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To cite this article: Firdha Meidya Buana *et al* 2025 *IOP Conf. Ser.: Earth Environ. Sci.* **1451** 012038

IOP Conf. Series: Earth and Environmental Science **1451** (2025) 012038 doi:10.1088/1755-1315/1451/1/012038

Variation of palm oil MES surfactant concentrations using CMG software

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Abstract. This study utilizes computer simulations to explore the potential use of Methyl Ester Sulfonate (MES) surfactants derived from palm oil to enhance oil recovery stability. The main function of MES in reducing interfacial tension (IFT) and boosting recovery factor (RF) includes several key actions. MES molecules align at the oil-water interface, reducing interfacial energy and IFT. It also forms micelles that encapsulate oil, further lowering IFT. By disrupting water's cohesive forces, MES helps disperse oil droplets, improving fluid dynamics and stabilizing emulsions. These effects enhance oil recovery, making MES effective in enhanced oil recovery applications. Using simulation software, this approach offers a simpler and more flexible way to evaluate different concentration levels, as it can be performed anytime and anywhere without incurring extra expenses typically associated with laboratory setups. It enables researchers to quickly identify the optimal concentration that yields the best recovery factor. Various concentration levels were tested to determine the optimal concentration that yields the best recovery factor. The tested concentrations ranged from 0.50% to 2.03%, with a specific gravity of 41 API for all variations and salinity brine at 8900 ppm. At a concentration of 0.50%, the lowest recovery factor (RF) obtained is 35.62%, while the highest RF is achieved at a concentration of 2.00%, with a value of 55.35%.

1. Introduction

The surfactants that are generally used, which are based on petroleum sulfonate, are quite expensive, are non-renewable, and are not resistant to formation water with high levels of salinity and temperature [1]. This creates an excellent opportunity to develop a local type of palm oil-based surfactant that is more affordable, abundant and environmentally friendly. Methyl ester sulfonate (MES), which is produced from palm oil, has renewable properties, is easily degraded, lower production costs, good dispersion characteristics, and effective washing properties, especially in water with a high level of hardness [2]. With a lower concentration, MES is able to provide cleaning power equivalent to petroleum sulfonate [3].

Several critical problems demand attention to enhance oil recovery processes. One primary challenge is developing an accurate model for surfactant injection within a laboratory setting using reservoir simulation techniques. This involves creating a realistic representation that can reliably predict the behaviour of surfactants in the subsurface environment. Another pertinent issue is understanding the effect of surfactant concentration on the recovery factor. Determining the optimal concentration is crucial for maximizing oil recovery while minimizing costs and

IOP Conf. Series: Earth and Environmental Science **1451** (2025) 012038 doi:10.1088/1755-1315/1451/1/012038

potential environmental impacts [4]. Finally, assessing the suitability of Computer Modelling Group (CMG) software for reservoir simulation modelling is essential [5]. CMG's capabilities and limitations must be thoroughly evaluated to ensure it can effectively simulate the complex interactions between surfactants and reservoir fluids [6], [7].

The palm oil-based surfactant Methyl Ester Sulfonate (MES) is a major breakthrough in the chemical industry, especially for use as emulsion stabilizers and cleaning agents. Sulfonation of methyl esters obtained from palm oil yields MES, an environmentally benign anionic surfactant. Because palm oil is a renewable resource and readily available, it presents MES as a more environmentally friendly surfactant than petroleum-based surfactants. Furthermore, MES has a low toxicity and is largely biodegradable, which makes it a great option for a variety of industrial uses, such as oil processing, detergents, and cosmetics.

By efficiently lowering surface tension and enhancing emulsion stability, the application of MES improves product performance while also lessening its negative effects on the environment. CMG simulation is utilized for the MES palm oil-based surfactant to analyse and optimize various operational parameters, such as environmental conditions and concentrations. This aims to determine the effectiveness of MES in enhancing oil stability and improving the efficiency of the oil recovery process.

The recovery factor for surfactants denotes the proportion of the original oil in place (OOIP) that can be extracted from a reservoir using surfactant-enhanced oil recovery methods [8]. This factor assesses how efficiently and effectively the surfactant mobilizes and displaces oil within the reservoir, thereby boosting the overall hydrocarbon recovery [9]. It serves as a crucial metric for evaluating the success of surfactant injection techniques in increasing oil production [10].

2. Methods

The CMG simulation software is employed alongside parameters derived from EOR laboratory data, with simulations carried out at Universitas Trisakti simulation and computer laboratory.

The first major step was the literature review, which was essential for establishing a solid theoretical foundation. During this phase, previous studies, publications, and relevant data were gathered and analysed to understand the background and context of the study. This step informed the research objectives and helped identify gaps in the existing knowledge.

