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Research Article

CO_2 Leakage, Storage and Injection Monitoring by Using Experimental, Numerical and Analytical Methods

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Abstract

The maintaining environment is priority to any plan in human life. It is planned for monitoring CO_2 injection, storage and leakage by using geophysical, numerical and analytical methods in seismic zone. In this regard the mineralogy, chemical composite, lithology, seismic wave propagation, small earthquake, accelerating natural earthquake, thermal stress-strain modeling, ground movement level and fault activation will be consider. It is expected to better understand CO_2 leakage, storage and injection process and problems.

Keywords: Environment, seismic zone, lithology, stress, risk assessment

1. Introduction

To maintain environment from CO_2 injection method is practicing around the world. The CO_2 inject into subsurface has to be maintain from leakage to the surface and contaminate to any natural resource due to exploration or extraction. The CO_2 has been created from industrial activities or natural environment. The main propose of CO_2 monitoring is human health. The CO_2 monitoring has to be done during injection and storage phase.

To reduce emission of greenhouse gases which burning from fossil fuels in atmosphere the geological CO_2 storage is recognize as an acceptable method (IPCC., 2005; Förster et al., 2006). The first CO_2 injection and storage into saline aquifers was in Canada on early 1990 (Michael et al., 2010). The CO_2 capture and storage (CCS) are subdivided in several distinct realms which are (i) quantity of CO_2 in atmosphere (ii) capacity of CO_2 in overburden (including faults and wells) (iii) reservoir with appropriate seals (iv) and time for storage (P. Winthaegen; 2005). The suitable deep of geological formations should be more than 800 m which is saline aquifers, depleted oil and gas fields or coal beds (Holloway., 1996; IEA., 2004, 2006). But sometimes depth is around 630 m (Andreas., 2008). And the site geological allowed to be more near surface and made more project economic effective. This processes are require experimental and modeling studies for analyzing leakage risk assessment as well as groundwater and minerals contamination due to any possible reason.

For near accurate CO_2 injection and storage monitoring in saline aquifers many research project in around the world especially in USA (Frio), Australia (Otway), Japan (Nagaoka), and Algeria (In Salah) and Germany (Ketzin) are going on (Michael et al., 2010). The research on CO2 storage for deformation of the reservoir zone has been modeled by using seismic data (D.J, White., 2011). And Rock and fluid physics measurements and modeling used for evaluation of CO_2 in controlling P-wave and S-wave velocity (Davie et al., 2003). The numerical models are used to understanding geological monitoring and storage operation for injection 18,000 t of CO2 in saline aquifer at Ketzin (Würdemann et al., 2010). And numerical simulator also is practiced for explanation water-rich brine phase, CO_2-rich phase and dissolution of both these components in the phases. (Assteerawatt et al., 2005). Natural tracers are to identify fluid origin and obtain constraints on fluid movements within the crust in petrology field (Ballentine et al., 1991; Wilkinson et al., 2008). The geochemical model for the hosting aquifers is used to reconstruct the pre-injection reservoir chemical composition, evolution of the system during injection and measure the geochemical trapping mechanisms for over 100 years and validate of simulation in short term of 3 years (Cantucci et al., 2009). The finite-difference elastic-wave-equation scheme was used to estimate synthetic seismograms (Cheng, 1994; Kamm et al., 1996). The monitoring and verification of CO_2 storage reservoirs was successful implemented at Sleipner (Arts et al., 2004a,b, 2008). The gravity surveys and electrical resistance tomography surveys are two other methods for CO_2 monitoring. Smith et al., (2001) indicated economic and engineering aspects of CO2 storage and injection. The studies show that deep saline aquifers have the acceptable capacity for CO2 storage (Bachu., 2003; Bradshaw et al., 2007). And for any CO_2 capture and storage (CCS) project the sedimentology, structural geology, fluid flow, reservoir characteristics and modeling, geophysical modeling and interpretation, mathematical modeling, mineral reactions, geochemistry, geomechanics, petrophysics and marine geology sciences as well as biological processes are required for storage performance, seal properties, monitoring techniques, operational aspects and marine environment (Eyvind Aker et al. 2011; Borm., 2005). The main objectives are monitoring CO_2 injection, storage and leakage in deep at seismic zone as well as analyzing seismic wave propagation

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and estimate liquefaction magnitude near surface by using numerical, analytical and experimental investigation. The CO_2 confide durability and stopping leakage are important in this reconnaissance.

