IMPROVED OIL RECOVERY BY SPONTANEOUS IMBIBITION OF GABE RUN WATER WITH CHANGE PH AND SALINITY FOR SHORT AND LONG PERIOD OF AGING PROCESS FOR CARBONATE AND SANDSTONE RESERVOIRS

Madi Naser[1], Mohammed Erhayem[2], Ali Hegaig[3] , Maamar khalleefah[1], Baskiri kalifa[1], Atia Masood[1]

madinaser2004@gmail.com, moamerkhalifa93@gmail.com, baskirikhalifa@gmail.com, moh.erhayem@sebhau.edu.ly

[1] (Petroleum Engineering of Faculty of Mining and Energy, Sebha University, Libya)
*Corresponding author email: madinaser2004@gmail.com

ABSTRACT

There are many types of oil production processes primary recovery, secondary recovery, and tertiary recovery (EOR process). This study done used Gaberoun Water with different Properties as EOR Process by Using Spontaneous Imbibition test. Spontaneous Imbibition test in this research was Conducted with Sandstone and Carbonate Core Samples, as many reservoir Rocks are Sandstone and Carbonate rock. In this research, done discussed two stages by the use of Gaberoun Water with Change Ph and Salinity, the First Stage We Use the Core Samples (Carbonate & Sandstone) that aged in Oil for a long period, while the Second Stage which used the Core Samples that aged in Oil for Short period (reach to two weeks). The spontaneous imbibition test in this study was performed at room temperature to oven temperature(30C,40C,50C,60C,70C) with different sandstone and carbonate rock with an aging time of (1123, 981:00,1201:00and 817:45) hours. The result shows that the Oil Recovery Decrease with Decreasing PH and increases with Decrease Salinity, However, the Oil Recovery in the Long Aging Process is Low Compared to the Short Aging process.

Keywords: Gaberoun Water Lake Injection; Oil recovery, Aging time.

Introduction

Improving oil recovery is recognized as the major target and challenge at the different stages of oil field development. Among several methods in oil recovery,

Injection of water into the reservoir is the usual way to push the oil in front of the water towards the production well ([1]; [7]). Much oil remains in carbonate and sandstone oil reservoirs after water-flooding and in some cases in paleo transition zones, which result from the oil/water contact moving upward before discovery [12]. At this point, a high remaining oil saturation is left in the reservoir, mainly because of wettability conditions, fractures, layers with large permeability contrasts, impermeable layers during imbibition. Capillary imbibition is described as a spontaneous penetration of a wetting phase into a porous media while displacing a non-wetting phase using capillary pressure, e.g., Water imbibes into an oil-saturated rock. It has been stated that the rate of imbibition increased with an increase in temperature due to reduction of oil-water interfacial tension, oil viscosity and water viscosity [[8]. The crude oil-brine-rock interactions are responsible for the dramatic increase in oil recovery with temperature increase rather than changes related to the rock properties alone [10]. Another study is performed by using a similar chalk core sample and the results were comparable. Temperature changes, using refined oil are not verified in this study [6].

The effect of temperature on oil recovery is the oil production rate increase or decrease with temperature, the studies show that the temperatures have an important factor in increasing the cumulative oil recovery ([13]; [14]). Therefore, the decrease in the viscosity ratio of oil and water due to increasing temperature result in oil being displaced more easily and the ultimate recovery is improved [2]. The time factor for equilibration has long been considered in restoring the original wetting condition of reservoir core samples. The length of time required to incubate the core samples, however, varies from one laboratory to another, ranging from a few days to months ([3]; [9]; [4]; [5]; [11]). Several research works have been published on the effect of hardness on oil recovery indicating that calcium ion Ca^{2+}, magnesium ion Mg^{2+}, and sulfate ion SO_4^{2-} in the brine injection process. Both the concentration of $Ca^{2+}$and SO^{2-} at the carbonate surface increase as the

temperature is increased. As Mg^{2+} is even able to displace Ca^{2+} from the carbonate rock at high temperature, it should also be able to displace the Ca^{2+} carboxylate complex from the surface. Investigation of the effect of brine concentration on oil recovery often showed a significant increase in laboratory water-flood recoveries with a decrease in salinity for duplicate outcrop core plugs [15]. This study was done to study the effect of pH and salinity on oil recovery by GWLI. The objective of this study is to study the effect of GWLI on the oil recovery on sandstone and carbonate reservoirs at different temperatures. To study theeffect of change pH and the salinity on oil recovery.

