Journal of Petroleum Research and Studies

Open Access
No. 37, December 2022, pp. 38-49

P- ISSN: 2220-5381
E- ISSN: 2710-1096

DOI: http://doi.org/10.52716/jprs.v12i4.579

Aging Effect on Rock Wettability Alteration

Ahmed Jubair Mahmood

Department of petroleum engineering, Al-Farabi university college, Baghdad, Iraq
*Corresponding Author E-mail: dr.ahmed.jabir@alfarabiuc.edu.iq

Received 22/2/2022, Accepted in revised form 8/5/2022, Published 15/12/2022

Abstract

One of the factors controlling fluid distribution in porous media is wettability, which is ranging from water-wet to oil wet. Wettability could be changed due to the long-time contact with hydrocarbon liquids. Wettability alteration resulting from the aging of core samples in hydrocarbon liquids becomes a widely used technique. The aging of Core samples from different locations in different types of liquids had been studied. The aging periods used in these studies range from hours to 110 days. In this work, synthetic core samples were aged for a period ranging from 205 to 824 days into two different hydrocarbon liquids (heavy crude from the East Baghdad oil field and gas oil). Results show that long time aging periods dramatically alter wettability; also, heavy crude oil alters wettability higher than that of light hydrocarbon.

Keywords: Aging Effect, Wettability, Imbibition Test, Alteration.

1. Introduction

Wettability is one of the major factors controlling the flow and distribution of fluids in a reservoir [1] - [3]. Several factors indicate the rock wettability could be changed. Due to, the rock interaction with hydrocarbon liquids that migrate to reservoir rock from the source rock; in addition to the interaction with some injected fluids containing asphaltenes and resin fraction [4-7]. Aging core samples in crude oil has become a widely used technique to study wettability alteration [8] - [11].

Many factors could affect the wettability of the original sample or may not demonstrate wettability alteration. Among these factors are the chemicals usually used in cleaning core

Open Access
No. 37, December 2022, pp. 38-49

P- ISSN: 2220-5381
E- ISSN: 2710-1096

samples before conducting the tests and saturating samples with water and displacing it with hydrocarbon to investigate the alteration in wettability due to aging [12-14]. The displacement process does not guarantee hydrocarbon contact with the grain surface since water will adhere to the grain surface leaving the hydrocarbon at the pore center. In addition, the aging periods are not enough to simulate the original conditions [15-16].

Recently, several researchers tried to tackle these issues as; [17] stated that wettability alteration by aging may result from the adsorption of crude oil components on high-energy mineral surfaces, or the alteration may be resulting from surface precipitation of asphaltic materials.

several researchers [18], investigate the change of fluid distribution occurring at the pore scale during wettability alteration using a combination of NMR T2 relaxation data and electrical impedance measurements. Sandstone core plugs were aged in crude oil at various conditions. After an aging time ranging from 35 to 108 days. A change in wettability is recognized since there is a change in oil/water configuration at the pore scale. conduct an experimental investigation of wettability alteration using two nonionic surfactants. Contact angle measurement and the USBM method were used to measure wettability. One hundred hours was the aging time for sandstone and limestone core plugs [19].

Researchers in [20] provide a systematic approach for wettability alteration. The subsequent results of their study are: Although contact angle measurement gives a fast and economical means to evaluate the alteration of surface wettability, the spontaneous imbibition test is the most reliable tool for wettability alteration measurement. possible rock wettability alteration due to exposure and aging in an Aqueous CO_2 environment [21]. A porous media of sand and kaolinite samples was prepared by crushed cap rock samples. The aging time ranges from 50 to 525 hours. Micro – CT scan was used to show the trapping of CO_2 in the brine system. Researchers in [22] investigate the effect of the carbon nanodots in high salinity brine with and without surfactant on static and dynamic wettability alteration of carbonate reservoirs. Outcrops of Indiana limestone and reservoir crude oil samples were used in the tests. Samples were aged for 1, 7, and 14 days then the contact angle between oil and sample surface was measured as an indication of wettability alteration.

