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Small scale laboratory design investigation of leakage of gaseous CO_2 through heterogeneous subsurface system

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The technology for geological sequestration of carbon dioxide has been developed to reduce the CO_2 emissions into the atmosphere from the use of fossil fuels in power generation and other industries. One of the main concerns associated with the geological storage is the possible leakage of CO_2 into the shallow aquifers, for which effective detection methods are needed. The processes related to the spreading and trapping of CO_2 in the reservoir formation and in supercritical conditions have received major attention and form the basis of understanding of CO_2 trapping processes. Some of the CO_2 may, however, also leak to the upper layers of the rock and all the way to land surface through faults and imperfections in the seal. A proper understanding and capability to detect such leaks is essential for a safe performance of any storage operation.

This, in turn, involves a proper understanding of the processes related to the transport of gaseous CO_2 in the near-surface conditions, a topic that has received considerably less attention. The objective of this study is to analyze the transport and migration of gaseous CO_2 in heterogeneous porous media, in controlled laboratory conditions. CO_2 may reach the unsaturated zone by different leak mechanisms which may subsequently affect how and where it can be detected by leakage monitoring program. These mechanisms include exsolution from CO_2 supersaturated water and continuous bubbling or gas flow along a leakage path. Below the water table, gaseous CO_2 can also be trapped under capillary barriers. However, as more CO_2 is supplied by leakage from below the water table, the pressure may at some point exceed the entry pressure of the barrier leading to a leak event. Similarly, fluctuations in the water table may also produce leak events of temporarily trapped CO_2. In the unsaturated zone, the CO_2 is heavier than air and may accumulate below ground surface and move laterally. The presence of heterogeneity influences both the movement and detectability of the CO_2. Our laboratory experiment is designed and implemented for measuring CO_2 distribution in time and space through the heterogeneous porous material. The CO_2 concentrations through the domain are measured by using sensitive gas sensors. To better understand the consequences of CO_2 leakage and how it can be detected, this study presents a conceptual model together with the design and setup of an experimental system to understand the transport, trapping and detectability of gaseous CO_2 in a heterogeneous shallow geological system.