InterPore

InterPore2021 Online Conference

Experimental investigation of physical dispersion and in-situ mixing during low salinity waterflooding

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Introduction

Low salinity waterflooding (LSWF) as an enhanced waterflooding technique is applicable in secondary and/or tertiary oil production. As a cost-effective method, the required amount of low-saline brine (LS) affects the efficiency of the process.

Although the theoretical background of mixing during low salinity waterflooding have been developed many years ago, underestimating the impact of these phenomenon have resulted in unsuccessful field applications of LSWF.

Problem Statement

The performance of LSWF depends on different factors including reservoir heterogeneity, the volume of injected brine, its salinity and in-situ mixing. If the injected volume of LS is not high enough, the expected efficiency of the LSWF will be reduced or even vanished. Consequently, more accurate estimation of the required volume of LS is crucial to guarantee the performance of LSWF.

Mixing is intensified due to adverse mobility ratio at low salinity – high salinity (HS) front. This research focuses on the impact of salinity of injection and resident brine (salinity gradient) on physical dispersion through single-phase (miscible) tests.

Methodology

A systematic series of single-phase sandpack tests were performed. In this manner, the sandpack was initially saturated with HS and flooded with LS, afterward. Consequently, the initially uniform salt distribution in the sandpack was altered gradually, leading to development of salinity gradient and mixing zone in the sandpack. The salinity of the effluent brine was measured as a function injected pore volume (Fig. 1). A coherent analytical approach was then carried out to estimate the length of mixing zone with respect to Peclet number and dispersivity.

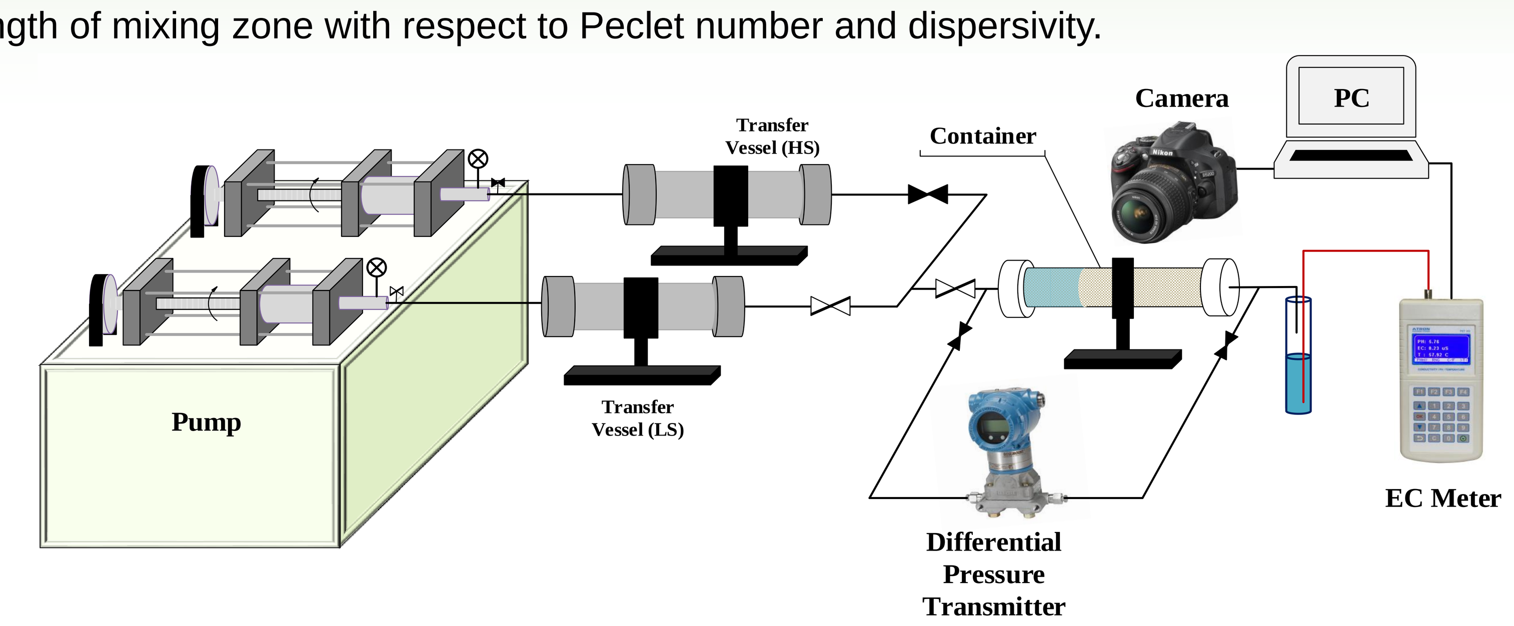

Fig. 1 Schematic of single phase sandpack flooding for dispersivity tests

Summary of the Results

Table 1 Results of sandpack tests

ID	HS (ppm)	LS (ppm)	Salinity Difference (ppm)	Dispersivity (ft)	Peclet Number
1	40,000	4,000	36,000	0.0040	205.1
2	40,000	6,000	34,000	0.0035	234.3
3	100,000	2,000	98,000	0.0069	118.9
4	100,000	6,000	94,000	0.0056	146.5
5	160,000	2,000	158,000	0.0078	105.2
6	160,000	4,000	156,000	0.0071	115.5

Why is salt dispersion impotant during Low Salinity Waterflooding?

