Feasibility of Long Term Carbon Dioxide Storage in Deep Saline Formations

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INTRODUCTION

As part of the U.S. commitments to the Framework Convention on Climate Change to stabilize CO_2 concentrations in the atmosphere at an acceptable level, U.S. Department of Energy (DOE) is evaluating various options for CO_2 sequestration. Deep saline formation sequestration of carbon dioxide (CO_2), generated from power plant and other industrial emissions, is being evaluated as one of these potential options. The major advantages of using deep geologic formations are that the disposal facilities can be located close to the sources, thus reducing the CO_2 transport costs and the potential capacity is much larger than the projected CO_2 emissions over the next century. It is a long-term/permanent sequestration option, because a large fraction of the injected CO_2 may be fixed into the aquifer by dissolution or mineralization. The major limitations include the potentially high cost, the risk of upward migration, and the public perception of risk. Most of the cost is due to the need to separate CO_2 from other flue gases, rather than the actual cost of disposal.

It is worth noting that hazardous and non-hazardous liquid waste and acid gas disposal in deep sedimentary formations is a well-established practice. As an example, in Ohio more than 35 million metric tons of waste (88% of which are hazardous) has been injected in wells at class I facilities. Much greater amounts have been injected in other types of injection wells such as the oil and gas drilling related wells. There are also numerous facilities for storage of natural gases in depleted oil and gas reservoirs. The only current facility for deep aquifer disposal of CO_2 is the offshore injection well at Sleipner Vest in the North Sea in Norway, operated by Statoil. The data and experience obtained from the existing deep-waste disposal facilities and from the Sleipner Vest site form a strong foundation for further research and development on CO_2 sequestration.

OBJECTIVE

The major objective of this project is to conduct a comprehensive evaluation of the feasibility of CO_2 sequestration in deep saline geologic formations. This includes scientific analyses of the geologic, hydrologic, geochemical, and seismic aspects of long-term or permanent storage of CO_2. It also includes analyses of regulatory and cost issues related to the disposal.

APPROACH

Aquifer disposal involves finding geologically suitable formations for sequestering large amounts of CO_2 for a long period, without a significant environmental risk, and at a reasonable cost. Usually, such aquifers are deep, regionally extensive, filled with saline waters, and separated from freshwater and other formations of economic interest by low permeability caprock. For CO_2 disposal applications, a minimum depth of 800 meters is required to maintain the pressure and temperature for retaining CO_2 in a dense supercritical phase. Other siting criteria include detailed evaluation of geologic, hydrogeologic, geochemical, and seismic issues. Due to the multitude of hydrogeologic and geochemical processes involved, the feasibility of CO_2 disposal needs to be evaluated at several different spatial (pore scale to regional scale) and temporal scales. These issues are being addressed using data from deep waste injection well facilities in the midwestern U.S. These site-specific data are being incorporated into the hydrodynamic and geochemical simulations to investigate the fate of injected CO_2.

PROJECT DESCRIPTION

Federal Energy Technology Center (FETC) is currently sponsoring a project that uses data from existing hazardous waste disposal facilities that are injecting in the deep aquifers in the midwest to evaluate hydrogeologic, geochemical, and social issues related to CO_2 disposal. This is a region with a large number of fossil-fuel based power plants, resulting in one of the highest levels of carbon-dioxide (CO_2) emissions in the world. One major option being considered is the disposal of pressurized CO_2 into one of the deep saline formation underlying the region. The formation, Mt. Simon Sandstone, is a basal sandstone formation overlain by lower permeability shale and dolomite formations throughout a region. Geologically this region consists of three deep basins, the Appalachian Basin in the east, the Illinois Basin to the south, and the Michigan Basin to the north, separated by an uplifted Cincinnati Arch region in the middle. The depth of Mt. Simon Sandstone ranges from about 800 meters in the uplifted arch areas to more than 3,000 meters in the deep basins. The thickness ranges from 0 to more than 700 meters. The porosity and permeability in the Mt. Simon and confining formations are suitable for evaluation of Mt. Simon as a host reservoir for long-term storage of flue gas-derived CO_2.

Mt. Simon Sandstone is currently being used for the disposal of hazardous and non-hazardous industrial liquid wastes from 15 injection wells in Ohio and several other wells in neighboring states. These facilities have injected millions of tons of waste. The proximity of this reservoir to CO_2 sources may result in substantial savings in pipeline transportation costs. Due to its prior use as a host formation for waste injection, a large amount of geologic, hydrologic, geochemical, and other relevant operational information is available from the no-migration petitions submitted to the regulatory agencies. This information can be readily used to evaluate the technical feasibility of aquifer disposal of CO_2 in this region of very high stack gas emissions. As part of the U.S. DOE-sponsored research, the available data from this reservoir has been used along with reservoir simulation models to determine the potential for safe storage of CO_2. The simulations incorporate geologic and hydrologic data into black-oil and compositional models to determine the potential capacity for injection from a single well or from a cluster of closely spaced wells.

The models address the relevant limiting criteria, such as increase in reservoir pressure during injection and decline in pressure following facility shut-down; the lateral and vertical movement of injection CO_2 within the reservoir and into the overlying confining zones at both short and long-term time horizons; sweep efficiency; and attenuation of CO_2 due to dissolution etc. The simulation results and other information are used to develop a detailed understanding of the fate of injected CO_2, associated environmental risks, and the siting criteria for disposal facilities.

ACCOMPLISHMENTS

During the first phase of the project a detailed literature review of the CO_2 aquifer disposal technologies and the available sources of geologic and hydrologic information in the midwestern U.S. was completed (Gupta et al., 1997). The second phase started in September 1997 data from the deep waste disposal facilities in the Midwest was collected for use in evaluation of CO_2 disposal in this region. Preliminary work with various computer simulation programs available for this purpose was also conducted. A letter report summarizing the data and suitable programs was submitted to FETC in May 1998 (Gupta el al., 1998).

A preliminary estimate of the potential for CO_2 storage in the Mt. Simon Sandstone was made using detailed three-dimensional mapping and volume estimates for this formation in Ohio and in the entire midwest. This estimate uses the equation for CO_2 storage in continuous reservoirs used for estimate of CO_2 storage in several European Union countries (Holloway, 1996). Based on this the potential capacity in Ohio is 15 Gt (giga ton) with a range of 8.6 to 43 Gt. For the entire midwest the potential capacity is 270 Gt with a range of 160 to 800 Gt. As a comparison, current annual CO_2 emissions from power plants in Ohio are about 150 million tons. This suggests that there is potential for sufficient storage for several decades in just one formation. It should be cautioned that the estimate presented here is very preliminary and based on several simplifying assumptions. More accurate estimates of capacity and safety issues can only be made after detailed simulations with site specific data are completed.

FUTURE ACTIVITIES

During the ongoing and future phases, hydrogeologic and geochemical information will be incorporated into the computer simulation models to determine the various hydrodynamic and geochemical constraints on the aquifer storage of CO_2 in the Mt. Simon Sandstone. The model results along with detailed analyses of seismic, regulatory, cost, and monitoring aspects will be presented in the final comprehensive report on feasibility of CO_2 disposal on deep saline formations.

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