-producing well with extensive flow line pressure, temperature, and well test data. Pipesim modeling revealed a strong correlation between temperature and water cut, which was validated through sensitivity analysis at various gas-to-oil ratio levels. This innovative technology provides an integrated workflow, encompassing data management, analytics, event detection, and visualization. Unlike existing oil rim management tools, this early warning system offers a proactive approach to detecting fluid movements and mitigating production losses. By harnessing novel data analytics techniques and leveraging readily available well data, operators can make informed decisions and take timely actions, ultimately enhancing the efficiency and effectiveness of oil rim management strategies. This technology serves as a valuable decision support tool, particularly in the absence of reliable models, and has the potential to improve the overall performance of oil rim management strategies.

Obinaba et al. (2024) explored the impact of aquifer strength, gas cap size, and permeability anisotropy on hydrocarbon recovery in thin oil rim reservoirs. Using design of experiment (DOE) methodology, the researchers systematically evaluated the effects of these factors on hydrocarbon recovery. The study employed a static model of the base case oil rim built in Petrel, and two additional reservoir models with varying gas cap sizes were created using Eclipse simulator. A total of 48 simulation cases were generated, incorporating different aquifer volume factors (0.7, 1.0, 1.5, and 2.5), gas cap sizes (0.5, 1.0, and 2.0), and permeability anisotropy values (0.01, 0.05, 0.10, and 0.40). The simulation results, which spanned a 20-year period, revealed that decreasing gas cap size enhances oil recovery, whereas increasing gas cap size boosts gas and water recoveries, secondly, for thin oil rim reservoirs with gas cap sizes between 0.5 and 2.0, increasing aquifer volume leads to improved recovery of gas, oil, and water finally, reservoirs with small to moderate gas cap sizes ($0.5 \leq m \leq 1.0$) exhibit higher oil recoveries, regardless of the kV/kH ratio. These findings provide valuable insights into optimizing hydrocarbon recovery in thin oil rim reservoirs.

Olabode et al. (2020) used synthetic oil rim models and black oil simulation to evaluate well placements at different distances from gas-oil contact. the results showed optimal oil recovery of (8.3-9.3%) achieved with wells placed 0.75 ft from gas-oil contact or mid-stream of pay zone.

Aladeitan et al. (2019) employed surrogate modelling and numerical reservoir simulations and evaluated three development strategies with uncertainty quantification, the result indicated that wells Placed just above oil-water contact (OWC) yielded highest oil recovery; methodology saves time and is reproducible.

Olamigoke and Isehunwa (2019) developed simple correlations to estimate primary recovery factors for thin oil rims with large gas caps. These correlations were based on oil recovery factor estimates from 3D, three-phase black oil reservoir simulation models, which accounted for spatial effects and the dynamics of oil rim and gas cap production. The researchers identified key factors influencing oil rim and gas cap production using Plackett-Burman screening designs. These factors included oil rim thickness, horizontal permeability, gas cap size, oil viscosity, gas cap offtake, aquifer strength, and reservoir dip. Response Surface Models (correlations) were then developed using Box-Behnken experimental design to estimate oil recovery under conventional and concurrent development scenarios. The correlations were validated using actual field production data and history-matched reservoir simulation results. The study found that the oil recovery factor estimates from the correlations were in good agreement with field data, with a mean average percentage error of 2.5% for conventional development and 4% for concurrent development. The developed correlations can be applied to reservoirs with oil columns less than 100 ft underlying large gas caps with a high degree of accuracy.

MATERIALS AND METHODS

The study employed eclipse 300 dynamic simulator, placket-Burman design of experiment and pearson correlation analysis.

Design of the Experiment

The dynamic simulation was carried out using ECLIPSE 300 dynamic simulator. The range of parameters used in the models is presented in Table 1.