PREVIOUS RESEARCH & POSITION OF THIS RESEARCH

NO	Researcher	Year	Topic	Objective
1	Farouq-Ali, S. M. and Stahl	1970	Increased oil recovery by improved water-flooding	EOR
2	Jadhunandan, P. P., Morrow	1991	Spontaneous Imbibition of Water by Crude Oil/Brine/Rock Systems	Wettability
3	Zhang, P., et al	2007	Wettability alteration and improved oil recovery by spontaneous imbibition of seawater into chalk: Impact of the potential determining ions Ca2+, Mg2+, and SO42−	Improved oil recovery
4	M Naser[1], M Erhayem[2], A Hegaig[3], M Abobakr[1], B Abobakr[1] and A Masood[1]	2018	Discover of GWLI as chemical flooding using SIT: experiment and analysis on key influence factor for oil recovery improvement	EOR

Materials and Methods

Figures 1 and 2 shows 12 cores of sandstone and 12 cores of carbonate from wells in

Figure 1. Carbonate cores are used In this study study.

Figure 2. Sandstone cores that used in this study.

the south of Libya was used. Oil sample used in this study with a density of 0.764123

g/cc and GWLI from Gaberoun Lake in Awbari desert. Ethylene Diamine Tetra Acetic Acid, E.D.T.A, was used to determine the amount of calcium and magnesium in GWLI. pH=10 organizer solution was used to determine the amount of calcium and magnesium in GWLI. EBT Guider powder and Murexide Guider Powder were used as indicators to determine the amount of calcium in GWLI. Sodium hydroxide solution, sodium chloride, toluene, barium chloride, and conditioning agent were used to determine sulfate concentration in GWLI.

SIT was conducted in test tubes as shown in Figure 3. Soxhcelete Extractor Device was used in the process of cleaning core samples from oil. A pH meter, Spectrometer Device, Flame Photometer Device, and Burette Bearer are used to measurement of properties of GWLI. Figure 4 shows Vacuum Chamber is used to saturate cores with distillate water and oil.

Figure3: Test tubes used in this study

1. Theory and Calculation

A. Pore volume PV

To calculate the pore volume of the core samples that used was done saturate cores with brine solution and measure the weight of it with brie after that calculate brine weight by subtracting (weight of core saturated – the weight of core dry), the final stage to calculate pore volume (that is equal to the volume of brine in pores) by divided (weight of brine solution in pores/density of brine) by using equation (1).

B. Bulk Volume

To calculate bulk volume easily measure the length and the radius of the core sample by using the Vernier caliper and calculating bulk volume by using equation (2).

C. OOIP calculation

This research was done vacuum chamber conducted with a vacuum pump for using it in saturate core samples with oil, that measure the weight of core samples saturated with oil and calculate OOIP/N from the equation number (3).

1.1 Mathematical Expressions and Symbols

$$Vp = \frac{Wcs - Wcd}{\rho b} \quad (1)$$

$$Vb = \pi r^2 L \quad (2)$$

$$OOIP = \frac{Wcs - Wcd}{\rho o} \quad (3)$$

Where:

Vp = pore volume.

Vb = bulk volume.

OOIP = original oil in place.

