# Analytical Model for Leakage Detection in $CO_2$ Sequestration in Deep Saline Aquifers: Application to ex Situ and in Situ $CO_2$ Sequestration Processes

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## Abstract

This study focuses on the sequestration of carbon dioxide ($CO_2$) in deep saline aquifers as a means of storing $CO_2$. The study emphasizes the assessment of cap rock sealing capacity in saline aquifers to ensure secure storage and prevent leakage. Analytical models in the Laplace domain are presented for both in situ and ex situ $CO_2$ sequestration methods, which are then transformed into the real domain using the Stehfest method. These models enable the determination of dimensionless pressure changes in monitoring and storage aquifers resulting from leakage, as well as dimensionless leakage rates. The importance of classifying cap rock competence for identifying potential leaky pathways is highlighted, particularly since saline aquifers often lack effective sealing cap rocks. The models consider the dimensionless representation of flow equations in the storage and monitoring aquifers, connected by a dimensionless flow rate at the leakage path. Overall, this study provides analytical models to assess dimensionless leakage rates and pressure responses during in situ and ex situ $CO_2$ sequestration, aiding in the detection and characterization of potential leakage paths in cap rocks and ensuring the safety and integrity of $CO_2$ storage in deep saline aquifers.

**Keyword:** $CO_2$ sequestration, in situ and ex situ $CO_2$ sequestration, deep saline aquifers, leakage detection.

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# Analytical Model for Leakage Detection in $CO_2$ Sequestration in Deep Saline Aquifers: Application to ex Situ and in Situ $CO_2$ Sequestration Processes

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**ABSTRACT:** One of the prominent methods for carbon dioxide sequestration is disposal into deep saline aquifers. This is mainly because deep saline aquifers provide significant capacity for storage of unwanted fluids underground for a long period. However, saline aquifers may have a leaky cap rock. The sealing capacity of a cap rock must, therefore, be evaluated to ensure the integrity and safety of its storage media; hence robust classifications of the cap rock are required even before starting the storage/disposal operations. Aqueous fluids can be injected into a target storage aquifer, and pressure changes owing to leakage can be monitored in an upper aquifer separated by a cap rock for a short period. The measurement of pressure responses in the monitoring aquifer can be used to identify and characterize any leakage path in the cap rock. This paper provides analytical models in the Laplace domain for both in situ and ex situ $CO_2$ sequestration methods. Using the numerical Laplace inverse method called the "Stehfest" method, the analytical solution in the real domain is calculated. The analytical solutions developed can be used for determining both dimensionless pressure changes in monitoring and storage aquifers due to leakages and dimensionless leakage rates.