Table 1: Range of parameters investigated

Rim Parameters	Lowest	Median	Highest
Anisotropy (Kv/Kh)	0.001	0.01	0.1
Permeability, Md (Kh)	100	1000	2000
Oil Rim Thickness, ft (Ho)	20	34	60
Oil Viscosity, cp Derived from API, degree (API)	0.4 39.18	1 32.65	2 24.16
Oil Rate, stb/day (Q)	1300	2500	5000
Gas factor (mfac) dimensionless	0.268	1	4.73
Relative permeability of water (Krw)	0.15	0.3	0.45
Residual Oil Saturation (Sor)	0.15	0.23	0.3
Horizontal well length, ft (HWL)	1200	1800	2400
Aquifer factor, dimensionless (Aqfac)	2	7	15
Height below GOC (HGOC)	2 cells beneath	3 cells beneath	4 cells beneath

Parameter Screening

The impact of various factors on recovery in oil rim reservoirs was rigorously assessed using Design Expert (DOE++), employing a linear screening method to analyze uncertainties through the Placket-Burman design of experiments. This structured approach allowed for the identification of significant uncertainties that could affect recovery performance. For this study, a Placket-Burman design was crafted to evaluate 11 specific uncertainties that were deemed critical. To thoroughly analyze these 11 factors, a two-level, 11-variable Placket-Burman design was implemented (as detailed in Table 2). To enhance the robustness of the linear screening, a folded Placket-Burman design was incorporated, which included a center point run representing all mid-case scenarios (run 14). Additionally, an extra run was introduced (run 13) to capture and define the maximum potential outcomes, thereby enriching the analysis and providing a comprehensive understanding of the effects of these uncertainties on oil recovery in the reservoir.

Table 2: Parameter Plackett-Burman Design

Run No.	**Ho**	**mfac**	**Aqfac**	**Kh**	**Kv/Kh**	**Sor**	**API**	**HGOC**	**HWL**	**Q**	**Krw**
1	60	4.73	2	2000	0.1	0.3	24.16	24.00	1200	5000	0.15
2	60	0.268	15	2000	0.1	0.15	24.16	48.00	2400	5000	0.45
3	20	4.73	15	2000	0.001	0.15	24.16	8.00	1200	5000	0.45
4	60	4.73	15	100	0.001	0.15	39.18	48.00	2400	5000	0.15
5	60	4.73	2	100	0.001	0.3	24.16	48.00	2400	1300	0.45
6	60	0.268	2	100	0.1	0.15	39.18	48.00	1200	5000	0.45
7	20	0.268	2	2000	0.001	0.3	39.18	8.00	2400	5000	0.45
8	20	0.268	15	100	0.1	0.3	24.16	16.00	2400	5000	0.15
9	20	4.73	2	2000	0.1	0.15	39.18	16.00	2400	1300	0.15
10	60	0.268	15	2000	0.001	0.3	39.18	48.00	1200	1300	0.15
11	20	4.73	15	100	0.1	0.3	39.18	8.00	1200	1300	0.45
12	20	0.268	2	100	0.001	0.15	24.16	8.00	1200	1300	0.15
13	60	4.73	15	2000	0.1	0.3	39.18	48.00	2400	5000	0.45
14	34	1	7	1000	0.01	0.23	32.65	20.40	1800	2500	0.3