2. Results and Discussion

GWLI Analyses Results

The average pH value of GWLI is 11.11, the conductivity is 173.5 ms/cm, the salinity is 1.7 ppt, and the acidity of GWLI is 0.00235. The densities of GWLI are 1.089 g/ml and distillate water is 0.998 g/ml. The average consuming volume of EDTA solution is 0.375, calcium is 15 mg/l, and the magnesium is
49.8 mg/ L. Table 1 showed the concentration of sulfite (SO_4) in GWLI with change in salinity and ph. The porosity ranges from 27% to 14% for carbonate

rocks, while it ranges from was 31% to 23% for sandstone rocks.

Results of Spontaneous Imbibition Test

Results of Carbonate core samples that aged in oil for the long period.

Figure 4 shows three carbonate core samples (C211, C212, and C213) with a pH is 11.17 and salinity is 170 ppt. At 71:55 hours, cumulative oil recovery at room temperature was reached at (2.24%, 19.84%, 5.11%), respectively. The cumulative oil recovery continues increasing at different temperatures until reaching maximum recovery with 70oC and 817:45hr to (53.94%, 53.44%, 51.13%), respectively.

Figure 5 shows carbonate cores (C210 and C214) that are imbibition by GWLI at pH=7 and C413 at pH=4 and salinity is 170 ppt. The cumulative oil recovery at room temperature was stable at (0.89%, 9.20%), respectively. The cumulative oil recovery increases gradually with increase the time and temperature until at 70oC to (34.05%, 57.09%) for (C210, C214).

Figure 6 shows the cumulative oil recovery in carbonate core samples ((C414, C412) and (C407, C409)) with salinity is 23ppt and 10ppt and pH is 11.17. At the room temperature and 169:30hr, the cumulative oil recovery is (3.83%, 0.78%) and (7.59%, 21.88%), respectively. At 70oC at with

1201:00hr, the oil recovery increase spontaneously to 44.10%, 35.13% and (60.74%, 39.15%), respectively. The cumulative oil recovery is increasing with decreasing the salinity. However, companion data sets for water-floods and SIT both showed increased recovery with a decrease in salinity ([17], [18], [19]; [20]).

Sandstone core samples that aged in oil for the long period.

Figure 7 shows sandstone core samples (S105, S115, S102), that aged in oil for nearly one year. SIT used with pH is 11.17 and salinity is 170 ppt. At room temperature & 71:55hr, the oil recovery are (6.89%, 5.80%, 5.33%), respectively. The cumulative oil recovery is increased gradually with increase oven temperature from room temperature to (30, 40, 50, 60, and 70oC). At 70oC & 817:45hr, the cumulative oil recovery are (63.05%, 55.16%, 54.41%), respectively. Figure 8 shows the result of cores (S107& S104) with pH is 7 and salinity is 170 ppt, and also shows the results of (S316 & S311) with pH is 4 and salinity is 170 ppt. At 400C & 286:00hr, the oil recovery is (1.89%, 4.00%) and (0.12%, 2.28%), respectively. At 70oC & 1201:00hr, the cumulative oil recovery reach with the maximum rate to (21.76%, 19.20%) and (24.01%, 21.29%), respectively. Figure 9 shows sandstone core that aged in oil for a long period with change salinity to 23 ppt (S307, S303) and 10 ppt (S116, S114) with constant pH is 11.17. At 216:30hr & 30oC, the cumulative oil recovery of (S116, S114) are (2.85%, 8.54%), respectively. At 169:30hr & room temperature, the cumulative oil recovery of (S307, S303) is (8.97%, 9.49%), respectively. The cumulative oil recovery continues is increased from 30oC to 70oC to (31.37%, 30.50%) for (S116, S114)

and (70.01%, 56.95%) for (S307, S303), respectively.

Results of Carbonate core samples that aged in oil for a Short-period.

Figure 10 shows the oil recovery on carbonate core (C009) with short time, high pH, and salinity. At 46:30hr & room temperature, the oil recovery is (12.11%) and at 50oC & 622:00hr it is 15.14%. After that, the cumulative oil recovery increases to 18.16%. At 886:30hr & 70oC, the cumulative oil recovery increased to 60.56%.

