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Geomechanical modeling of CO_2 sequestration: A review focused on CO_2 injection and monitoring

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ABSTRACT

The dependence on fossil fuels is the primary cause of the increased carbon dioxide emissions into the atmosphere that have resulted in drastic global climate changes due to greenhouse effects and associated global warming. Carbon capture and sequestration (CCS) is a multidisciplinary technology that is gaining momentum in the quest to mitigate the effects of CO_2 emissions. In this paper, we review the current status of research pertinent to the geomechanical modeling of CO_2 sequestration and highlight the key research accomplishments, unresolved problems, and pending challenges and opportunities. The paper begins with a brief overview of the geological sequestration process and then proceeds to review the main aspects of geomechanical modeling, including different numerical methods for modeling the reservoir pressure, ground uplift due to pressure buildup, caprock fault reactivation, carbon dioxide leakage, and induced seismicity. The effects of the number and distribution of injection and production wells on the pore pressure buildup are discussed. Finally, a topical overview of monitoring techniques for stored carbon dioxide is presented.

1. Introduction

1.1. Carbon dioxide emission and global warming

The continuous dependence on fossil fuels in the past few decades has led to a significant increase in CO_2 emissions being released into the atmosphere. The presence of greenhouse gases, especially CO_2, has caused global climatic changes such as global warming [1,2]. In the last few decades, the natural cycle of carbon dioxide has been significantly affected by the increase in CO_2 emissions. Before the excessive burning of fossil fuels, the natural level of CO_2 was preserved in the atmosphere [2,3]. Increased industrialization and deforestation have disturbed the natural CO_2 levels in the atmosphere [4–7]. The atmospheric CO_2 concentration has increased by nearly 50% since the Industrial Revolution that started in the 1750 s. The carbon dioxide concentration was 410 ppm in 2019, and it is expected to increase to 570 ppm by the end of the 21st century if the current levels of CO_2 emissions continue [8,9].

The excessive emissions of CO_2 into the atmosphere have already motivated the world scientific community to find ways of mitigating the increasing levels of atmospheric CO_2 [10–12]. Carbon dioxide level in the atmosphere can be significantly reduced by using three principal strategies: reducing the rate of CO_2 emissions, sequestering CO_2, and utilizing CO_2 as a feedstock [13–17].

To gauge greenhouse gases, the Environmental Protection Agency (EPA) of the United States has introduced the Global Warming Potential (GWP). The GWP quantitatively compares the energy absorbed by one ton of greenhouse gas to that of one ton of CO_2 during the same period. If the GWP indicator is higher for a given gas than that of carbon dioxide for the same duration, it implies that such a gas will have a higher contribution to global warming. Although, the GWP value of various

Abbreviations: CCS, Carbon Capture and Sequestration; GWP, Global Warming Potential; EOR, Enhanced Oil Recovery; EM, Electromagnetic; InSAR, Interferometric Synthetic Aperture Radar; CO_2-EWR, Carbon Dioxide Enhanced Water Recovery; CSEM, Controlled Source Electromagnetic; CRIM, Complex Refraction Index Method.

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