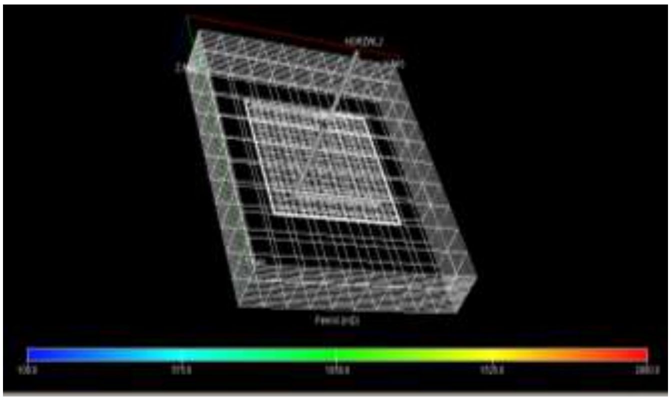


Fig 1. Oil rim eclipse simulation

Well Description

Two horizontal oil production wells were strategically positioned at the centre of the oil rim section in the models to effectively simulate the primary production case. In a further development of the simulation, one of these production wells was converted into an injection well to model the water injection scenario. This thoughtful arrangement is designed to establish a precise relationship between oil recovery and various reservoir parameters. As part of the analysis, well length was treated as a variable, allowing for a detailed examination of its impact on recovery. To accurately assess the dynamics of pressure changes along the horizontal section of the well, Prosper IPM was employed to construct a comprehensive wellbore model. This model takes into account the complexities of pressure drop, thereby enhancing the reliability and accuracy of the simulation outcomes.

Determination of an optimum injection rate

Utilizing the previously described model, a thickness of 40 feet was established, along with the initialization parameters specified. A sensitivity analysis was conducted to determine an optimal injection rate, resulting in the adoption of a water injection rate set at 2000 STB/day, which will be consistently applied throughout the experiment.

Determination of the significant parameters to recovery factor (RF)

The most significant factors that influence the oil recovery factor of oil rim reservoir under water flooding scenario was analyzed using, Pearson Correlation analysis, Regression analysis, sensitivity ANALYSIS AND DECISION TREE.

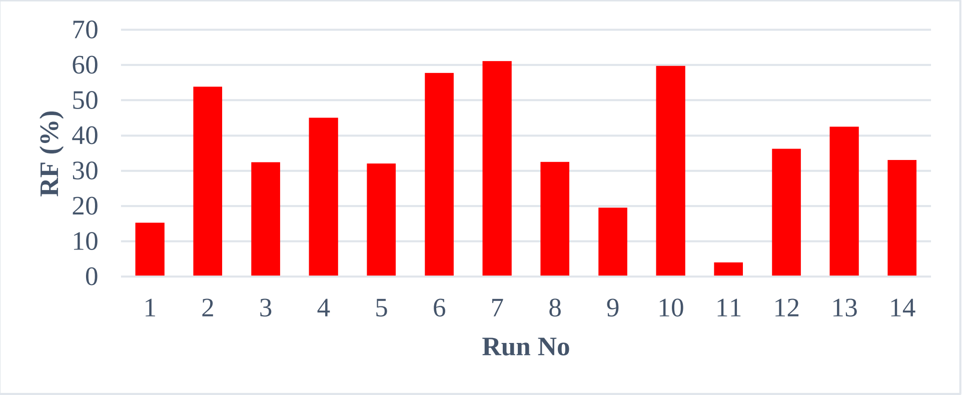
RESULTS

Table 3. critical injection rate

2000	**1.2719E+07**	**174000**

Table 4: Eleven-variable Plackett-Burman design and recoveries under water injection