Figure 11 shows the effect of pH is 7 and pH is 4 with constant salinity is 170 ppt on oil recovery. At 160:30hr, the cumulative oil recovery reach to (38.90%, 23.05%) in cores (C002, C006) with pH is 7. While are (3.91%, 26.53%) in (C001, C003) with pH is 4 at 300C. At 40oC & 309.30hr, the cumulative oil recovery continues increasing in (C002) is (48.24%), and at (51.87%) in (C006) at 500:30hr. At 454:00hr, the cumulative oil recovery reach to (5.86%) in (C001), where it reach to (36.09%), while in core (C003) at 405:30 hours. At 1123:00hr & 70oC, the cumulative oil recovery increase gradually and reached (57.57%, 72.04%) in (C002, C006), and to (39.11%, 48.83%) in core (C001, C003), respectively. Figure 12 shows cores (C004 & C005) with 10 ppt and cores (C008 & C007) with 7 ppt at constant pH is 11.17. At 118:30hr & room temperature, the cumulative oil recovery is (48.06%, 50.97%) in (C004, C005). At 260:30hr, the cumulative oil recovery is (23.77%, 20.56%) in (C008, C007). At 40oC &333:30hr, the cumulative oil recovery increase is (40.56%) in (C008). At 454:00hr, the cumulative oil recovery is (41.12%) in core (C007). At 357:00hr, the cumulative oil recovery is (57.67%) in core (C004), while is it still stable in core (C005). The cumulative oil recovery increase exponentially with increasing the aging time 1123:00hr & 70oC to (53.15%, 56.55%, 58.87%, 54.37%) in (C008, C007, C004, C005), respectively.

Figure 13 shows cores (S009 & S010) with a pH is 11 and salinity is 170 ppt for short time. At 118:00hr & room temperature, the cumulative oil recovery is (41.19%, 7.87%) in cores (S009 & S010), respectively. At 40oC & 263:00hr, the cumulative oil recovery increases gradually until reach for core (S009) is (72.31%), and at 360:00hr in (S010) is (28.33%). The cumulative oil recovery is increasing with increasing the temperature to 70oC for (S009, S010) to (81.47%, 64.53%) at 981:00hr, respectively.

Figure 14 shows core (S001, S002) with pH=7 and (S006, S004) with pH=4 with high salinity. At room temperature, there was no oil produced from the core (S001, S002), while the cumulative oil recovery for the core (S006, S004) is (7.82%, 17.00%) at 260:30hr. At 40oC & 407:00hr, the cumulative oil recovery is (21.77%, 3.34%) in core (S001, S002). In core (S006, S004), the cumulative oil recovery increases gradually until reaches (13.69%, 36.55%) with 500:30hr. At 70oC &1123:00hr, the cumulative oil recovery increase exponentially are (18.58%,

54.40%, 49.60%, 15.88%) in (S006, S004, S001, S002), respectively. Figure 15 shows (S008, S007) with 23 ppt and for (S003, S005) with 10 ppt A constant pH is 11.17 with a short time. At:30hr & with room temperature, the cumulative oil recovery for (S008, S007, S003, S005) are (14.12%, 16.51%, 71.46%, 7.46%), respectively. At 1123hr & 70oC, the cumulative oil recovery for (S008, S007, S003, S005) are (72.97%, 72.86%, 73.3%, 43.52%), respectively.

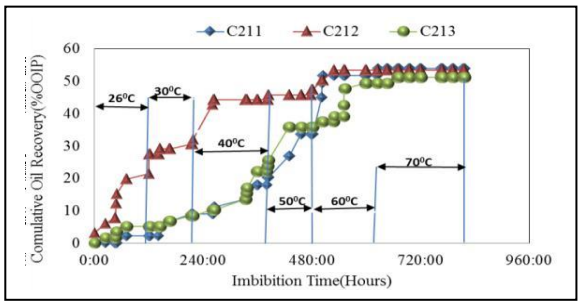


Figure 4. Effect of GWLI on cumulative oil recovery for carbonate samples aged in oil for