Following the literature review, laboratory data collection was conducted. In this phase, experimental work was carried out to gather empirical data that would be critical for the later stages of the project. These experiments involved measuring parameters such as interfacial tension, which could directly influence the accuracy of the subsequent simulation.

The next step was the inputting of laboratory data into CMG STAR. Here, the collected data were inputted into CMG STAR, a simulation tool that played a vital role in predicting the behaviour of the system under different conditions based on the input data.

The subsequent step, history matching, involved comparing the simulation results to actual field or laboratory data. The aim was to ensure that the model's output reflected real-world conditions accurately. If discrepancies arose, the model underwent adjustments or recalibration. This iterative process of tuning the model parameters ensured that the simulation was reliable and valid for further analysis.

Once the history matching was successful, the process moved to results and data analysis, where the validated simulation results were thoroughly examined. This stage was critical for interpreting the outcomes of the research and drawing conclusions about the system's behaviour or the effectiveness of the process being studied.

Finally, the project concluded by marking the successful completion of the research after all data had been collected, simulated, and analysed. Figure 1 shows the whole process that illustrated on the flow chart as follows:

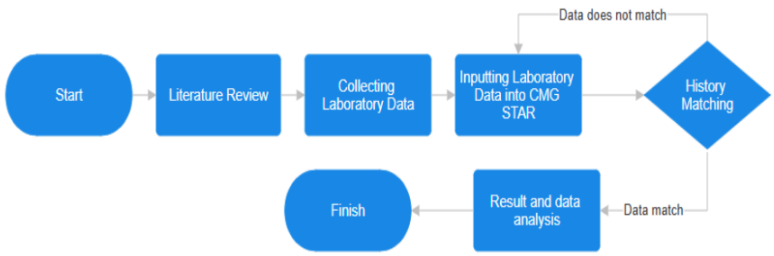

Figure 1. Flow chart

3. Materials

The core sample used is Berea Sandstone, with a diameter of 2.48 cm and a length of 2.96 cm. The injection rate is 0.3 cm^3/min. From the data obtained in the EOR laboratory at Universitas Trisakti, the parameters to be input into the CMG application as seen on Table 1:

Table 1. Parameters Input

No	Parameter	Value
1	Oil Gravity	41 API
2	Injection Rate	0.3 cm^3/cc
3	Core Diameter	2.48 cm
4	Permeability	170 mD
5	Rock Compressibility	psi-1
6	Porosity	19%
7	Bubble Point Pressure	1364.733 psi
8	Reservoir Temperature	60°C
9	Reservoir Pressure	14.7 psi
10	Water Density	1.0011 gr/cm^3

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4. CMG STAR

The advanced reservoir modeling program CMG STARS (Steam, Thermal, and Advanced Processes Reservoir Simulator) was developed by Computer Modelling Group Ltd. This program can simulate complex chemical, thermal, and sophisticated recovery processes in reservoirs. Because of its accuracy in replicating the fluid behavior of reservoirs under several enhanced oil recovery (EOR) procedures, such as chemical flooding, thermal recovery, and steam injection, it is widely used in the petroleum sector.

5. Result and Discussion

In this research, the rock core initially had a cylindrical shape, but for simulation purposes, the researchers decided to use a Cartesian type grid, as seen on Figure 2. In applying the Cartesian grid, the core rock which was originally round is assumed to be a cube with a known diameter of around 2.5 cm, which is equivalent to a radius of around 1.25 cm. Thus, the surface area of the core rock obtained is 4.908738521 cm^2. In the context of a Cartesian grid, the side of the cube obtained is about 2.70 cm, which is obtained by calculating the known area. In determining the Cartesian grid, the researcher decided to use 10 grids in the I direction, 1 grid in the J direction, and 1 grid in the K direction.

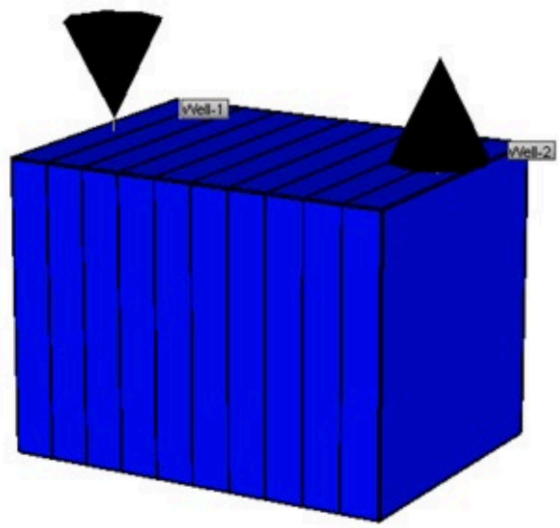

Figure 2. 3D grid model

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The test results of Palm Oil MES from the EOR Laboratory had been inputted into the CMG simulation, that can be seen at the Table 2 as follows:

