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الدراسات المختبرية لعملية تدفق ثاني أكسيد الكربون الغير قابلة للامتزاج الناتج من انتاج النفط في غرب الكويت

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الخلاصـة

مع اقتراب مكامن النفط إلى مرحلة النضج، تصبح عملية فهم وتنفيذ عمليات الاستخلاص المعزز للنفط ضرورية لتلبية حاجة العالم للنفط في ظل النمو للطلب على النفط. تتضمن عمليات استخلاص المعزز للنفط عن طريق حقن السوائل لإزاحة النفط وإنتاجه. واساليب الاستخلاص المعزز للنفط في صناعة البترول تشمل العمليات الحرارية والامتزاجية والكيميائية. طرق الامتزاج تنطوي على حقن الغازات والمذيبات التي من شأنها الامتزاج مع النفط لتسهيل التنقل وإنتاج النفط والتقليل من تشبع النفط في المكمن. وهذا العمل هو جزء من تركيز دولة الكويت القوي على تطبيقات استخلاص المعزز للنفط في مكامن النفط الكويتية لتحقيق أقصى قدر من عوامل إنتعاش النفط والغاز لتحقيق النمو المستدام في إنتاج النفط. وهذه الدراسة هي دراسة مختبريه لتقيم كفاءة الحقن الامتزاجي في الكويت. وقد تم اختيار المكمن النفطي كمستودع مرشح لهذه الدراسة وبعد إجراء معايير الفرز للاستخلاص المعزز للنفط، تم جمع الصخور وعينات السوائل وجرى تقييم خواصها. وأجريت تجارب الحقن للسوائل بسيناريوهات مختلفه وتقيم كفاءتها من حيث الإنتاج. وتضمنت سيناريوهات الحقن المختبري تأثير العديد من العوامل بما في ذلك نسبة الغاز للماء في عملية الحقن، وعدد إعادة تكرار عملية حقن. وأظهرت هذه المعايير تأثيرات مختلفة على معامل انتاج النفط. وسيناريو الحقن الأمثل الذي تعطي أعلى استخلاص للنفط كانت نسبة الغاز إلى الماء (WAG 1: 2)، وعدد الدورات إثنان ونتائج هذا البحث توفر معلومات قيمة لتنفيذ الميداني لعملية الحقن الامتزاجي للكويت في المستقبل.

Experimental investigation of CO_2 miscible flood in West Kuwait

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ABSTRACT

As reservoirs approach maturity, the understanding and implementation of enhanced oil recovery (EOR) techniques become essential to meet the growing world oil demand. EOR processes involve the displacement of one fluid by another. The major EOR methods in the petroleum industry include thermal, miscible and chemical processes. Miscible displacement methods involve the injection of solvents that will inter-mix with the reservoir oil to increase its mobility and reduce the oil saturation to low values in the swept zone of an oil reservoir. This work is part of Kuwait strong focus on EOR applications in Kuwaiti reservoirs to maximize the hydrocarbon recovery factors for a sustainable growth in oil production. This study is an experimental study that evaluates and investigates the miscible flood performance in Kuwait. An oil formation was selected as a candidate reservoir for this study after conducting EOR screening criteria. Core and fluid samples were collected and their properties were evaluated. Slim tube experiments were conducted to measure the minimum miscibility pressure of oil with CO_2. Core flooding experiments were conducted to evaluate the recovery factor from different injection scenarios. The experimental injection scenarios included the effect of several design parameters including water alternating gas (WAG) ratio and number of cycles per WAG. These parameters showed different effects on the recovery factor. Optimum injection scenario was obtained, which gave the highest recovery factor (WAG 1:2 and number of cycles 2). In this study, the in-situ miscibility achievement was quantified and evaluated at different injection scenarios. The outcomes of this work provide valuable information for future miscible flood field implementation.

Keywords: Enhanced oil reecovery; miscible flood; reservoir engineering and core flooding.