Open Access
No. 37, December 2022, pp. 38-49

P- ISSN: 2220-5381
E- ISSN: 2710-1096

Use simple mica substrates to investigate the impact of aging conditions on the macroscopic contact angle and the microscopic properties of the surface. Mica samples were pre-aged in the brine of variable salt contents for 24 hours before aging in crude oil at elevated temperature for 4 days [23]. Results declared a wettability alteration. Researchers in [24] studied the wettability alteration of an oil-wet Iranian carbonate reservoir undergoing seawater injection. The indirect contact angle measurement using the rise core technique was used to determine rock wettability. The results show that neutral wetting is recognized after the aging process. The wettability of higher permeability samples remains unchanged after the aging process in seawater, while the wettability of low permeable samples changes to be slightly water wet. A comparison between the weighing technique and the direct volume measurement technique to measure the spontaneous imbibition. Samples of different sizes taken from the same rock source were used. Results show that the weighing method gives more accurate results compared with the direct measurement. [24]

This work is conducted to overcome these drawbacks by using strongly water-wet samples taken from synthetic porous media. So, there is no need for a cleaning process and completely saturating the core samples with the hydrocarbon under test. Five samples were saturated with heavy hydrocarbon and the other five samples were saturated with light hydrocarbon. All samples then aged for periods of 0, 205,304, 504, and 824 days.

The paper is classified into four main sections; the materials and methods are discussed in Section II. Section III represents the results and discussion. Finally, the conclusion is presented in Section IV.

2. <u>Experimental Work</u>

2.1 Materials and Method

2.1.1 Materials

- **Liquids:** The aging process is achieved using two hydrocarbon liquids. The first is heavy crude oil collected from the East Baghdad Iraqi oilfield in IRAQ and the second is gas oil. The properties of the two fluids are given in Table (1).

Open Access
No. 37, December 2022, pp. 38-49

P- ISSN: 2220-5381
E- ISSN: 2710-1096

Table (1) Physical Properties of the Two Liquids.

Fluid	Specific gravity	API gravity	Molecular weight (g/mol)	Viscosity (NS/m^2)
East Baghdad crude	0.935	19.8	541	170
Gas oil	0.8386	37.2	209	4

- **Core Plugs:** To accomplish the tests, cylindrical core plugs were taken from synthetic blocks composed of a mixture of clay and sand fired at a temperature ranging from 750 to 800°C. These blocks have high porosity and are strongly water wet. Ten core plugs were prepared then they were divided into two groups; each group consist of five core samples. The first group was saturated with the EB heavy crude while the second group was saturated with gas oil.

2.1.2 Method

The spontaneous imbibition test is considered an indicator of core wettability. The tests were performed on one core sample from each group namely at zero aging period. The rest four cores from the first group were aged in EB crude while the other four cores from the second group were aged in gas oil. The aging was performed at ambient temperature for 205, 304, 504, and 824 days at ambient conditions.

At the end of each aging period, the spontaneous imbibition test was carried out to evaluate the wettability alteration. The tests were carried out for each sample as follows;

1. The saturated sample hanged by the metallic wire and completely immersed into the water container (the sample must not touch the wall or the bottom of the container), then its weight was recorded as the weight at zero-time.
2. While leaving the sample completely immersed into water, its weight recorded at different periods.
3. The test continued until there was no appreciable change in the weight readings between two successive steps.

Figures (1) and (2) depicted experimental setup and the stages of methodology that follow in this research.

Open Access
No. 37, December 2022, pp. 38-49

P- ISSN: 2220-5381
E- ISSN: 2710-1096

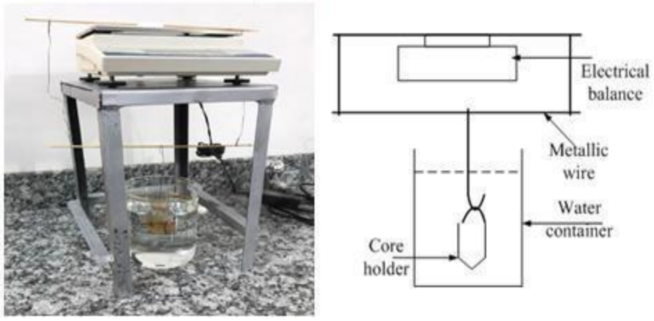

Fig. (1): The experimental setup. (After ref.25)