Table 2. Reservoir condition

No	Parameter	Mark
1	Permeability i	170 ms
2	Permeability j	170 ms
3	Permeability k	170 ms
4	Grid Top	230.94 cm
5	Grid Thickness	2,197 cm
6	Porosity	15.151%

Furthermore, the parameters related to the numerical method has been identified in the system process simulation, by entering a first time interval of 1 minute after a change occurs in the well.

In the final stage, as seen on Table 3, researchers input the parameters required for making the well. There are two types of wells used, namely injection wells and production wells. In the injection well, researchers input a surface water rate of 0.3 cc/min.

Table 3. Well and recurrent

Fluid Type	Fluid Composition
Water	98%
Surfactant	2%
Total	100%

In the surfactant flooding process, water is still used because its presence allows oil, which has experienced a decrease in surface tension due to the surfactant, to be pushed to the surface. The next step, researchers made a production well in base case conditions by entering a bottom hole pressure value of 101,325 kPa.

After perforating the well, researchers determine the time for waterflooding and surfactant flooding. Waterflooding starts in the time range 0 to 14 minutes, while surfactant flooding starts in the time range 14 to 30 minutes. At this stage, the model creation has been completed, and the cumulative oil results in surfactant trials from palm oil can be seen.

In the initial stage, the OOIP (original oil in place) obtained from laboratory testing will be adjusted (history matching) with the data generated by the CMG application. Table 4 shows the OOIP number from laboratory tests was 1.40 cm^3 and compared with CMG data.

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Table 4. Comparison of error results

Items	LAB	CMG	ERROR
OOIP	1.40	1.39	0.01%

Surfactants from palm oil can be used and seen by varying the concentration value in obtaining the recovery factor as seen on Table 5, therefore the optimal recovery can be known which is recommended for use.

Table 5. Recovery factor value

Concentration	RF CMG (%)
0.50%	35.62177
0.75%	38.90137
1.00%	42.06398
1.25%	44.74862
1.50%	48.49816
1.75%	52.1187
2.00%	55.34526

The table explains that each variation in surfactant concentration has an impact on the recovery factor, but the optimal concentration is 2%. With this concentration, there is an increase in oil production or a recovery factor of 55.34526%, as seen on Figure 3.

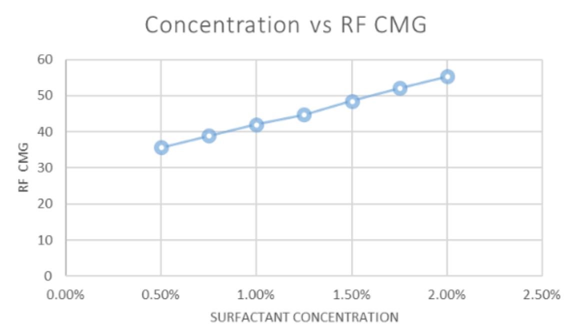

Figure 3. Surfactant concentration vs RF CMG

As the surfactant concentration rises, it enhances its capability to lower the tension between oil and water interfaces, thereby improving the mobilization and displacement of oil in the reservoir. This often results in a higher recovery factor, allowing more oil to be extracted effectively. However, it's crucial to pinpoint the ideal concentration because excessively high levels could lead to economic inefficiencies and potentially harm the reservoir's characteristics.

6. Conclusions

The influence of surfactant concentration on the recovery factor indicates that among the tested levels (0.5%, 1.0%, 1.5%, and 2.0%), the concentration of 2% achieves the highest recovery factor. This implies that as the concentration of surfactant increases, it improves its capability to reduce the interfacial tension between oil and water in the reservoir, thereby facilitating better mobilization and displacement of oil. As a result, higher concentrations are expected to enhance the efficiency of oil recovery. However, it's important to acknowledge that while higher concentrations of surfactant generally correlate with increased recovery factors, there are cases where further increases in concentration may not necessarily lead to higher recovery rates. This highlights the critical importance of carefully optimizing surfactant concentrations in reservoir engineering to maximize both the efficiency of oil recovery and economic viability.

7. Acknowledgement

This acknowledgement is dedicated to the Faculty of Earth Technology and Energy, Petroleum Engineering Department of Trisakti University, for their support in this research.

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