INTRODUCTION

The expansion of industries, new technologies, transportation, and increase of population and housing are all factors for continuous increase of oil demand. Organization of the Petroleum Exporting Countries (OPEC) published in their World Oil Outlook (2014) that by year 2030, the world oil demand would grow approximately 16% reaching 105 million barrels per day. Meeting this increase in demand for oil comes by discovering new oil fields and managing and development the existing ones. As the rate of new oil field discoveries is declining, the development of the existing oil fields has become essential. Wilkinson *et al.* (2006) stated in their paper that oil producing countries in the Middle East can play a major role to meet this oil demand increase. They mentioned that the Middle East region has great opportunity to continue supplying oil by applying enhanced oil recovery (EOR) development techniques. They approximated that one of the two trillion barrels of remaining oil is in the Middle East. EOR techniques are used after the primary natural depletion stage to produce the large amount of remaining oil. They are applied to enhance the oil mobility and increase oil production. They involve the displacement of one fluid by another. The major EOR methods in the petroleum industry include thermal, miscible and chemical processes (Green & Willhite, 1998). Thermal methods add heat to the reservoir to reduce the oil viscosity and allow it to flow to the production wells, while chemical EOR methods add chemicals (surfactants, polymer) to the injected water to reduce residual oil saturation to low values in the swept zone of an oil reservoir. Finally, miscible methods involve the injection of solvents that will inter-mix with the reservoir oil to improve its mobility. It is also known as solvent flood, which involves the injection of solvents (e.g. carbon dioxide, light hydrocarbons, nitrogen) that will mix and swell the reservoir oil to increase its mobility. The displacement of oil by a solvent is a very efficient method, since there are no capillary forces that cause oil entrapment.

Until today, Kuwait does not produce oil from EOR methods as indicated by Al-Mayyan *et al.* (2007). With this in mind and as several reservoirs are approaching maturity from the primary depletion methods in Kuwait, the understanding and implementation of EOR techniques become essential. Figarella and Al-Mezel (2012) explained in their paper that Kuwait Oil Company (KOC) forecast is to produce 4 millions barrel per day by the year 2030. They stated that 50% of the production will come from production optimization and enhanced oil recovery techniques as shown in Figure 1.

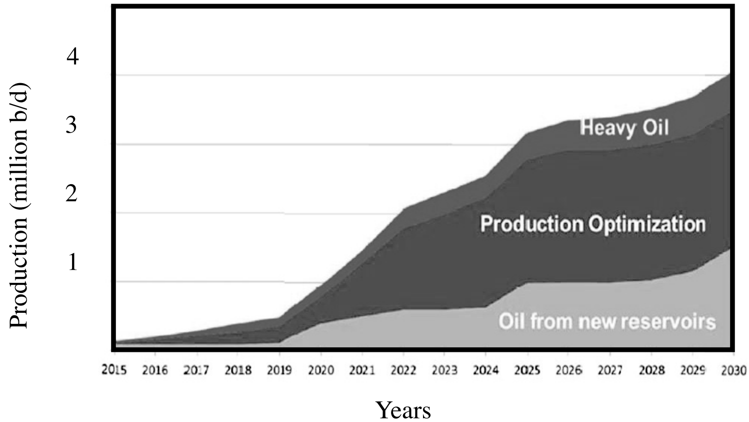

Fig. 1. KOC expected oil production from different sources *(from: Figarella and Al-Mezel, 2012)*.

Al-Bahar *et al.* (2004) investigated the potential of EOR technologies in improving the oil recovery. They screened 81 Kuwaiti reservoirs. They used Taber *et al.* (1997) screening criteria technique, and found that most of these reservoirs passed the EOR screening. Water flood and gas miscible flood were on the top of these methods. Alkafeef & Zaid (2007) carried out an investigation on the performance of EOR methods in candidate Kuwait reservoirs. They estimated the incremental increase of oil recovery by gas miscible flood to be 10-12%, and by polymer flood to be 4-5%, while surfactant/polymer flood would give 20-22 %.

CO_2 gas injection is a popular EOR method due to the improvement of oil mobility and the reduction of Carbon Dioxide (CO_2) gas emission, as an environmental concern. Algharaib (2009) presented the advantage of CO_2 storage and using it as EOR technique to increase oil production in Middle East. Another advantage of CO_2 gas injection as stated by Stalkup Jr. (1983) is that CO_2 achieves dynamic miscibility at lower pressure compared with other gases, which makes it suitable for a large range of reservoirs.

