

An Indian-Australian research partnership

Project Title: Numerical investigation of the integrity of the caprock behaviour of saline aquifers: CO₂ sequestration

Project Number IMURA0060

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Research Academy Themes:

Highlight which of the Academy's Theme(s) this project will address?

(Feel free to nominate more than one. For more information, see www.iitbmonash.org)

1. **Advanced computational engineering, simulation and manufacture**
2. Infrastructure Engineering
3. Clean Energy
4. **Water**
5. Nanotechnology
6. Biotechnology and Stem Cell Research

The research problem

This research problem deals with multiphase flow in deep saline aquifers. The excessive use of non-renewable hydrocarbon resources (Oil, Gas and Coal etc.) during power generation and other industrial processes on the land causing emission of Green House Gases (GHG) such as CO₂ and CH₄ etc., which eventually leads to Global warming and Climate change. In order to mitigate these effects, the excessive GHG level on the atmosphere need to be reduced. To do so one of the most promising, clean, sustainable and environmentally friendly method is deep geological sequestration of GHG in large underground reservoirs or coastal and deep-sea reservoirs or Saline aquifers below cap rocks. In this research, one of

the primary GHG (CO₂) is considered for deep geological sequestration. Efficient injection and management of CO₂ sequestration requires a detailed understanding of the complex flow conditions, in-situ stresses, temperature effects and chemical reactions with minerals. In order to better understand this kind of multi-physics problem, one needs to investigate these processes by performing coupled numerical simulations. Due to unavailability of direct analytical solution to study these complex multiphase flow problems in subsurface conditions, one of the economically viable option is developing numerical models for solving these type of coupled physics problems. This research work aims to develop a coupled numerical model for simulating various physical flow processes in subsurface conditions near caprock integrity zones.

Project aims

The main aim of the proposed project is to develop a coupled numerical model to simulate the multiphase flow processes, in-situ stresses, temperature effects and chemical reactions with mineral and the impacts of these multiphysics effects on Caprock Integrity in geosequestration of Carbon Dioxide in Saline Aquifers. The objectives of research are:

1. To do exhaustive literature review for understanding the mechanisms of coupled processes occurring in deep saline aquifers while injection of CO₂ below caprock particularly accounting for advances in computing over last decade.
2. To develop computational model of multiphase flow through deep saline aquifers.
3. To extend the above model and develop additional models to incorporate multiphysics in Thermo-Hydro-Mechanical-Chemical reaction processes (THMC) coupled model.
4. To understand the integrity of caprock behaviour in the presence of fractures and its impacts due to above developed THMC coupled model.
4. To calibrate and validate the above proposed models.
5. To demonstrate the application of developed models by carrying out numerical investigations and applying to a real field case study problem from literatures.

Expected outcomes

The problems associated with Caprock Integrity in geosequestration of carbon dioxide in deep saline aquifers are very complex in nature. A coupled numerical model will be developed to understand THMC processes. Numerical investigations will be carried out for a typical flow of supercritical CO₂ through porous or fractured media. This data will be highly useful in calibration of the numerical model with analytical solution or experimental results. The model will then be validated with established field studies. The validated model can be used to analyse the problems and to propose alternative strategies for geosequestration of carbon dioxide in deep saline aquifers for better quantification/flow budget and spatial and temporal monitoring purposes. The proposed research will help environmental engineers to make a decision in evaluating various alternative strategies in greenhouse gas emission and its impact on global climate.

How will the project address the Goals of the above Themes?

The project involves numerical solution of isotropic/anisotropic multiphase flow and transport partial

differential equations and hence requires high-end computation. Simulations are targeted towards improved understanding of multiphase flow in deep saline aquifers. The outcome of the above aim would be to quantify and compare maximum storage of CO₂ in the saline aquifer system with and without presence of fracture (single to multiple fracture) in the caprock. If there is an injection well located in a hypothetical field/site where multiple fractures are existing along the length of the caprock, what will be the safe/permissible operating condition such as injection pressure of the well, in situ permissible stress criterion etc., without future aggravation or growth of fracture in the caprock. If the system exceeds the permissible limit, what will be the time required for CO₂ to reach the atmosphere by migrating through fracture and its spatio-temporal plume evolution etc., can be answered using simulations. The model, once calibrated and validated would be used to provide possible profile of multiphase flow in the real field scale problem. Hence, the present project will address the goals of both the themes highlighted above.

Capabilities and Degrees Required

Persons with the following qualification should be considered eligible:

B.Tech/M.Tech degree in Civil, Environmental, Water Resources engineering and petroleum engineering.

Capabilities: An ideal candidate will have a strong interest in computational studies of multiphase flow through porous media. The candidate with some experience and interest in basic computer programming languages (Fortran/C/C++/MATLAB) and commercial softwares like COMSOL multiphysics will be preferred.

If the candidate has studied any of these following subjects Numerical methods particularly FEM, Advanced Fluid Mechanics, Environmental system modelling and Rock mechanics are highly preferable.

Potential Collaborators

Oil and Natural Gas Corporations, Central and State Ground Water Boards, Petroleum Corporations