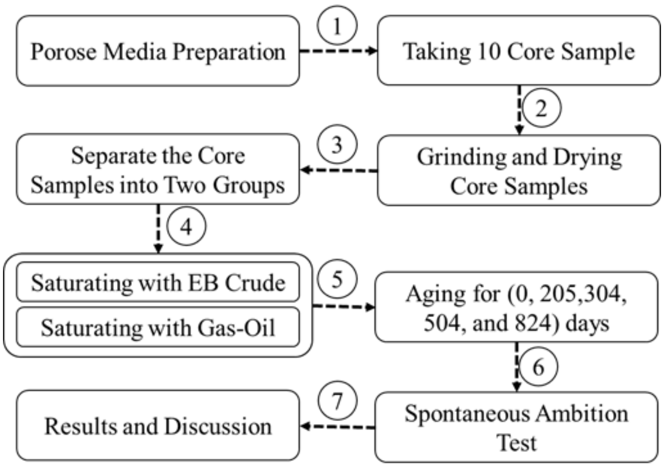

Fig. (2): Research Methodology.

3. Results and Discussion.

The readings resulting from the spontaneous imbibition tests were recorded and plotted as water saturation against time for the two groups of aged samples into two different hydrocarbons. Figure (3) is for cores aged into EB crude while the plot in Figure (4) is for those cores aged in gas oil.

Open Access
No. 37, December 2022, pp. 38-49

P- ISSN: 2220-5381
E- ISSN: 2710-1096

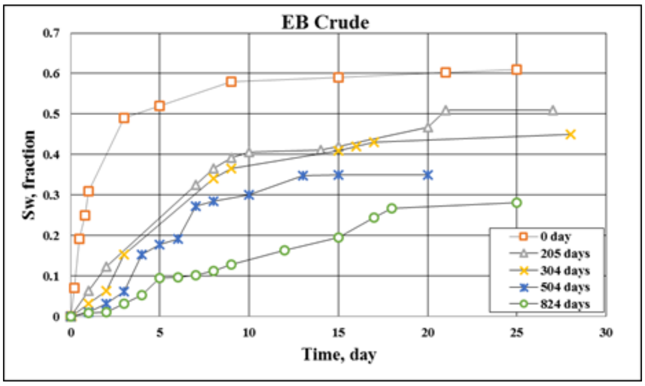

Fig. (3): Spontaneous imbibition tests for cores aged in EB crude.

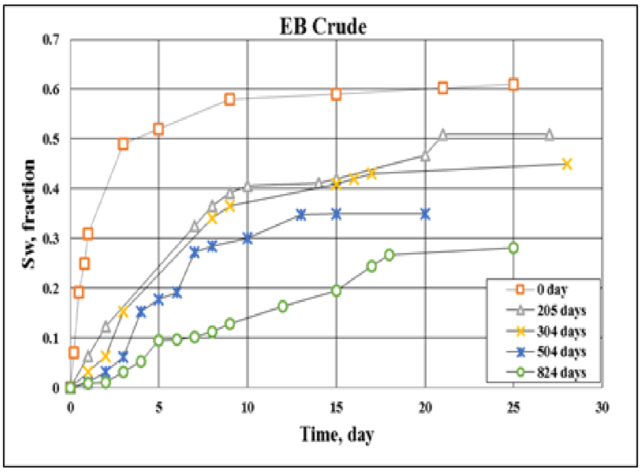

Fig. (4): Spontaneous imbibition tests for cores aged in gas oil.

Both figures show that the aging of core samples into hydrocarbons alters wettability from a strongly water-wet system as shown in a zero-time aging curve to a one that has a lower tendency to water as the aging period increases from 205 to 824 days. In addition, heavy crude shows that its effect on wettability alteration is higher than that for gas oil.

This wettability alteration could be attributed to the change in the grain surface properties due to the long-time contact with hydrocarbon. It is also clearly shown that heavy crude has a higher effect on wettability alteration than that of light hydrocarbon resulting from the precipitation of heavy components and asphaltenes on the grain surface of the porous media. To have a better understanding of the criteria of alteration, water saturation after one day and 25 days from starting the spontaneous imbibition tests is given in Table (2).

Open Access
No. 37, December 2022, pp. 38-49

P- ISSN: 2220-5381
E- ISSN: 2710-1096

Table (2) Physical Properties of the Two Liquids.