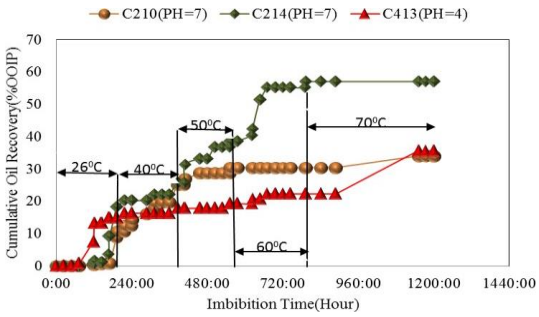


Figure 4. Effect of pH on cumulative oil recovery for carbonate samples aged in oil for long time

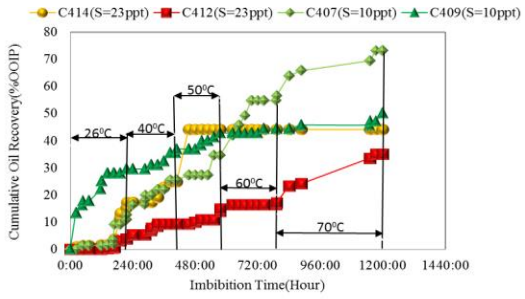


Figure 6. Effect of salinity on cumulative oil recovery for carbonate aged in oil for a long time.

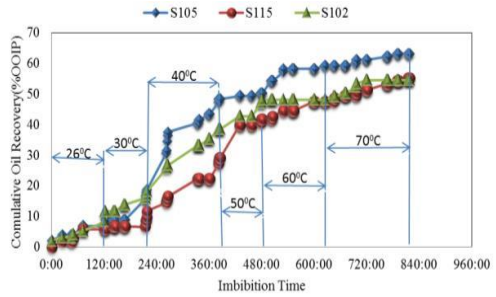


Figure 7. Effect of GWLI on cumulative oil recovery for sandstone core that aged in oil for a long time.

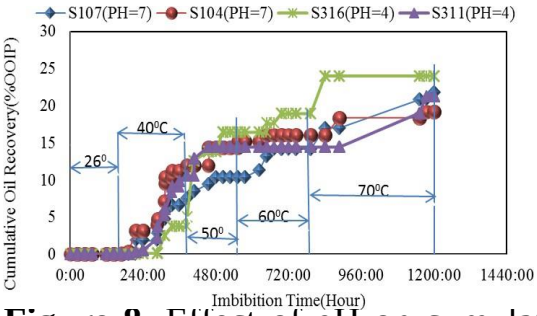


Figure 8. Effect of pH on cumulative oil recovery for sandstone core that aged in oil for a long time.

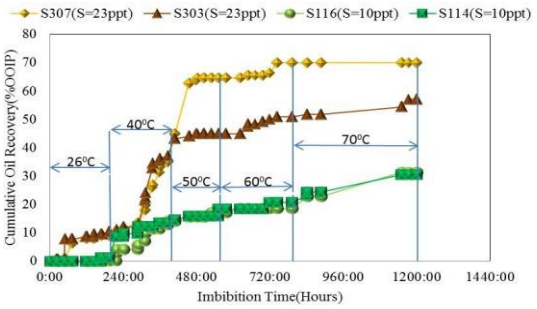


Figure 9. Effect of salinity on cumulative oil recovery for sandstone core that aged in oil for a long time.

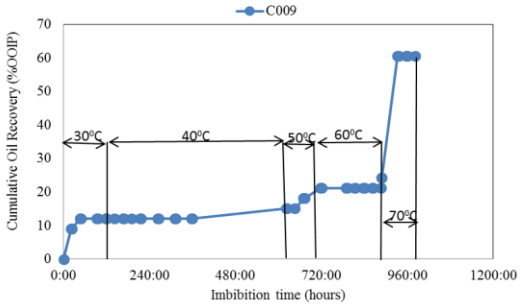


Figure 10. Effect of GWLI on cumulative oil recovery for carbonate that aged in oil for short time.