Hamouda & Tabrizy (2013) compared the CO_2 miscible flood in sandstone and chalk cores. Their observations were that oil recovery was lower in sandstone and chalk because of fingering due to the nature of the two types of rock. Laochamroonvorapongse *et al.* (2014) studied different analytical tools to monitor the flood performance in miscible WAG (MWAG) and immiscible WAG (IWAG) floods using different well-patterns. These tools are the capacitance-resistance model (CRM) and several diagnostic plots, such as the reciprocal-productivity index (RPI), the water–oil ratio (WOR), EOR-efficiency-measure plot, and modified Hall plot (MH). Duchenne *et al.* (2014) preformed a laboratory work on CO_2 WAG miscible injection efficiency in carbonate rocks. Their objectives were to quantify the fluid residual saturation and three phase relative permeability by conducting several core flooding experiments.

Strategic future plan of Kuwait Oil Company is to build a prospective road map of understanding and implementing gas miscible flood as EOR techniques in Kuwait. Al-Mayyan *et al.* (2007) investigated experimentally and numerically the potential of gas miscible flood in North Kuwait. They predicted the minimum miscibility pressure (MMP) and investigated various gas injection scenarios. Alajmi *et al.* (2010) carried out a feasibility study on the gas miscible flood in North Kuwait. Their study covered the type of flood (CO_2 and CO_2/NGL mixture), PVT analysis, facilities, economics, and flooding processes. Al-Saad *et al.* (2013) presented an evaluation of miscible and chemical EOR techniques in North Kuwait. Their study showed that gas flood, water alternating gas flood (WAG), polymer flood, and surfactant flood can increase the oil reserves and improve the production of northern Kuwaiti reservoirs.

Because of the huge capital investment and the uncertainty involved in EOR processes, laboratory experimental studies are necessary to assist in the decision making tasks and allow variety of parameters to be investigated. The importance of research and experimental laboratory studies is to provide valuable information about the suitable methods that should be followed to manage hydrocarbon recovery from subsurface reservoirs. The outcomes of the experimental work can provide many important inputs to the reservoir simulation modeling.

This work is an experimental study that investigates and evaluates CO_2 miscible flood performance in West Kuwait. Minagish Oolite reservoir in West Kuwait was selected as candidate for this study. Figure 2 shows the location of the reservoir on the Kuwaiti map. This work is used to pave the way for a CO_2 miscible gas injection pilot, which is proposed to be implemented in the Minagish Oolite reservoir in the near future. This work is also part of Kuwait strong focus on EOR applications in Kuwaiti reservoirs in general and CO_2 miscible flood in particular to maximize the hydrocarbon recovery factors for a sustainable growth in oil production.

Minagish Oolite is a thick carbonate under-saturated reservoir. The initial pressure was 4750 psi and current pressure is 3750 psi, (The reservoir was discovered in 1959). The estimated oil production is 10% of the original oil in place under natural forces of water drive and gas expansion (Al-Mutairi et al., 2001 and Al-Ajmi *et al.,* 2009). This study investigated the effect of several flooding design parameters including: injection WAG ratio and slug size per WAG cycle on the oil recovery.

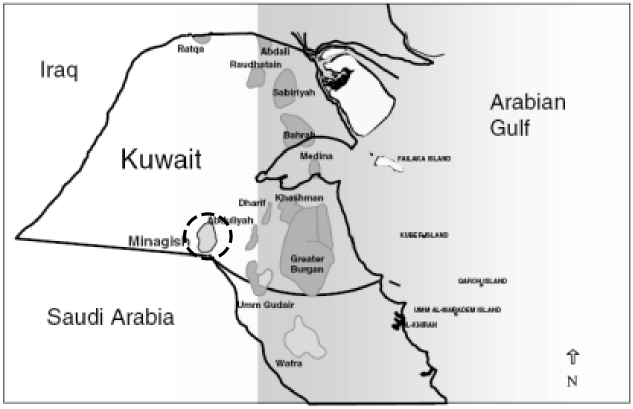

Fig. 2. Minagish field *(from Al-Mutairi et al., 2001).*

METHODOLOGY

To carry out this study, the work was divided into three phases. First phase was to prepare and design the experimental setup, collect reservoir core samples and live fluid samples. Second phase was to determine the minimum miscibility pressure (MMP) for the injected pure CO_2 at reservoir condition. Third Phase was to conduct and investigate the effect of the different core flooding scenarios on oil recovery. Three cases were studied in this phase. First case was to conduct a water flood experiment as base case for comparison purpose. The second case was to test CO_2 miscible flood performance as tertiary recovery method after water flood. The third case was to investigate the efficiency of the water alternating gas (WAG) technique on oil recovery. Six experiments were conducted in this case to obtain an optimum WAG flooding scenario. Total of eight core flooding experiments were conducted in phase three.