- ✓ Salt dispersion significantly depends on the salinity difference of the injected and resident brines, which affects front stability. The higher the salinity difference (C_{HS}-C_{LS}), the lower the Peclet Number (Pe). Front stability depends on mobility ratio of HS/LS. (Fig. 5)
- ✓ The Peclet Number (dispersivity) is a weak function of C_{LS}(Fig. 2), while it considerably decreases if the salinity of HS (C_{HS}) is increased (Fig. 3). Additionally, visual evidences are presented in Fig. 4.
- ✓ Interestingly, it was concluded that in single-phase sandpack tests, the estimated dispersivity is logarithmically correlated to $(C_{HS}-C_{LS})^2/C_{LS}$ (see Fig. 6).
- ✓ Hence, higher pore volume (PV) of low-saline brine might be required in a reservoir with higher resident brine salinity, if other factors are identical.

$$\mathrm{Pe} = \frac{\mathit{Convection}}{\mathrm{Dispersion}}$$

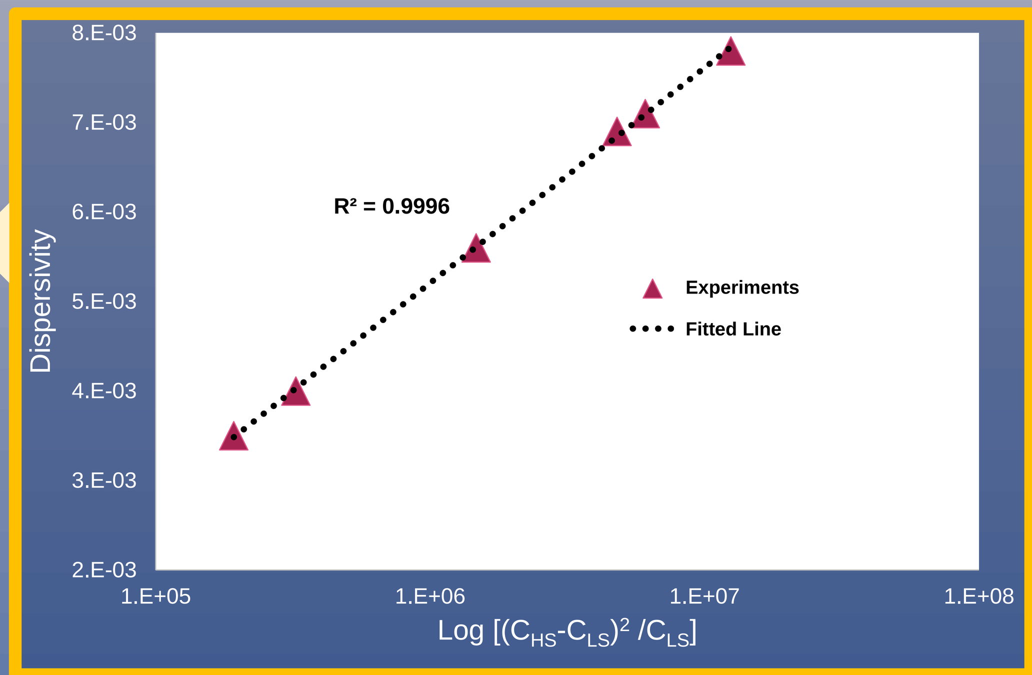

Fig. 6 Correlation between dispersivity and salinity of brines

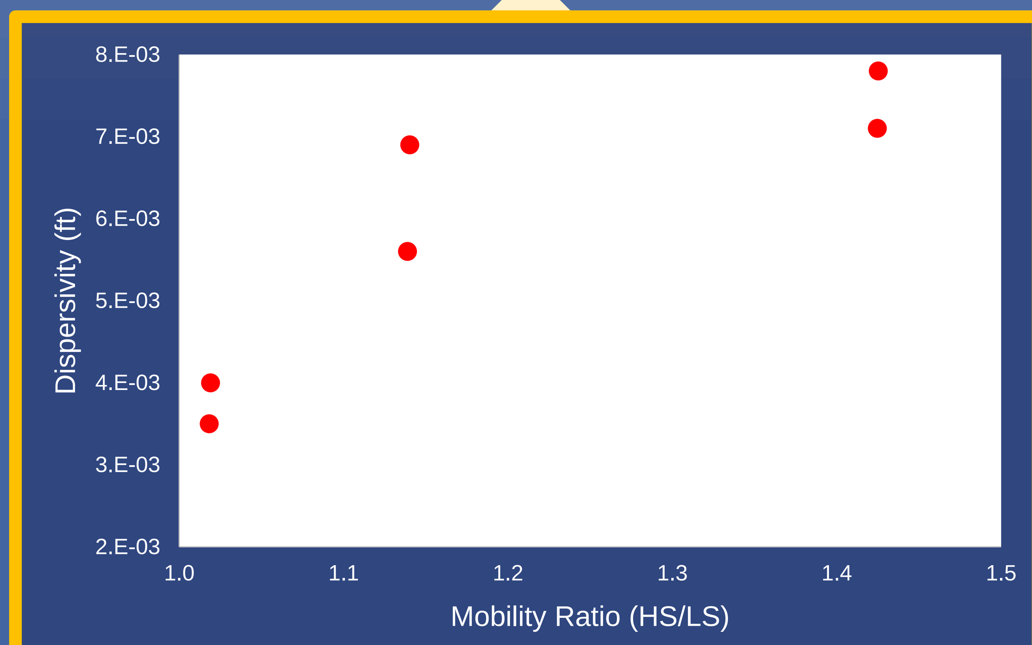

Fig. 5 Impact of mobility ratio on dispersivity of single-phase tests

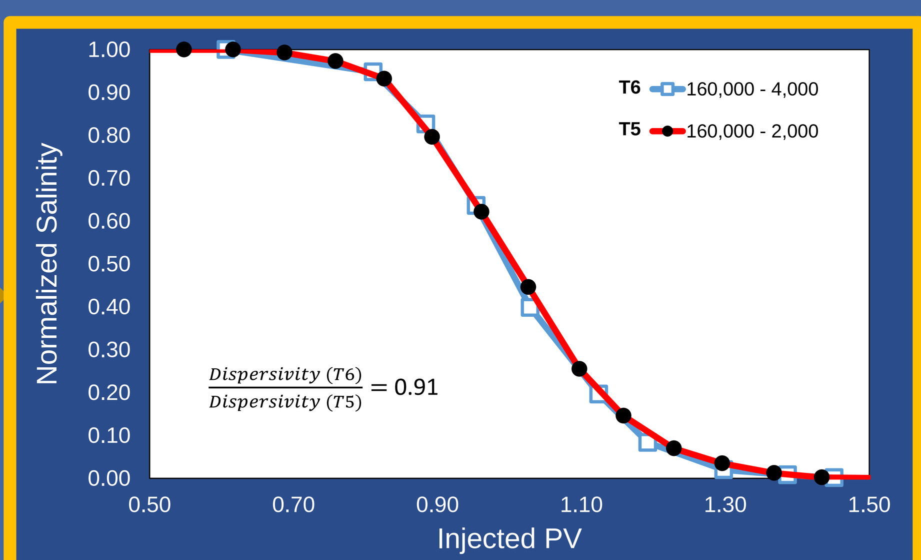