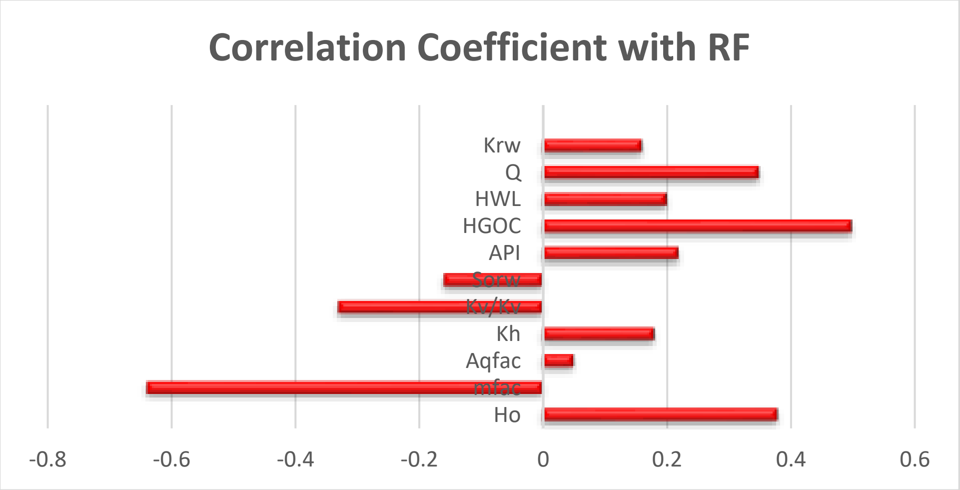
Run No.	**Ho**	**mfac**	**Aqfac**	**Kh**	**Kv/Kh**	**Sorw**	**API**	**HGOC**	**HWL**	**Q**	**Krw**	**FIP**	**FOPT**	**RF (%)**
1	60	4.73	2	2000	0.1	0.3	24.16	24.00	1200	5000	0.15	**1.2145E+08**	**1.8531E+07**	**15.2578**
2	60	0.268	15	2000	0.1	0.15	24.16	48.00	2400	5000	0.45	**1.2143E+08**	**6.5386E+07**	**53.8457**
3	20	4.73	15	2000	0.001	0.15	24.16	8.00	1200	5000	0.45	**4.2942E+07**	**1.3938E+07**	**32.4563**
4	60	4.73	15	100	0.001	0.15	39.18	48.00	2400	5000	0.15	**1.4149E+08**	**6.3721E+07**	**45.0356**
5	60	4.73	2	100	0.001	0.3	24.16	48.00	2400	1300	0.45	**1.2033E+08**	**3.8610E+07**	**32.0875**
6	60	0.268	2	100	0.1	0.15	39.18	48.00	1200	5000	0.45	**2.3564E+08**	**1.3610E+08**	**57.7593**
7	20	0.268	2	2000	0.001	0.3	39.18	8.00	2400	5000	0.45	**4.0052E+07**	**2.4459E+07**	**61.0678**
8	20	0.268	15	100	0.1	0.3	24.16	16.00	2400	5000	0.15	**3.9246E+07**	**1.2774E+07**	**32.5479**
9	20	4.73	2	2000	0.1	0.15	39.18	16.00	2400	1300	0.15	**4.3578E+07**	**8.5278E+06**	**19.5689**
10	60	0.268	15	2000	0.001	0.3	39.18	48.00	1200	1300	0.15	**3.5487E+08**	**2.1205E+08**	**59.7560**
11	20	4.73	15	100	0.1	0.3	39.18	8.00	1200	1300	0.45	**7.2673E+07**	**2.8843E+06**	**3.9689**
12	20	0.268	2	100	0.001	0.15	24.16	8.00	1200	1300	0.15	**3.9642E+07**	**1.4348E+07**	**36.1945**
13	60	4.73	15	2000	0.1	0.3	39.18	48.00	2400	5000	0.45	**2.5669E+08**	**1.0916E+08**	**42.5246**
14	34	1	7	1000	0.01	0.23	32.65	20.40	1800	2500	0.3	**1.5809E+07**	**5.2227E+06**	**33.0357**



Graph 1. Placket-Burman run against Recovery factor (RF)

Table 5: Parameter correlation coefficients with Recovery factor (RF)

Parameter	**Ho**	**mfac**	**Aqfac**	**Kh**	**Kv/Kv**	**Sorw**	**API**	**HGOC**	**HWL**	**Q**	**Krw**
Correlation Coefficient with RF	0.38	-0.64	0.05	0.18	-0.33	-0.16	0.22	0.50	0.20	0.35	0.16



Graph 2. Sensitivity analysis of parameters to recovery factor

DISCUSSIONS

The simulation resultse contains 14 runs with 11 parameters and 1 response variable, Recovery Factor (RF). The influence of these parameters on recovery factor (RF) was analyzed using several tools. Firstly, the correlation analysis identified the most significant parameters as shown in table

Graph 1 shows the correlation coefficients between 11 parameters and the Recovery Factor (RF). The influence of each parameter on recovery factor (RF) is analyzed considering Pearson Correlation formula.

Strong Negative correlation (r < -0.6)

Mfac has a correlation coefficient of -0.64, mfac has a strong negative relationship with RF. This suggests that increasing mfac leads to a significant decrease in RF because the higher the mfac the higher the tendency of gas cusping which is a production problem leading to reduced oil recovery.