Rock and Fluid preparation

Rock preparation

Core and live fluid samples from the candidate reservoir were collected. Porosity and permeability tests were conducted on these samples. The well logs were studied to locate the depth intervals for the rock samples selection. Figure 3 shows the reservoir core samples.

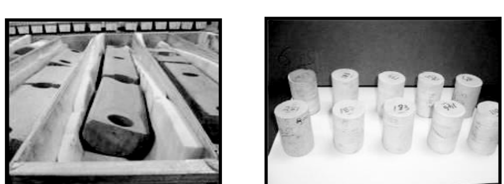

Fig. 3. Core selection procedure.

The core plugs were scanned dry by CT X-ray scanner to study the pore structure of plugs. Figure 4 shows some selected dry images. The porosity and permeability of the core plugs were measured under reservoir conditions. Figure 5 shows a porosity profile across core plugs utilizing the CT data obtained by the X-Ray scanner.

Porosity was obtained by the amount of water entering the core plug by vacuum (Table 1). The permeability was obtained by using Darcy's Law by measuring the pressure drop across the core at constant flow rate (Table 2). In this study, the permeability was measured under reservoir conditions of overburden pressure, pore pressure and reservoir water salinity. In addition, for each of the core plugs and in order to guarantee accurate results, the permeability was measured at different injection rates of 0.5 cc/min, 1 cc/min, and 1.5 cc/min. An average permeability value was then obtained for each of the core plugs.

Fluid Preparation

Reservoir fluids (live and dead) were collected. Bubble point (P_b) pressure and gas-oil ratio (GOR) tests were conducted at room temperature. The average P_b pressure was 1134 psi. The P_b is higher at reservoir temperature (around 1800 psi). The gas-oil ratio (GOR) was 490 SCF/STB.

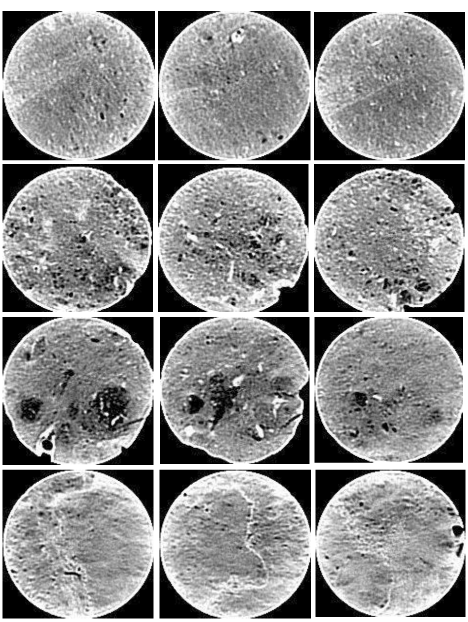

Fig. 4. Selected cross section images of some sample plugs.

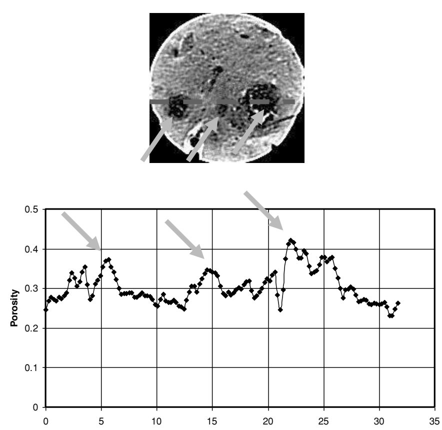

Fig. 5. Porosity profile across an image.

Table 1. Porosity measurements.

Plug No.	Diameter cm	Length cm	Pore Volume cc	Porosity %
1	3.75	5.85	17.75	27.47
2	3.75	8.65	16.04	21.84
3	3.75	5.75	20.04	31.55
4	3.75	5.75	20.54	32.34
5	3.75	6.0	22.04	33.25
6	3.75	5.95	19.54	29.73
7	3.75	5.65	19.04	30.51
8	3.75	5.8	21.04	32.84
9	3.75	5.8	14.54	22.69
10	3.75	5.8	14.04	21.91

Table 2. Permeability measurements, md.