Fig. 2 Impact of salinity of LS on salt dispersivity

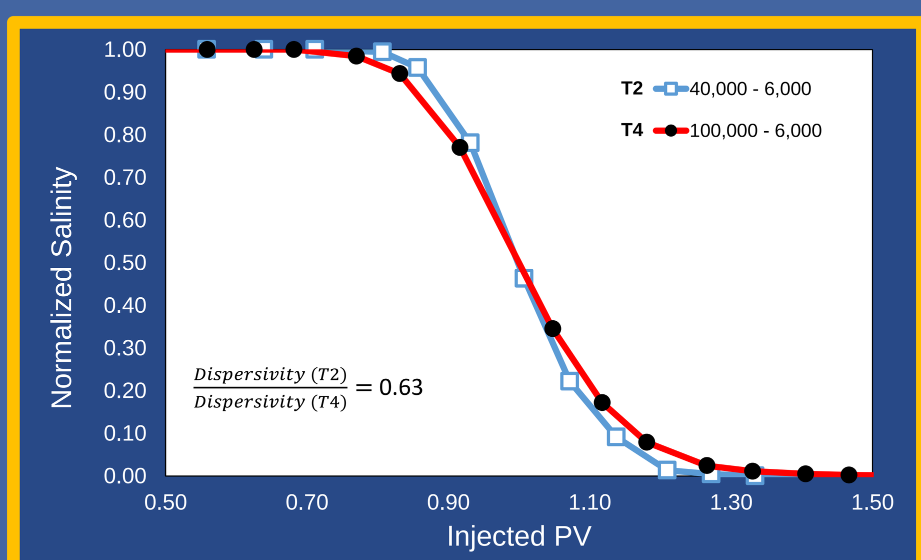

Fig. 3 Impact of salinity of HS on salt dispersivity

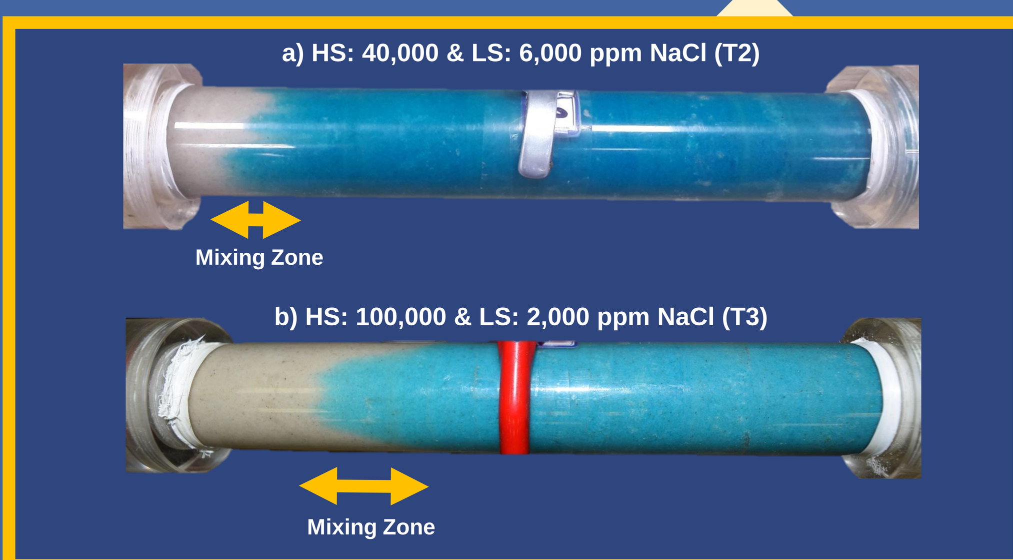

Fig. 4 Visual comparison of dispersion between HS and dyed LS

References

1. Sarvestani, A. D., Rostami, B., & Mahani, H. (2020). Polymer Augmented Low Salinity Brine for Mixing Control in Low Salinity Waterflooding. In *82nd EAGE Annual Conference & Exhibition* (Vol. 2020, No. 1, pp. 1-5). European Association of Geoscientists & Engineers.
2. Barenblatt, G. I.; Entov, V. M.; Ryzhik, V. M., Theory of fluid flows through natural rocks. **1989.**
3. Arya, A.; Hewett, T. A.; Larson, R. G.; Lake, L. W., Dispersion and reservoir heterogeneity. *SPE Reservoir Engineering* **1988,** *3* (01), 139-148, https://doi.org/10.2118/14364-PA.
4. Jerauld, G. R.; Webb, K. J.; Lin, C.-Y.; Seccombe, J. In *Modeling low-salinity waterflooding*, SPE Annual Technical Conference and Exhibition, Society of Petroleum Engineers: 2006; https://doi.org/10.2118/102239-MS.