Strong Positive Correlation (r > 0.4)

HGOC has a correlation coefficient of 0.50, HGOC has a strong positive relationship with RF. This suggests that increasing HGOC leads to a significant increase in RF. The height of the oil column (HGOC) is a critical parameter in oil recovery, and a higher HGOC value indicates a thicker oil column, leading to improved oil recovery.

Moderate Positive Correlation (0.2 < r < 0.4)

Ho: has a correlation coefficient of 0.38, Ho has a moderate positive relationship with RF. This suggests that increasing Ho leads to a moderate increase in RF. The oil rim thickness (Ho) is a critical parameter in oil recovery, and a higher Ho value indicates a larger oil-bearing area, leading to improved oil recovery.

Q has a correlation coefficient of 0.35, Q has a moderate positive relationship with RF. This suggests that increasing Q leads to a moderate increase in RF. The flow rate (Q) is a critical parameter in oil recovery, and a higher Q value indicates a higher oil production rate, leading to improved oil recovery until the critical rate is pass

Moderate Negative Correlation (-0.4 < r < -0.2)

Kv/Kh has a correlation coefficient of -0.33, Kv/Kh has a moderate negative relationship with RF. This suggests that increasing Kv/Kh leads to a moderate decrease in RF. The permeability ratio or anisotropy (Kv/Kh) is a critical parameter in oil recovery, and a higher Kv/Kh value indicates a less favorable permeability ratio, leading to reduced oil recovery.

Weak Correlation (-0.2 < r < 0.2)

Aqfac has a correlation coefficient of 0.05, Aqfac has a weak positive relationship with RF. This suggests that increasing Aqfac has a minimal impact on RF.

Kh has a correlation coefficient of 0.18, Kh has a weak positive relationship with RF. This suggests that increasing Kh has a minimal impact on RF.

Sor has a correlation coefficient of -0.16, Residual oil saturation (Sor) has a weak negative relationship with RF. This suggests that increasing Sor has a minimal impact on RF.

API: With a correlation coefficient of 0.22, API has a weak positive relationship with RF. This suggests that increasing API has a minimal impact on RF.

HWL: With a correlation coefficient of 0.20, HWL has a weak positive relationship with RF. This suggests that increasing HWL has a minimal impact on RF.

Krw: With a correlation coefficient of 0.16, Krw has a weak positive relationship with RF. This suggests that increasing Krw has a minimal impact on RF.

Implication to Research and Practice

More than seventy percent of the Niger delta wells are marginal wells, the reserve in some of these wells may the quite small that the reservoir may act like an oil rim, therefore it is crucial to know the factors or parameters that can be optimized to improve the recovery factors from such wells.

CONCLUSION

The study reveals that HGOC, Ho, Q, have the most significant influence on RF. The reasons for their impact are:

- mfac: A higher mfac value indicates a less favourable gas factor which may result togas cusping, therefore leading to reduced oil recovery.
- HGOC: A higher HGOC value indicates a thicker oil column, leading to improved oil recovery.
- Ho: A higher Ho value indicates a larger oil-bearing area, leading to improved oil recovery.
- Q: A higher Q value indicates a higher oil production rate, leading to improved oil recovery
- Kv/Kh: A higher Kv/Kh value indicates a less favourable permeability ratio, leading to reduced oil recovery.

Future Research

More research will be carried out to determine the optmal value of these influencing parameters that can be applied to recover more oil from oil rim reservoirs without damaging the wells

REFERENCES

Ahmed Tarek (2006). Reservoir Engineering Handbook. Houston, Texas. Gulf Professional Publishing.583-649

Aladeitan, Y. M., Arinkoola, A. O., Udebhulu, O. D., & Ogbe, D. O. (2019). Surrogate modelling approach: A solution to oil rim production optimization. *Cogent Engineering*, *6*(1). https://doi.org/10.1080/23311916.2019.163100

Amir, M. M., Wei, T. N., Bahrim, R. K., Piah, M. B. M., Tewari, R. D., Kechut, N., Razak, A. A., Manaf, N. A., and Castillano, E.(2024) Digital twin for oil rim management using early warning system and exception based surveillance, offshore Malaysia. Paper presented at the Offshore Technology Conference Asia, Kuala Lumpur, Malaysia, February 2024. doi: https://doi.org/10.4043/34863-MS

Behrenbruch P., Mason I.T. Optimal Oilfield Development of Fields with a Small Gas Cap Strong Aquifer, (1993); SPE 25353.

