View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Open Access Institutional Repository at Robert Gordon University

WUYEP, E., OLUYEMI, G., YATES, K. and AKISANYA, A. 2019. Sand failure: effect of biocide on the geomechanical properties of outcrop carbonate rock under static conditions. In: Kallel A., Erguler, Z.A., Cui, Z.-D., Karrech, A., Karakus, M., Kulatilake, P. and Shukla, S.K. (eds.) Recent advances in geo-environmental engineering, geomechanics and geotechnics, and geohazards: proceedings of the 1st Springer conference of the Arabian Journal of Geosciences (CAJG-1), 12-15 November 2018, Hammamet, Tunisia. Advances in science, technology and innovation: IEREK interdisciplinary series for sustainable development. Cham: Springer [online], pages 183-185. Available from: https://doi.org/10.1007/978-3-030-01665-4_43

Sand failure: effect of biocide on the geomechanical properties of outcrop carbonate rock under static conditions.

WUYEP, E., OLUYEMI, G., YATES, K., AKISANYA, A.

2019

OpenAIR @RGU

This document was downloaded from https://openair.rgu.ac.uk

CC BY NC

Sand failure: Effect of Biocide on the geomechanical properties of outcrop carbonate rock under static condition

Elizabeth Wuyep[1], Gbenga Oluyemi[2], Kyari Yates[3] and Alfred Akisanya[4]

[1,2]School of Engineering, Robert Gordon University, Aberdeen, AB10 7GJ, United Kingdom.

[2]School of Pharmacy and Life Science, Robert Gordon University, Aberdeen, AB10 7GJ, United Kingdom.
[4]School of Engineering, University of Aberdeen, Aberdeen, AB24 3UE, United Kingdom.

corresponding-author- e.o.wuyep@rgu.ac.uk

Abstract. The effects of chemical interaction of a biocide with formation rocks on the rock geomechanical strength are examined. A combination of analytical test (Scanning Electron Microscopy/Energy-Dispersive X-Ray Analysis - SEM/EDX, X-Ray Powder Diffraction - XRPD and Particle Size Distribution) and uniaxial compressive test was used in this study. The particle size distribution showed an increase in D_{50} with poor sorting for the chemically treated carbonate core sample. The XRPD shows evidence of altered minerals in the chemically treated samples. It was observed that the interaction led to precipitation of new materials that clogged the pore space of the rock samples leading to about 150% increase in compressive strength of the carbonate following treatment with the biocide. The results give more insight into the limitations of the existing sand production prediction models with respect to the effect of oilfield chemicals on the strength of the reservoir rocks.

Keywords: Chemical interaction, glutaraldehyde, carbonate, uniaxial compressive strength, reservoir rock

1 Introduction

Biocides are typically used in the oil and gas industry to control the activities of undesirable bacteria and microorganisms that can cause corrosion of the pipelines and also produce some substances such as H_2S, organic acids, etc. that affect the yield and quality of oil and gas negatively. Unfortunately, the deleterious effect of the interaction of the biocide with the reservoir rock has not always been accounted for. Seto et al. (1997)[4] examined the effect of polyethylene oxide (PEO), aluminium chloride (AlCl3) and dodecyltrimethyl ammonium bromide (DTAB) on sandstone under static condition and found that these chemicals did not cause any significant change in the compressive strength of the sandstone. Nevertheless, the chemistries and composition of the chemicals used in the work are different from those of biocide and other commonly used oilfield chemicals.

The current work investigates the effects of biocide on the geomechanical strength of reservoir rock and sand production potentials under static condition. The results give more insight into the limitations of the existing sand production prediction models with respect to the effect of oilfield chemicals on the reservoir strength.

2 Materials and Experimental Implementation

Glutaraldehyde ($C_5H_8O_2$), a biocide was obtained from REDA oilfield UK. Ltd; whilst a synthetic brine was used as control. Four (4) cylindrical outcrop core samples with a diameter of 38mm and length 51mm obtained from Texas, USA through Kocurek Industries Ltd were the substrates.

