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Synergistic Effects of Dimethyl Ether and LSW in a CO_2 WAG Process for Enhanced Oil Recovery and CO_2 Sequestration

Yongho Seong [1], Bomi Kim [1], Qingquan Liu [2], Liang Wang [2] and Kun Sang Lee [1,2,*]

[1] Department of Earth Resources and Environmental Engineering, Hanyang University, Seoul 04763, Republic of Korea; yhseong@hanyang.ac.kr (Y.S.); bomi02@hanyang.ac.kr (B.K.)
[2] School of Safety Engineering, China University of Mining and Technology, Xuzhou 221116, China; cumtsafe@cumt.edu.cn (Q.L.); wangliang@cumt.edu.cn (L.W.)
* Correspondence: kunslee@hanyang.ac.kr

Abstract

The integrated injection of low-salinity water (LSW) and carbon dioxide (CO_2) into the water-alternating-gas (WAG) process offers advantages, primarily increasing oil recovery and reducing operating costs. However, CO_2 has challenges in sweep efficiency due to significant differences in density and viscosity compared with oil. While LSW and dimethyl ether (DME) have shown promise in improving recovery through wettability alteration and reducing minimum miscible pressure, interfacial tension (IFT), and CO_2 mobility, their synergistic integration with CO_2-WAG remains poorly understood. Existing DME-based enhanced oil recovery (EOR) studies have not explored low-salinity water injection as a cost-effective alternative to mitigate high DME operating costs. This study introduces the CO_2/DME-LSWAG method, systematically evaluating the effect of DME concentrations (0%, 10%, 25%) and LSWs (seawater, twice-diluted seawater, ten-times-diluted seawater) on sweep and displacement efficiencies, oil recovery, and CO_2 storage in a 2D cross-sectional carbonate reservoir model. Results showed that DME dramatically reduces IFT (67% and 95% at 10% and 25% DME solvent, respectively) while salinity effects are relatively small. Compared with CO_2-LSWAG, the oil recovery factor improved by 5.2–13.1% depending on DME concentration and water salinity, with DME performance maximized at higher salinity water. CO_2 storage efficiency showed opposing trends. Structural trapping decreased, while solubility trapping increased with lower salinity. The sensitivity analysis identified DME concentration as the dominant factor for CO_2 storage. The composition modeling and simulation of the CO_2/DME-LSWAG process provide critical engineering guidance for the design of future EOR and CO_2 storage projects that utilize DME in carbonate reservoirs.

Keywords: dimethyl ether (DME); low-salinity water (LSW); enhanced oil recovery (EOR); water alternating gas (WAG); carbonate reservoir; CO_2 storage

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1. Introduction

CO_2 is the solvent most widely used in enhanced oil recovery (EOR) processes. However, CO_2 causes problems such as early breakthrough and viscous fingering due to large differences in density and viscosity compared with oil [1–3]. To compensate for that, the water-alternating-gas (WAG) injection method was developed to enable geological CO_2 storage and enhanced oil recovery [4].

Low-salinity water injection (LSWI) has been recognized as a cost-effective, eco-friendly, and effective method for EOR [5]. Although numerous studies have been conducted to elucidate the fundamental mechanism of LSWI, it has not yet been fully identified.