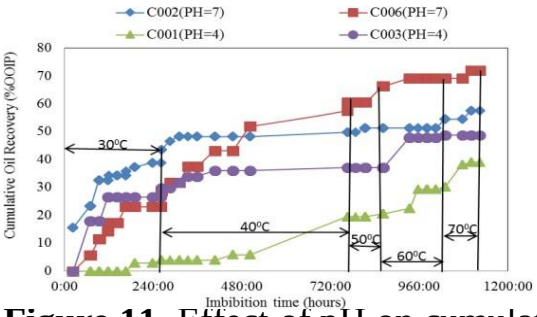


Figure 11. Effect of pH on cumulative oil recovery for carbonate that aged in oil for short time.

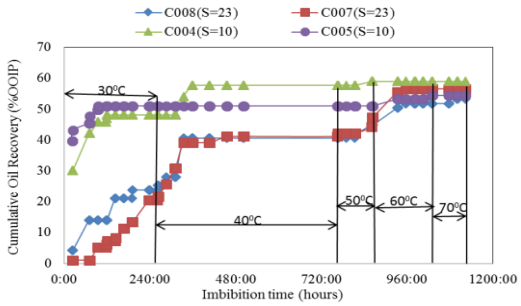


Figure 12. Effect of salinity on cumulative oil recovery for carbonate core that aged in oil for short time.

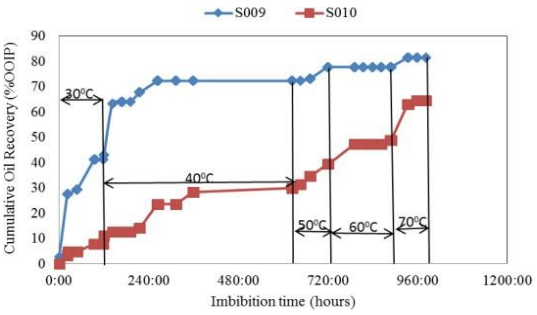
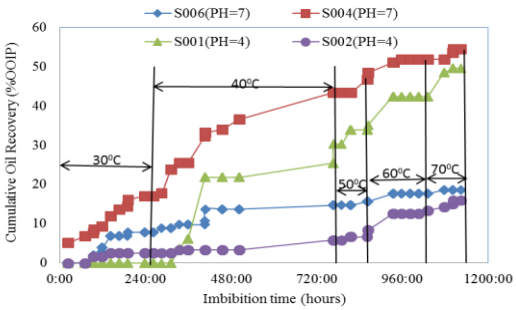


Figure 13. Effect of GWLI on cumulative oil recovery for sandstone that aged in oil for short time.



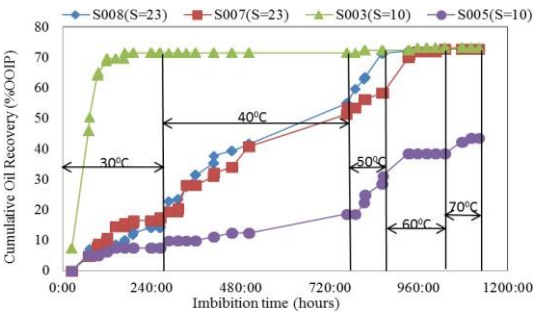


Figure 14. Effect of pH on cumulative oil recovery for sandstone core that aged in oil for short time.

Figure 15. Effect of salinity on the oil recovery for sandstone core that aged in oil for short time.

3. Conclusion and Recommendation of the Study

SIT was conducted by GWLI with pH is 7 & 4 and salinity is 23 ppt & 10 ppt for long and short aging time. GWLI acidity (pH) has an impact effect on oil recovery, when the pH is 4 the oil recovery is higher than pH is 7. The oil recovery without change the salinity and the acidity of GWLI are higher. The oil recovery is increased with decreased salinity of GWLI. The oil recovery in sandstone with original properties of GWLI is higher than with change any properties. The aging time has an impact effect on oil recovery, it decreased with increasing aging time and increases with decreased aging time. Hopefully, the research findings shown in this study can be useful for references and operating companies as an important source for understanding and visualizing the effects of pH, salinity, and aging core in oil, on oil recovery from sandstone and carbonate reservoirs using GWLI. SIT should have amott cell that provides more accurate results. If the amott cell is not available, then SIT must have a wider diameter pipe, to let the oil-free from the core samples. Most cells should be in one place and do not move it, only in emergency cases.