Aging period, Day	Water saturation after one day, percent		Water saturation after 25 days, percent	
	EB crude	Gas oil	EB crude	Gas oil
0	31	42	61.1	63.3
205	6.04	9.01	51.2	56.4
304	3.2	2.8	44.02	54.5
504	1.02	2.3	35.07	42
824	0.8	1.37	28.1	40.1

From Table (2), we can conclude the first-day measurement of water saturation could give an initial indication for wettability alteration since there is a rapid increase of water saturation on the first day of the imbibition test in a strongly water-wet system while the readings of water saturation are much lower in age's core samples.

In addition, the reduction of the water saturation after 25 days of imbibition test for the aged samples compared with that of non-aged samples shows that wettability tendency moving from strongly water-wet system to medium and oil-wet one especially if aging is in heavy crude. A comparison between water saturation readings after 25 days of test for samples aged in EB heavy crude and that aged in gas oil indicates that heavy crude has a higher effect on wettability. The results of the spontaneous imbibition test for every two core samples having the same aging period but aged in two different hydrocarbons were shown in Figures (5, 6, 7) and 8 foraging periods of 205, 304, 504, and 824 days respectively.

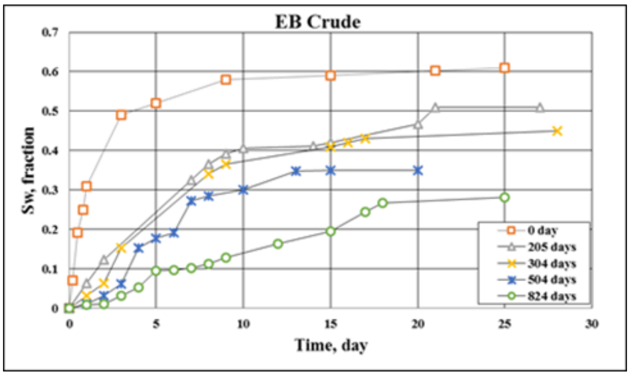

Fig. (5): Spontaneous imbibition tests for cores aged 205 days.

Open Access
No. 37, December 2022, pp. 38-49

P- ISSN: 2220-5381
E- ISSN: 2710-1096

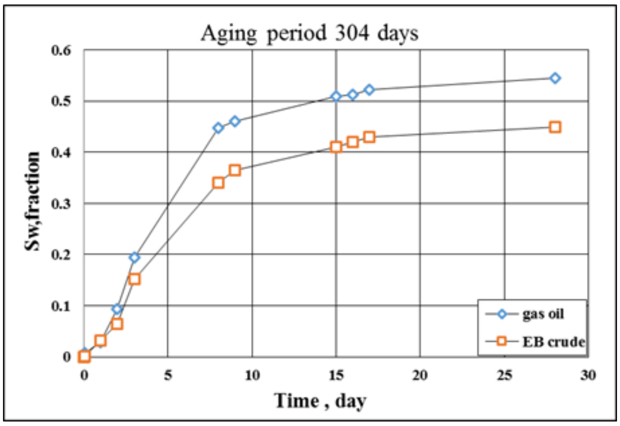

Fig. (6): Spontaneous imbibition tests for cores aged 304 days.

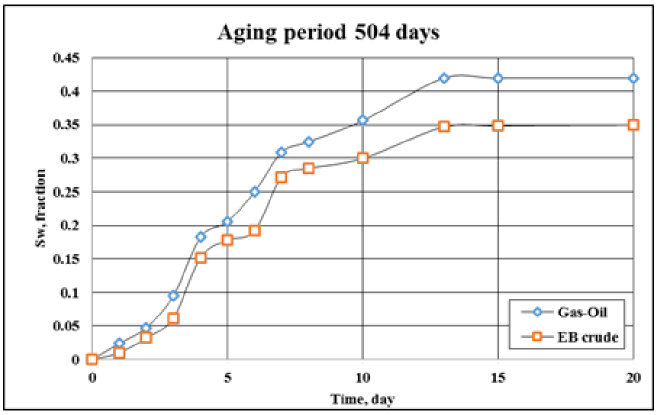

Fig. (7): Spontaneous imbibition tests for cores aged 504 days.