A combination of saturation test, analytical tests, particle size distribution analysis and mechanical tests were carried out on untreated and chemically treated (biocide) core samples (carbonate). X-ray Powder Diffraction (XRPD) and Energy Dispersive X-Ray Analyser (EDXA) techniques were used to determine mineral and element compositions respectively. Scanning Electron Microscope (SEM) was used to analyse the mineral textural characteristic. While the particle size distribution was analysed with the use of Malvern Mastersizer. Compressive strength was investigated under uniaxial compression test. The results of the tests were then analysed using an integrated approach

3 Results

3.1 Evaluation of elemental and mineralogical composition of the rock sample

A cross-section of untreated carbonate (Edward brown) under SEM revealed dolomitized limestone with moderately sorted euhedral-subhedral dolomite ($CaMg(CO_3)_2$) mineral with sucrosic texture (Wuyep et al. 2018b)[6]. Observed in the SEM micrograph are cloudy centres and light rims which are typical of dolomites. Several interconnected pore spaces were observed in the sample. The EDX spectrum indicates the presence of Mg, C, O, Ca, Al, K, Cl, Si and Fe.

On the other hand, the SEM micrograph shows the glutaraldehyde treated carbonate to have about 90% of the pore spaces filled with the precipitated materials which are believed to have originated from the dissolution and precipitation. EDX scan revealed 58% and 11% increase in Ca and Mg content respectively in the glutaraldehyde and brine treated samples. According to existing literature (Plummer et al. 1978)[3], three simultaneous reaction mechanisms are identified with calcite dissolution process. Thus, in this work, the likely reactions involving the calcite dissolution and dolomite precipitation when the rock is exposed to brine and glutaraldehyde are as presented below:

$$\mathrm{CaCO_3} \leftrightarrow \mathrm{Ca^{2+}} + \mathrm{HCO_3^-} \quad [1]$$

$$\mathrm{CaCO_3} + \mathrm{H_2CO_3^0} \xleftrightarrow{\mathrm{H^+}} 2\mathrm{HCO_3^-} \quad [2]$$

$$\mathrm{CaCO_3} + \mathrm{H_2O} \leftrightarrow \mathrm{Ca^{2+}HCO_3^-} + \mathrm{OH^-} \quad [3]$$

$$\mathrm{Ca^{2+}} + \mathrm{Mg^{2+}} + 2\mathrm{C^+7O^-} \leftrightarrow \mathrm{CaMg(CO_3)_2} + \mathrm{H_2O} \quad [4]$$

2H+

3.2 Grain size distribution analysis

The D_{10}, D_{50} and D_{90} values for the glutaraldehyde effluents from carbonate increased remarkably (a factor of 10) relative to those of brine (Table 1).

Table 1. : Grain size distribution with sorting of the original brine and the effluents

Effluents	Particle Size (µm)			Folks (1966)[1]	
Carbonate	D10	D50	D90	Sorting (σ_1)	Description
Original brine	3	7	30	0.01	Very well sorted
Carb-Brine	2	15	41	0.54	Moderately sorted
Carb-Glut 1	7	70	407	0.84	Moderately sorted
Carb-Glut 2	7	71	408	0.85	Moderately sorted