2. Brief discussion

CO_2 injection and storage

The CO_2 capture and storage (CCS) is a greenhouse gas mitigation technology (Korbul., 1995). After CO_2 capture it will be transporting by pipeline or shipping to a suitable site for injection into an underground geological formation for long term storage (IPCC., 2005). The CO2 is injected for enhanced oil recovery (EOR) operations worldwide especially in the Permian Basin of west TX, USA (Hsu., 1995). To monitoring CO_2 injection in subsurface electrical sounding methods has been discussed (Ramirez, A., 2003). The electrical resistivity can be imaged due to availability of metal-cased boreholes (Daily, W et al., 2004). And according to Albright, J. C. (1986) assumed CO_2 is increased resistivity. One of the commercial-scale CO_2 storage is started at In Salah, Algeria (Riddiford et al., 2003).

CO_2 leakage

The CO_2 leakage may be expected from some storage sites if extensively applied CO_2 injection technology (Holloway et al., 2006). Soil gas measurements shown leakage is through narrow gas vents and CO_2 is migrating in this process only from small area of leakage at the surface (Beaubien et al., 2008). The acceptable leakage level is in range from 0.001% per year around 1% over 1000 years to 0.01% per year which is equal 1% over 100 years (Bowden., 2005), and more than this level of CO_2 leakage can have harmful effect on the atmosphere or local marine and terrestrial ecology as well as directly hazardous to man (Williams, SN., 1995). And it is require investigating for better understanding CO_2 leakage possibility during natural hazard especially earthquake and contaminate to the extractable natural resources. It can be understood the strata permeability and porous has direct correlation with CO_2 leakage. Eyvind Aker et al., (2011) mentioned high permeable fault plane is measurable by using InSAR even outside the reach of the injected CO_2 plume. In This regard Klinginger (2006) presented an investigation for carbon dioxide propagation in the subsurface which is depending on the rock permeability. Andreas., (2008) explained that increasing temperature caused decreasing density and viscosity and resulted in vertical migration CO_2 and also thermal arrival time depending on the sweeping efficiency . Onuma, T. in (2009) developed method and concept to explain CO_2 potential leakage during injection and reservoir and later Eyvind Aker et al. (2011) used finite element model for surface heave for injection and model test at In Salah, Algeria. The figure 3 has been indicated the reduction of heave during 3 years for three different projects. It is requiring more investigation under considering different factors included sedimentology, structural geology, fluid flow behaviour, reservoir characteristics, mineral reactions, geochemistry, geomechanics, petrophysics and marine geology for middle period and long term. In figure. 2 the 3D seismic data and geological models are used for assessing fundamental stratigraphic imaging of the geological structure to minimize CCS risk and accurate identify gas storage formation. (Juhlin et al. 2007; Hilke., et al. 2010). The CCS risk assessment is depend on site characteristics, data accuracy, assessing future direct and indirect potential problems, project cost, project feasibility and application of management art, all these process require computer modelling and imaging before performance. The result of CCS will be in acceptable level if all stage of risk management performed perfectly through near accurate computer simulation.