Jill, M and Richard, A. D (2010) The challenge of producing thin oil rim in Trinidad. The West Indian Journal of Engineering .32(1&2), pp.36-41

Kabir, C.S., Agamini, M.O., and Holguin, R.A. (2004). Production strategy for thin oil columns in saturated reservoirs. SPE Reservoir Evaluation and Engineering, 11(1).

Lawal, K.A., Yadua A.U., Ovuru M.I., Okoh, O.M., Eyitayo S.I., Matemilola, S. and Olamigoke, O. (2020). Rapid Screening of Oil-rim Reservoirs for Development and Management.

Journal of Petroleum Exploration and Production Technology 10,1155-1168 https://doi.org/10.1007/s13202-019-00810-6

Masoudi, R; Karkooti, Hand Othman, M.B. (2013). How to get the most out of your oil rim reservoirs? IPTC 16740. *Proceedings of the International Petroleum Technology Conference*, Beijing, 26–28 March

Masoudi, R., Karkooti, H., Othman, M. B., and Nasir H. D. (2011) Reliable characterization and modeling of the capillary transition zone and flow dynamics in the oil rim reservoirs. Paper presented at the SPE Enhanced Oil Recovery Conference, Kuala Lumpur, Malaysia, July 2011. doi: https://doi.org/10.2118/143983-MS

Moosai, R., Alleyne, B., Thomas, S., Smith, D., Cavaleri, N., and M. Anthony Quinn (2012). Race for liquids vs gas: How to redesign a depletion strategy to maximise fluids recovery in a mature thin-oil rim reservoir. Paper presented at the SPETT 2012 Energy Conference and Exhibition, Port-of-Spain, Trinidad, June 2012. doi: https://doi.org/10.2118/157949-MS

Obinaba, H.N., Mbachu, I. I., Ogali, O.O.I., and Onyekonwu,M.O (2024) Effect of Aquifer Strength and Gas-cap Size on Oil Recovery Efficiency in Thin-Oil Rim.International Journal of Current Science Research and Review, 07(02), DOI:10.47191/ijcsrr/V7-i2-39

Olabode, O., Isehunwa, S., Orodu, O., and Daniel, E (2021). Optimizing productivity in oil rims: simulation studies on horizontal well placement under simultaneous oil and gas production. Journal of Petroleum Exploration and Production Technology, 11, 385–397. https://doi.org/10.1007/s13202-020-01018-9

Olamigoke, O., and Ishehunwa, S.O (2019) primary recovery factor correlations for thin oil rims with large gas caps. Journal of Engineering Science and Technology Vol. 14, No. 4 (2019) 2359 – 2371

Razak, E A., Chan, K. S, and Nasir, D (2011). Breaking oil recovery limit in Malaysian thin oil rim reservoirs: Enhanced oil recovery by gas and water injection. Paper presented at the SPE Enhanced Oil Recovery Conference, Kuala Lumpur, Malaysia, July 2011. doi: https://doi.org/10.2118/143736-MS

Sascha V., Marc N. (2008) Concurrent oil and gas development wells: A smart well solution to thin oil rim presence in gas reservoirs. IPTC 12344, International Petroleum Technology Conference Kuala Lumpur, Malaysia, 3–5, 2008

Vijah, K. S., Ashok, K. S., and James, J. W. (1998). Strategy for control of water and gas cresting in a thin oil column using horizontal wells. SPE 39549, SPE Indian Oil and Gas Conference and Exhibition, New Delhi, Indian, 17-19 February.