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Optimization of injection strategies for field-scale leakage remediation using microbially induced calcite precipitation

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In large-scale geological storage of CO2 one of the key factors for effective storage capacity is how much one can inject before reaching critical pressure build-ups. If potential leakage paths in the caprock experience pressure value beyond their critical threshold, sequestrated CO2 might leak out of the storage site. Several sealing technologies have been suggested to close leakage paths in case they develop, where microbially induced calcite precipitation (MICP) is a novel technology that has gained much attention in recent years. MICP consists of accelerating the production of calcite (i.e., the sealing agent) using suitable bacteria, and requires injection of several components: microbial solution of pre-cultivated bacteria; growth solution to establish biofilm at leakage location; and cementation solution to initiate the calcite precipitation. A major challenge in applying MICP in CO2 storage sites is the possibility of leakage paths developing several tens-of-meters away from the injection well. Thus, placing the components needed in MICP at the correct location and completely sealing the leakage paths without negatively impacting the rest of the storage site, i.e., sealing the near-well area, is a difficult task. Adding to the challenge is sealing the leakage paths in the least amount of time to avoid long shutdown of CO2 injection.

To maximize sealing of leakage paths while penalizing total MICP operational time, we have developed an optimization procedure with a new injection strategy where growth and cementation solutions are injected in separate well segments. With the proposed injection strategy, we minimize the production of biofilm, and subsequent calcite, in other places than in the leakage paths after an initial injection of microbial solution. The optimization procedure uses a newly developed field-scale MICP mathematical model [1] implemented in the Open Porous Media (OPM) simulator. The model approximates the chemical and physical processes to capture the necessary field-scale behavior of MICP at relatively low computational cost compared to contemporary models. To solve the optimization problem, we use a stochastic approximation of the gradient known as the ensemble-based optimization (EnOpt) method. The EnOPT method allows for easy parallelization, requires only input-output interaction with the simulator, and has been shown to perform well in realistic optimization studies.

The optimization procedure was applied to 3D synthetic test cases involving various scenarios with explicitly modeled leakage paths. The control variables were the injection and no-flow periods associated with our proposed injection strategy. The numerical results showed that in all scenarios, the leakage paths were effectively sealed, measured by comparing CO2 leakage before and after optimization. The distribution of calcite in each scenario was localized in and around the leakage paths, with no unnecessary clogging elsewhere in the reservoir. Furthermore, the total injection and no-flow time was low in the final optimization results.

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References

[1] Landa-Marbán, D., Tveit, S., Kumar, K., Gasda, S.E.: Practical approaches to study microbially induced calcite precipitation at the field scale. Int. J. Greenh. Gas Cont. 106, 103256 (2021).

Time Block Preference

Time Block A (09:00-12:00 CET)

Participation

Online

Primary authors: TVEIT, Svenn; Dr LANDA MARBÁN, David (NORCE Norwegian Research Centre)

Presenter: TVEIT, Svenn

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