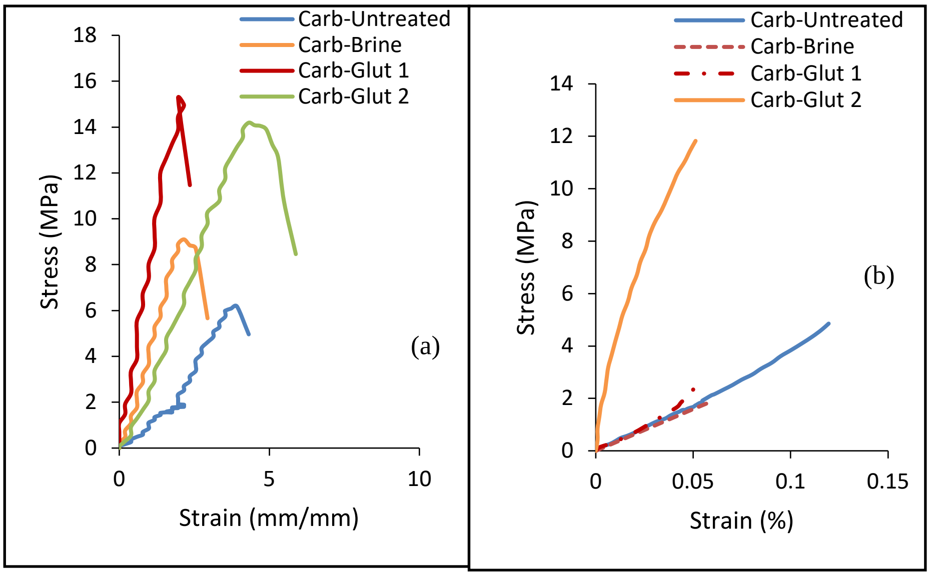

Fig 1. Stress-strain relationship in plastic regions of untreated and chemically treated Edward brown carbonate: (a) complete response to failure; (b) stress-small strain response.

3.3 Response of strength and Young's modulus to chemical treatment

Fig. 1a shows an increase in mean strength of untreated carbonates (Edward brown) from 5.6 MPa to about 8.4, and 15 MPa owing to treatment with brine and glutaraldehyde (1 &2) respectively. The 50% and approximately 150% increase in strength of carbonate post chemical treatment with brine and glutaraldehyde confirms the pore space filling by the precipitated materials made possible by the dissolution/precipitation reaction.

The measured Young's modulus, *E*, of carbonate from the test results shows an increase from 4GPa to 12GPa following treatment with glutaraldehyde and no change (5 GPa) with brine treated sample (Fig.1b).

4 Discussion

The 89 - 92% decrease in calcite content indicated by XRPD suggests dissolution reaction; whilst the 25 - 29% increase in dolomite indicates precipitation reaction. The clay fraction shows little or no change with the clay minerals content (kaolinite, illite and mixed-layered illite-smectite) when exposed to brine and glutaraldehyde.

The interaction between glutaraldehyde and the carbonates as well as the interaction between the brine and glutaraldehyde can lead to precipitation of new materials that fill the pore spaces (pore clogging).

The increment of the particle size distribution on exposure to glutaraldehyde suggests some dissolution/precipitation reaction orchestrated by diffusion and adsorption might have taken place between the chemical and the rock samples that led to deterioration of the grain to grain binding resulting in grains detachment and release into the fluid stream. The result is consistent with earlier works (Wuyep et al. 2018, Oluyemi 2014)[5, 2].

5 Conclusions

The results show that chemical reactions, namely, diffusion, adsorption, dissolution and precipitation took place. The interaction between biocide and carbonate rock led to precipitation of new materials that filled the pore spaces giving rise to approximately 150% uniaxial compressive strength increase, a phenomenon that potentially leads to formation damage and hydrocarbon production impediment.

References

1. Folk, R.: A review of grain-size parameter. Sedimentology 6(2), 73-93 (1966).
2. Oluyemi, G.: Conceptual Physicochemical Models for Scale Inhibitor-Formation Rock Interaction. Pet. Sci. and Tech. 32(3), 253-260 (2014).
3. Plummer, L. N., Wigley, T. M. L. & Parkhurst, D. L., 1978. The kinetics of calcite dissolution in CO2-water systems at 5 degrees to 60 degrees C and 0.0 to 1.0 atm CO2. *American J. Sci*. **278(2),** 179–216.
4. Seto, M. Nag, D.K., Vutukuri, V.S. and Katsuyyama, K., 1997. Effect of chemical additives on the strength of sandstone. *Int J. Rock Mech. and Mining Sci*, 34:3-4.
5. Wuyep, E., Oluyemi, G., Yates, K., Akisanya, A.: Geochemical effects of oilfield chemicals on sand failure in reservoir rocks. J. Pet. Sci. and Eng. 165, 347-357 (2018).
6. Wuyep, E., Oluyemi, G., Yates, K., Akisanya, A.: Evaluation of the interactions between oilfield chemicals and reservoir rocks. Submitted to J. Pet. Sci. and Eng. (2018b).