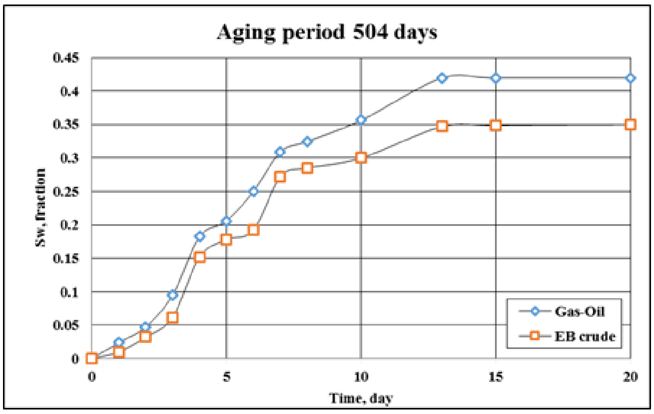

Fig. (8): Spontaneous imbibition tests for cores aged 824 days.

Open Access
No. 37, December 2022, pp. 38-49

P- ISSN: 2220-5381
E- ISSN: 2710-1096

These figures depicted that the longer the aging period the higher is wettability alteration and EB heavy crude has a higher effect on wettability than that of gas oil.

4. Conclusions

1. Generally, the aging of porous media in hydrocarbon liquids alters its wettability from strongly water-wet toward intermediate and oil-wet one.
2. Wettability alteration resulting from aging in heavier hydrocarbon is higher than that in lighter hydrocarbon.
3. Wettability alteration resulting from aging into the crude oil of East Baghdad oil field is higher than that resulted from aging into gas oil could be attributed to adhering of the heavy hydrocarbon component to the grains surface of the porous media.
4. Longer aging periods means enough time for the hydrocarbon molecules to adhere to the grain surfaces resulted in higher wettability alteration.
5. The first day reading of water saturation in an imbibition test could give a good idea about wettability alteration also the readings of water saturation at the end of the test shows the wettability tendency.

Open Access
No. 37, December 2022, pp. 38-49

P- ISSN: 2220-5381
E- ISSN: 2710-1096

References

[1] A. Paiaman, M. Palangar, S. Djezzar, S. Kord, "A new approach to measure wettability by relative permeability measurements," JPSE. Journal of Petroleum Science and Engineering. 3:109191, Jul, 2021.

[2] M. A. Fernø, M. Torsvik, S. Haugland, and A. Graue, "Dynamic laboratory wettability alteration," EF. Energy & Fuels, 24, no. 7,3950-3958, 2010.

[3] H. Eltoum, YL. Yang, JR. Hou, "The effect of nanoparticles on reservoir wettability alteration: a critical review," PS. Petroleum Science, 18(1):136-53, Feb, 2021.

[4] X. Deng, MS. Kamal, S. Patil, SM. Hussain, X. Zhou, "A review on wettability alteration in carbonate rocks: Wettability modifiers," EF. Energy & Fuels, 4; 34(1):31-54, Dec, 2019.

[5] N. Kumar, A. Mandal, "Wettability alteration of sandstone rock by surfactant stabilized nanoemulsion for enhanced oil recovery—A mechanistic study," CSPEA. Colloids and Surfaces A: Physicochemical and Engineering Aspects, 20;601:125043, Sep, 2020.

[6] J. Song, S. Rezaee, W. Guo, B. Hernandez, M. Puerto, FM. Vargas, GJ. Hirasaki, SL. Biswal, "Evaluating physicochemical properties of crude oil as indicators of low-salinity–induced wettability alteration in carbonate minerals," SR. Scientific reports, 28;10(1):1-6, Feb, 2020.

[7] K. Al-Garadi, A. El-Husseiny, M. Elsayed, P. Connolly, M. Mahmoud, M. Johns, A. Adebayo, "A rock core wettability index using NMR T2 measurements," JPSE. Journal of Petroleum Science and Engineering, 1;208:109386, Jan, 2022.

[8] A. Graue, BG. Viksund, T. Eilertsen, R. Moe, "Systematic wettability alteration by aging sandstone and carbonate rock in crude oil," JPSE. Journal of Petroleum Science and Engineering, 1;24(2-4):85-97, Dec, 1999.

[9] S. Sakthivel, M. Elsayed, "Enhanced oil recovery by spontaneous imbibition of imidazolium based ionic liquids on the carbonate reservoir," JML. Journal of Molecular Liquids, 15;340:117301, Oct, 2021.

