1 Introduction

The industrial CO_2 emission rate is expected to increase over the next decade if necessary preventive actions are not taken. For example, according to the Energy Information Administration, carbon dioxide emissions in the United States are forecast to reach 6.41 billion tonnes by 2030. The Kyoto Protocol proposed an emission cut that requires a reduction of 1.75 billion tonnes of carbon dioxide [16].

Geological storage of CO_2 is a proposed solution to fight global climate change. Clear operational criteria and policies must be put forward to avert unwanted consequences. Concerns connected to putting large volumes of CO_2 into underground geological formations are not limited to the spatial distribution of the injected fluid. The pressure signals imposed through the injection point can travel beyond the scale of the zones where CO_2 is present. Although geological barriers can hinder the pressure exchange between different regions, pressure can transfer through low-permeable rocks where the CO_2 is trapped by capillarity.

In addition to the depleted oil and gas fields, deep geological aquifers are practical targets for the geological storage of CO_2. If one is injecting into brine aquifers, the pressure waves can push the brine into connected fresh water aquifers, contaminating them. Brine displacement issues are discussed in [5] by defining open, closed, and semi-closed aquifer boundaries. Brine might also leak through abandoned wells into other zones. Cailly et al. [4] discuss how to design the injection process to prevent any leakage through wells.

Geomechanical deformations are important during the injection period. They can lead to changes in effective permeability and porosity. It is possible that the pressure buildup around injection wells can crack the rock with uncontrolled fractures extending to the structural sealing layers. Faults can be activated due to high pressure in the system, providing a leakage path across layers. In addition to the increased spatial spread of CO_2, an intensive induced fracture network can result in local earthquakes.

Simplified geological assumptions allow the use of established analytical solution of the flow governing equations. Neuman and Witherspoon [11] presented solutions that are useful for determining the hydraulic properties of leaky confined aquifer systems. They assumed that the aquifer is homogeneous, isotropic, and of uniform thickness. Moreover, they assumed the spatial extent of the aquifer to be infinite. Chabora and Benson [6] used the analytical solution provided in [11] to study the leakage of the stored CO_2 through the caprock by measuring the pressure buildup in the aquifer. They performed sensitivity analysis on the pressure variation by changing the formation parameters and injection criteria. Chabora and Benson found a correlation between the pressure buildup values in the medium and the specifications of aquifer and injection operations. This correlation gives insight in the design and monitoring phases of the storage operations. Such pressure monitoring approaches are based on geological simplifications.

Injection causes pressure evolution in the domain that starts by transient pressure buildup near the injector. As the injection proceeds, the injected CO_2 invades larger region in the domain. The two-phase region grows in size and the injected CO_2 moves in both vertical and horizontal directions within the aquifer. In the vertical direction, the CO_2 moves upward due to the buoyancy forces and in the horizontal direction the influx from the injector pushes the CO_2 through the two-phase zone. When the pressure pulse imposed by the injector reaches the boundaries of the domain, the average pressure in the aquifer increases in a