Plug No.	0.5 cc/min md	1.0 cc/min md	1.5 cc/min md	Average md
1	440.459	441.999	405.253	429.237
2	1.270	1.360	1.369	1.333
3	693.882	685.180	693.681	690.914
4	412.506	392.545	405.302	403.451
5	823.911	1082.619	1019.864	975.465
6	924.799	956.834	938.767	940.134
7	305.497	354.339	339.942	333.259
8	856.168	924.155	955.373	911.899
9	2.072	2.279	2.430	2.261
10	2.130	2.248	2.344	2.241

Figure 6 compares the core samples' porosity to permeability. The figure shows that 7 core samples out of 10 were relatively in the same range of porosity and permeability. Based on this observation, core samples 2, 9, and 10 were eliminated from the core flooding experiments, since they were out of the range.

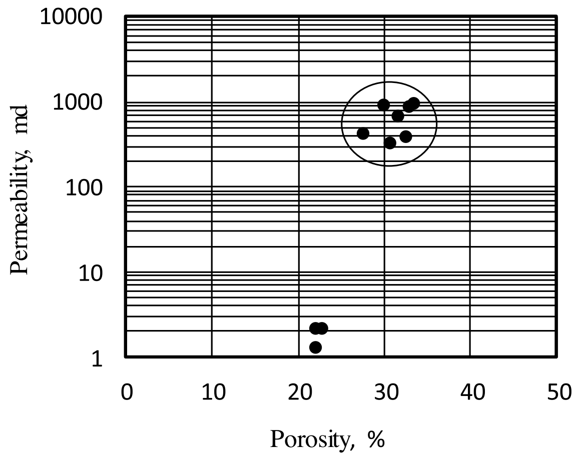

Fig. 6. Porosity and permeability relationship in the selected core samples.

EXPERIMENTAL WORK

CO_2 MMP Test

Reservoir live oil was used to conduct the minimum miscibility pressure (MMP) tests. Dead oil was collected from separator to be used in the MMP slim tube experiments as a pre-saturated agent fluid.

The live oil cylinders were maintained at reservoir pressure (above 4500 psi) during the course of the experimental work to assure a single phase condition. The experimental apparatus for MMP tests was prepared, which included, porous coil, CO_2 cylinder, dead oil cylinder, live oil cylinder, pump, oven, production fraction collector, and gas flow meter (Figure 7).

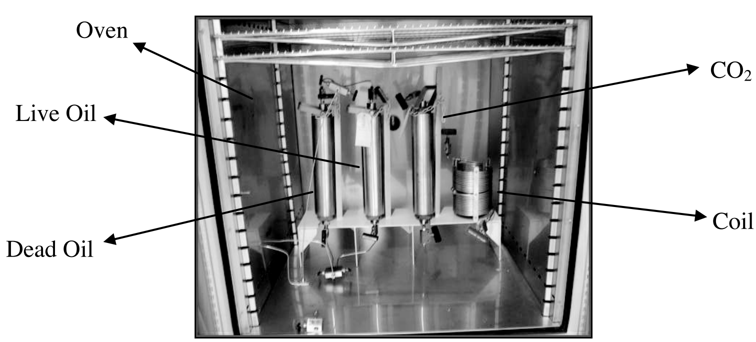

Fig.7. Slim tube oven components.

Each test followed these experimental steps below:

1. Coil is dry.
2. Coil porosity measured for pore volume measurement.

3. Coil is saturated with dead oil.
4. Coil pressure is raised to desired pressure by back pressure.
5. Live oil injection.
6. CO_2 flood.
7. Live oil recovery by CO_2 flood is measured.

In order to generate the MMP plot and measure the MMP value, six tests were conducted by injecting pure CO_2 to coil saturated with live oil. Figure 8 shows the recoveries of the six tests. To obtain the MMP value from the graph, two tangent lines were used to show the cross point of recoveries as indicated in the graph below. The graph estimates the MMP to be 2520 psi. Since the reservoir pressure is 3700 psi, the injected CO_2 will achieve the miscibility. Table 3 shows the pure CO_2 MMP values from different correlations (Maklavani *et al.,* 2010). The pure CO_2 MMP obtained in this study is within the range and in agreement with these correlations.