5. Al-Ibadi, H.; Stephen, K. D.; Mackay, E., Insights into the fractional flow of low salinity water flooding in the light of solute dispersion and effective salinity interactions. *Journal of Petroleum Science and Engineering* **2019,** *174*, 1236-1248, https://doi.org/10.1016/j.petrol.2018.12.001.
6. Mohammadi, S.; Mahani, H.; Ayatollahi, S.; Niasar, V., Impact of Oil Polarity on the Mixing Time at the Pore Scale in Low Salinity Waterflooding. *Energy & Fuels* **2020,** *34* (10), 12247-12259, https://doi.org/10.1021/acs.energyfuels.0c01972.
7. Bartels, W.-B.; Mahani, H.; Berg, S.; Hassanizadeh, S., Literature review of low salinity waterflooding from a length and time scale perspective. *Fuel* **2019,** *236*, 338-353, https://doi.org/10.1016/j.fuel.2018.09.018.
8. Sorbie, K.; Mackay, E., Mixing of injected, connate and aquifer brines in waterflooding and its relevance to oilfield scaling. *Journal of Petroleum Science and Engineering* **2000,** *27* (1-2), 85-106, https://doi.org/10.1016/S0920-4105(00)00050-4.
9. Al-Shalabi, E. W.; Sepehrnoori, K., A comprehensive review of low salinity/engineered water injections and their applications in sandstone and carbonate rocks. *Journal of Petroleum Science and Engineering* **2016,** *139*, 137-161, https://doi.org/10.1016/j.petrol.2015.11.027.