[10] I. Torrijos, A. Mamonov, T. Puntervold, S. Strand, "The role of polar organic components in dynamic crude oil adsorption on sandstones and carbonates," CT&F-Ciencia, Tecnología y Futuro, 10(2):5-16, Dec, 2020.

Open Access
No. 37, December 2022, pp. 38-49

P- ISSN: 2220-5381
E- ISSN: 2710-1096

[11] P. Viste, B. Watson, C. Nelson, M. SWACO, "The influence of wettability on return permeability," In SPE European Formation Damage Conference & Exhibition, 2013, 5. OnePetro.

[12] D. Kim, G. Kim, N. Chu, "Aging effect on the wettability of stainless steel," Materials Letters, 1, 170:18-20, May, 2016.

[13] M. Gindl, A. Reiterer, G. Sinn, SE. Tschegg, "Effects of surface ageing on wettability, surface chemistry, and adhesion of wood," Holz als Roh-und Werkstoff, 1;62(4):273-80, Aug, 2004.

[14] H. Khairuddin, I. Yusoff, K. Badri, S. Koting, N.Tawil, P. Ng, A. Misnon, "Effect of Aging on the Chemical, Morphological and Wettability Characteristics of Polyurethane Modified Binder," In Advances in Civil Engineering Materials, Singapore, (pp. 261-270), Springer, 2021.

[15] S. Sakthivel, Y. Kanj, "Spontaneous imbibition characteristics of carbon nanofluids in carbonate reservoirs," ER. Energy Reports, 1;7:4235-48, Nov, 2021.

[16] M. Bonto, A. Eftekhari, H. Nick, "Wettability Indicator Parameter Based on the Thermodynamic Modeling of Chalk-Oil-Brine Systems," EF. Energy & Fuels. 10;34 (7):8018-36, Jun, 2020.

[17] J.S. Buckly and Y. Liu, "Some mechanisms of crude oil/brine/solid interactions," JPSE. Journal of petroleum science and engineering, 20, 155-160, 1998.

[18] S.H. Al-Mahrooqi, C.A. Grattoni, A. H. Muggeridge and X. D. Jing, "Wettability alteration during aging: The application of NMR to monitor fluid redistribution," SCA. Society of Core Analyst, 2005.

[19] M. Mohammed, T. Babadagli,"A comprehensive review of material/methods and testing the selected ones on heavy-oil containing oil-wet systems," ACIS. Adv. Colloid Interface Sci. 220, 54-77, 2015.

[20] M. Amirpour, S. R. Shadizadeh, H. Esfandyari, S. Ahmadi, "Experimental investigation of wettability alteration on residual oil saturation using nonionic surfactants: Capillary pressure measurement," KARESP. KeAi Advancing research evolving science, Petroleum 1, 289-299, 2015.

Open Access
No. 37, December 2022, pp. 38-49

P- ISSN: 2220-5381
E- ISSN: 2710-1096

[21] A. Taheria, I. Akervollb, and O. Torsartera, “Rock Wettability Alterations due to Exposure and Aging in Aqueous CO2 Environment,” ICEER. International Center for environment-friendly energy research, 2017.

[22] M. Kanja, S. Sakthivel, E. Giannelis, “Wettability Alteration in Carbonate Reservoirs by Carbon Nanofluids,” CSPEA. Colloids and Surfaces A: Physicochemical and Engineering Aspects 598 124819, 2020.

[23] M. E. J. Haagh, N. Schilderink, M. H. G. Duits, I. Siretanu, P. Krawiec, I. R. Collins, F. Mugele, “Aging brine-dependent deposition of crude oil components onto mica substrates, and its consequences for wettability,” Fuel, 274 (2020) 117856.

[24] S. Omolbanin, M. Zahedzadeh, E. Roayaei, M. Aminnaji, and H. Fazeli, “Experimental and modeling study of wettability alteration through seawater injection in limestone: a case study,” PS. Petroleum Science, 1-10, 2020.

[25] A. J. Mahmood, “Spontaneous Imbibition Test for Wettability Measurement Using the Weighing Method,” TRKU. Technology reports of Kanasai university, Volume 62, Issue 08, September, 2020.