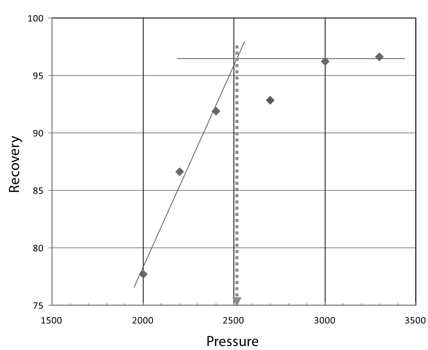

Fig. 8. Slim tube MMP test for CO_2.

Table 3. MMP values for Pure CO_2.

	Method	MMP, psia
1	Holm &Josendal	2800
2	Mungn EXT	2800
3	NPC	3350
4	Cronquist	2865
5	Yelling &Metcalfe	2679
6	Orr & Silva	2500
7	Alston et al	2397
8	Glaso	2453
9	Yuan et. Al	2698
This Study MMP CO_2		2520

Core flooding experiments

As described in the third phase of the methodology, several core flooding experiments were conducted to investigate different CO_2 flooding scenarios performance. A schematic of the experimental setup used in this study is shown in Figure 9.

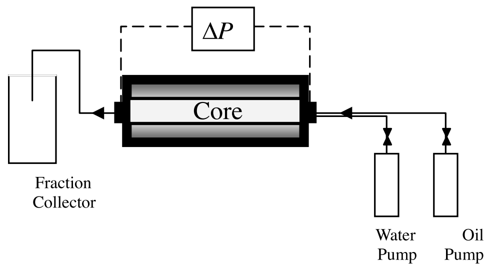

Fig. 9. Schematic of the experimental setup.

The experimental procedure for each core flooding experiment followed these steps:

1. Assemble the core holder with the core sample inside.
2. Apply confining pressure to the core sample.
3. Vacuum the core sample, extract the air out.
4. Saturate with brine, measure porosity and permeability.
5. Live oil is injected until irreducible water saturation (Swirr) is established.
6. Flooding fluid is injected until residual oil saturation is established.
7. Oil recovery is measured.

Three core flooding cases where studied; case 1: Water flooding (base case), case 2: CO_2 flood following water flood, and case 3: Water alternating CO_2 Gas (WAG). Case 3 was subdivided into 6 cases.

RESULTS AND DISCUSSION

Case 1: Water flood (base case)

The objective of this experiment was to have a base case for CO_2 miscible flood comparison and evaluation. The experiment followed the core flooding experimental procedure mentioned earlier. The oil recovery outcome of this experiment was presented in Figure 10. It can be observed that the oil recovery from water flood was around 63%.

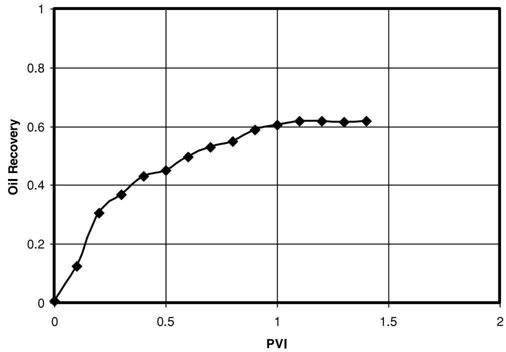

Fig.10. Water flooding.

Case 2: CO_2 Flood following water flood

When the system was at oil residual saturation after water flood, the core was flooded by CO_2 miscible injection. Figure 11 shows the oil recovery of 83% with an improvement over water flood by 20%. This case represents a tertiary oil recovery prospective by injecting CO_2 gas as miscible flood after water flood.

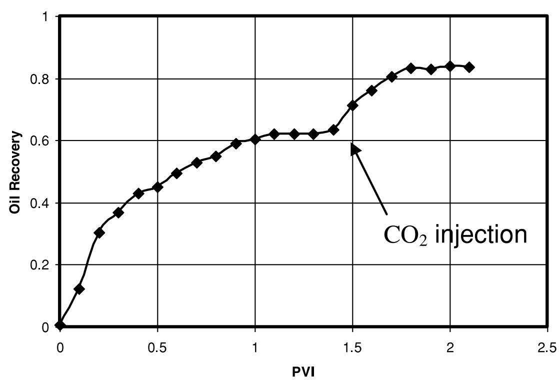

Fig. 11. CO_2 following water flood for MN-104.

