Environ Geol (2008) 54:1677–1686
DOI 10.1007/s00254-007-0945-x

ORIGINAL ARTICLE

On CO_2 fluid flow and heat transfer behavior in the subsurface, following leakage from a geologic storage reservoir

Karsten Pruess

Received: 23 May 2006 / Accepted: 27 November 2006 / Published online: 25 July 2007

Abstract Geologic storage of CO_2 is expected to produce plumes of large areal extent, and some leakage may occur along fractures, fault zones, or improperly plugged pre-existing wellbores. A review of physical and chemical processes accompanying leakage suggests a potential for self-enhancement. The numerical simulations presented here confirm this expectation, but reveal self-limiting features as well. It seems unlikely that CO_2 leakage could trigger a high-energy run-away discharge, a so-called "pneumatic eruption," but present understanding is insufficient to rule out this possibility. The most promising avenue for increasing understanding of CO_2 leakage behavior is the study of natural analogues.

Keywords Leaky faults · Leaky wellbores · CO_2 sequestration · Numerical simulation · Pneumatic eruption

Introduction

The amounts of CO_2 that would need to be injected into geologic storage reservoirs to achieve a significant reduction of atmospheric emissions are very large. A 1,000 MWe coal-fired power plant emits ~30,000 tonnes of CO_2 per day, 10 Mtonnes per year (Hitchon 1996). When injected underground over a typical lifetime of 30 years of such a plant, the CO_2 plume may occupy a large area of order 100 km^2 or more, and fluid pressure increase in excess of 1 bar (corresponding to 10 m water head) may extend over an area of more than 2,500 km^2 (Pruess et al. 2003). The large areal extent expected for CO_2 plumes makes it likely that caprock imperfections will be encountered, such as fault zones or fractures, which may allow some CO_2 to escape from the primary storage reservoir. Under most subsurface conditions of temperature and pressure, CO_2 is buoyant relative to groundwaters. If (sub-)vertical pathways are available, CO_2 will tend to flow upward and, depending on geologic conditions, may eventually reach potable groundwater aquifers or even the land surface. Leakage of CO_2 could also occur along wellbores, including pre-existing and improperly abandoned wells, or wells drilled in connection with the CO_2 storage operations.

Escape of CO_2 from a primary geologic storage reservoir and potential hazards associated with its discharge at the land surface raise a number of concerns, including (1) acidification of groundwater resources, (2) asphyxiation hazard when leaking CO_2 is discharged at the land surface, (3) increase in atmospheric concentrations of CO_2, which would reduce the efficiency of sequestration, and (4) damage from a high-energy, eruptive discharge (if such discharge is physically possible). For the purposes of this paper, we define "eruption" as a release or discharge of mass and energy that is localized in space and time; i.e., a flow event that occurs over a specific, generally brief period of time and in a specific location, as opposed to being spread out over a large area and a large time period.

In order to gain public acceptance for geologic storage as a viable technology for reducing atmospheric emissions of CO_2, it is necessary to address concerns related to leakage from the primary storage reservoir and demonstrate that CO_2 can be injected and stored safely in geologic formations. This requires an understanding of the risks and hazards associated with geologic storage, and a

K. Pruess (✉)
Earth Sciences Division,
Lawrence Berkeley National Laboratory,
Berkeley, CA 94720, USA
e-mail: K_Pruess@lbl.gov