4. Acknowledgment.

The authors would like to thank the department of petroleum engineering, faculty of mining and energy and department of chemistry, faculty of science, Sebha University, and Mechanical Engineering, Faculty of Engineering, Misurata University, Libya.

References.

[1] Castor, T. P., Somerton, W. H., and Kelly, J, F., 1981. “Recovery Mechanisms of Alkaline Flooding. In Surface Phenomena in Enhanced Oil Recovery”. Ed. Shah, D. O. Plenum Press, New York City, pp. 249-291.

[2] Anderson, W. G., 1986b. “Wettability Literature Survey – Part2: Wettability Measurements”.
Journal of petroleum technology, trans., AIME281, pp. 1246-1262.

[3] Craig, F. F., 1971. “The Reservoir Engineering Aspects of Water-flooding”, Society of Petroleum Engineers Monograph Series, No. 3, Dallas, Texas.

[4] Quiet, L., 1975. "Restoration of the Natural State of Core Samples," paper SPE 5634 presented atthe SPE Annual Technical Conference and Exhibition, Dallas, Sept. 28-Oct. 1.
[5] Quiet, L., 1977. "Study of Problems Related to the Restoration of the Natural State of CoreSamples," J. Cdn. Pet. Tech., 16, Oct-Dec, pp. 66-80.
[6] Dangerfield, J.A., and Brown, D.A., 1985. "The Ekofisk Field: North Sea Oil and GasReservoirs", J. Kleppe et al. (eds), Graham and Trotman, London, pp.3-22.
[7] Farouq-Ali, S. M. and Stahl, C. D., 1970. "Increased oil recovery by improved water-flooding".
Earth and Mineral Sciences, Volume 39, No. 4, January, pp. 25-28.
[8] Handy, L.L., 1960. "Determination of Effective Capillary Pressures for Porous Media from Imbibition Data", Trans. AIME, Vol.80.
[9] Mungan, N., 1972. "Relative Permeability Measurements Using Reservoir Fluids," Soc. Pet. Eng.J., Oct. pp. 348-402.
[10] Tang G. and Morrow, N.R., 1997. "Salinity, Temperature, Oil Composition and Oil Recovery by Water-flooding", SPE Reservoir Engineering, pp.269-276.
[11] Wendel, D. J., Anderson, W. G. And Mayers, J. D., 1987. "Restored-state Core Analysis for the Hutton Reservoir," SPE Formation Evaluation, December, pp 509-517.
[12] George, H, and Danhua L, Z, Rice, U., 2004 "Surface Chemistry of Oil Recovery from Fractured, Oil-Wet, Carbonate Formation". SPE 88365. SPE International Symposium on Oilfield Chemistry, Houston, 5–8 February.
[13] Madi, A, N., Mohamed, E. Hesham, A. Muammar, A. Abdalsalam, M., 2018 "Effects of Temperature and Aging Time on Oil Recovery in Carbonate and Sandstone Reservoirs using Sea-Water". First International Conference on Science and Technology., 12th – 14th February2018
[14] Madi, A, N, 2016., "A laboratory investigation of the effects of temperature, hardness, surfactants, and alkaline on oil recovery from carbonate reservoirs using spontaneous imbibition tests"., J Fundam Renewable Energy App.
[15] Austad, T., RezaeiDoust, A. and Puntervold, T., 2010. "Chemical mechanism of low salinity water flooding in sandstone reservoirs". Paper SPE 129767 prepared for presentation at the 2010 SPE Improved Oil Recovery Symposium, 24-28 April.