Case 3: Water alternating CO2 gas (WAG)

Water alternating gas (WAG) technique was investigated in this case as a secondary recovery method following the primary recovery stage. The idea of water alternating gas was developed by Dyes (1963) to increase oil recovery. It is done by injecting slug of gas followed by water at a certain volume. The number of combinations could be repeated as required to reach the optimum oil recovery. The advantage of WAG technique is to prevent gas override and provide drive by the water injected. In this study, different combination and design of WAG was selected and oil recovery was quantified. A WAG ratio of 1:1 (equal volume of water and gas per slug) and 1:2 (gas volume is double the water volume per slug) were tested. Number of cycles per WAG ratios injected of 1, 2, and 3 were examined. The total volume of slug combination injected was fixed at 40% of pore volume. Figure 12 and Table 4 explain the selected injection scenarios.

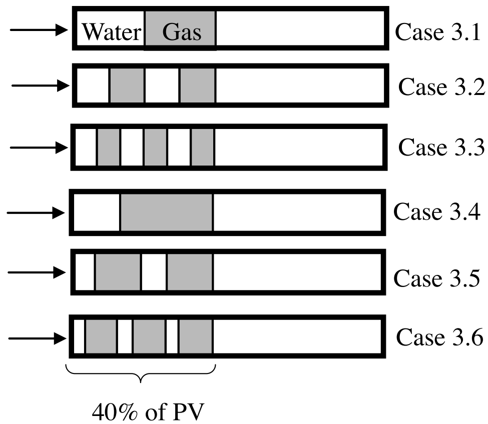

Fig.12. Schematic layout of the injection scenarios.

Table 4. Design of injection scenarios.

	WAG Ratio	Total number of cycle per WAG
Case 3.1	1:1	1
Case 3.2	1:1	2
Case 3.3	1:1	3
Case 3.4	1:2	1
Case 3.5	1:2	2
Case 3.6	1:2	3

These different injection scenarios gave different oil recovery results. Table 5 shows the oil recovery after 1.5 PV was injected. Another presentation of the results is shown in Figure 13. For a WAG ratio of 1:1, the highest oil recovery was 78% (case 3.2) and the number of cycles was 2. For a WAG ratio of 1:2, the highest oil recovery was 85% (case 3.5) and again the number of cycles was 2. The results indicated that the optimum scenario was a WAG ratio of 1:2 and number of cycles was 2 which is in case 3.5. Number of cycles of 2 in both WAG ratio cases gave the highest oil recovery. This is believed to be due to the fact that injecting two cycles of WAG slug provided an optimum intermix gas volume and an optimum water volume following as a drive.

Table 5. Oil recovery of the different injection scenarios.

WAG Scenarios	Recovery %
Case 3.1	72
Case 3.2	78
Case 3.3	75
Case 3.4	76
Case 3.5	85
Case 3.6	82

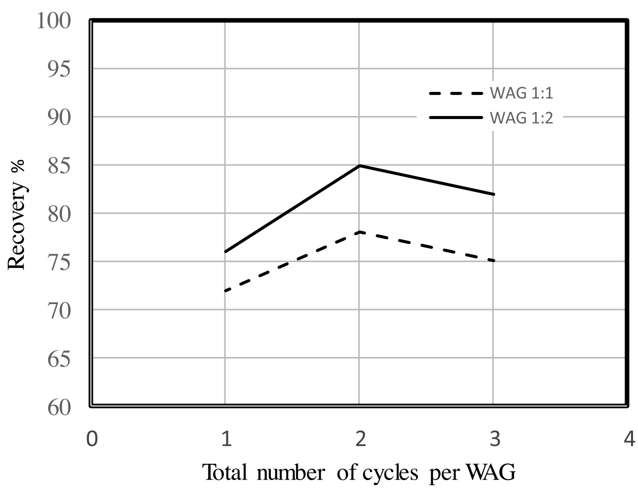

Fig. 13. Oil recovery at different number of cycles per WAG ratio.

CONCLUSIONS

The goal of this study was to investigate the performance of CO_2 miscible flood in west Kuwait. Based on the results, the conclusions of this study are:

1. The minimum miscibility pressure (MMP) for the Minagish Oolite formation was measured experimentally to be 2520 psi. This measurement was in agreement with the popular correlations. Since the reservoir pressure is 3700 psi, the injected CO_2 will achieve the miscibility.
2. The investigated miscible CO_2 core flooding scenarios showed different effect on the oil recovery. An optimum scenario was identified.
3. The ratio of water alternating gas (WAG) of (1:2) with a total number of cycles of 2 gave the optimum oil recovery.
4. Miscible flood is a promising improved oil recovery (IOR) technique for Kuwait.

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REFERENCES

Al-Ajmi, M., Al-Anzi, E., Al-Anzi, H., Karaoguz, O., Al-Ghadban, A., Baroon, B., Al-Dhuwaihi, A., Al-Otaibi, B. &Wigg, H. 2010. North Kuwait miscible gas EOR study. Oman. SPE 127072.

Al-Ajmi, M., Alomair, O. & Elsharkawy, A. 2009. Planning miscibility tests and gas injection projects for four major Kuwaiti reservoirs. Kuwait City, Kuwait. SPE 127537.

Al-Bahar, M., Merrill, R., Peake, W., Jumaa, M. & Oskui, R. 2004. Evaluation of IOR potential within Kuwait. Abu Dhabi, UAE. SPE 88716.

Algharaib, M. 2009. Potential applications of CO_2-EOR in Middle East. Kingdom of Bahrain. SPE 120231.

Alkafeef, S. & Zaid, A. 2007. Review of and outlook for enhanced oil recovery techniques in Kuwait oil reservoirs. Dubai, UAE. IPTC 11234.

Al-Mayyan, H., Al-Anzi, E. & Al-Ajmi, M. 2007. Investigation of miscible gas flooding in north kuwait reservoirs by experimental and modeling approaches. Dubai, UAE. IPTC 11688.

AL-Mutairi, S., AL-Medhadi, F., AL-Ajmi, H., Meadows, D. & Oosthuizen, U. 2001. A full field simulation model of the minagish oolite reservoir in Kuwait. Midland, Texas. SPE 70046.

Al-Saad, B., Pathak, A., Tiwari, S. & Baroon, B. 2013. EOR in North Kuwait-from concept to field test. Mishref, Kuwait. SPE 167281.

Duchenne, S., Puyou, G., Cordelier, P., Bourgeois, M. & Hamon, G. 2014. Laboratory investigation of miscible CO2 WAG injection efficiency in carbonate. Muscat, Oman. SPE 169658.

Dyes, A.B. 1963. Method for increasing recovery of oil. U.S. Patent No. 3,096,821.

Figarella, L. & AL-Mezel, F. S. 2012. Technology applications in Kuwait Oil Company to reach objectives set in 2030 strategy. Abu Dhabi, UAE. SPE 162227.

Green, D. & Willhite, G. 1998. Enhanced Oil Recovery. SPE Textbook Series. Volume 6.

Hamouda, A. A. & Tabrizy, V. A. 2013. The effect of light gas on miscible CO2 flooding to enhance oil recovery from sandstone and chalk reservoirs. Journal of Petroleum Science and Engineering, Volume 108, Pages 259-266.

Laochamroonvorapongse R., Kabir, C.S. & Lake L. W. 2014. Performance assessment of miscible and immiscible water-alternating gas floods with simple tools. Journal of Petroleum Science and Engineering, Volume **122**, Pages 18-30.

Maklavani,A., Vatani, A., Moradi, B. & Tangsirfard, J. 2010. New minimum miscibility pressure (MMP) correlations for hydrocarbon miscible injections. Brazilian Journal of Petroleum and Gas. Vol **4**. No. 1. Pages 11-19.

Organization of the Petroleum Exporting Countries (OPEC). 2014. World Oil Outlook.

Stalkup Jr. F. 1983. Status of miscible displacement. Journal of Petroleum Technology. Volume 35. Issue 04. Pages 815-826.

Taber, J., Martin, F. & Seright, R. 1997. EOR screening criteria revised – Parts 1 and 2. SPE Reservoir Engineering Journal. Pages 189-205.

Wilkinson, J., Teletzke, G. & King, K. 2006. Opportunities and challenges for enhanced recovery in Middle East. Abu Dhabi, UAE. SPE 101679.

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