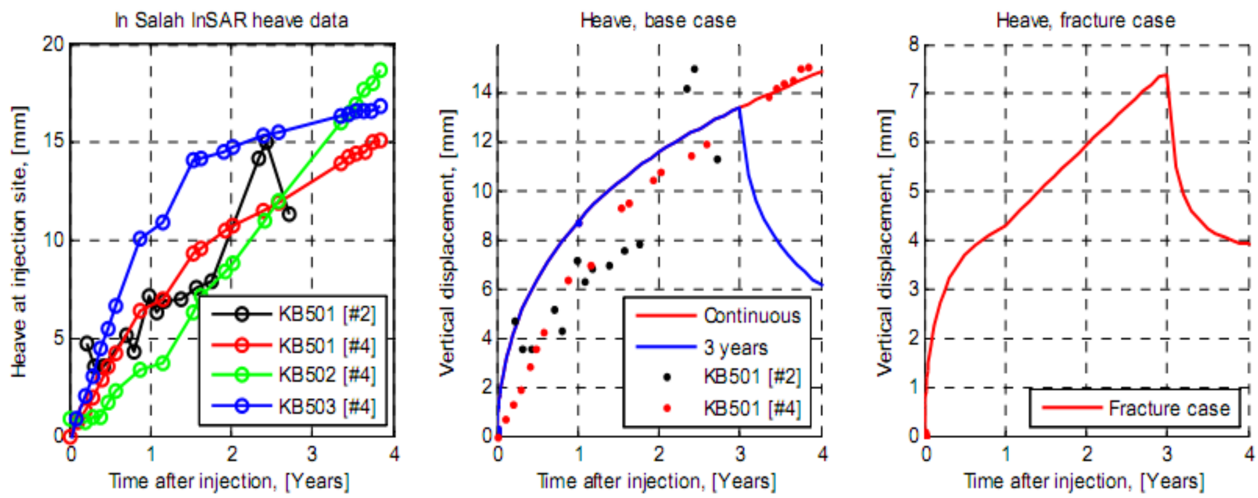

Fig. 1. Left: Measured heave data at the injection wells from two different references (Onuma, T. 2009; Rutquist, J. 2009). Centre: Close-up (0-4 years after injection) of surface heave (modelled Base case; line) compared with measured data for injection well KB501(dots). Red curve is from continuous injection and blue curve when injection is stopped after 3 years. Right close-up (0-4 years after injection) of surface heave (Fracture case) (Eyvind Aker et al. 2011).

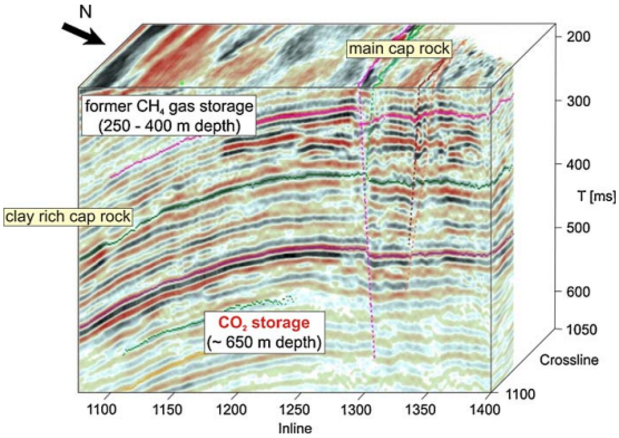

Fig. 2. Cross-section derived from3D seismic tomography showing the abandoned gas storage, the fault structure, cap rock, and reservoir (Juhlin et al., 2007; Hilke., et al. 2010).

Mineralogy and Chemical composite

The multi-mineral reactive is a difficult parameter to be measured (Xu et al., 2007). The dissolving CO_2 in deep where groundwater not presence mineral trapping may take place for several thousand years (Ennis-king; 2003). The CO_2 can dissolves in water and reacts with minerals and caused carbonate mineral like dawsonite (Na Al $(OH)_2 CO_3$) (Eyvind Aker et al., 2011), and impacts on deep subsurface microbial ecosystem and biogeochemical process (Julia M, West et al., 2011). And also microbe could be affected by injected CO_2 while it could survive exposure due to its physical and chemical properties (Werner, BG., 2006). Among the all point have been mentioned there scope for assessing feasibility of microbes utilising CO2 as an energy source (Julia M, West et al., 2011). The CO_2 leakage mechanism is depending on chemistry and mineralogy (Scherer et al., 2005). And CO_2 injection has influenced on cement sealing properties and clarified typically crack resulted carbonation (Eyvind Aker et al., 2011). According to G, Rimmele (2008) some cement carbonation reaction occurs only at surface of the plug in the presence of the acid gas. O, Brandvoll (2009) identified CO2 spreads into cement along crack and pores and caused carbonation in deep after 40 days of exposure. The degassing magma is zone caused more energetic emissions (Holloway et al., 2006), and created CO2 and subsequently migrates to the Earth's surface and is emitted through volcanic (Baines., 2004). And also the CO_2 can migrate through natural fracture networks in the rock strata, and/or through the matrix of porous and permeable sedimentary rocks (Czernochowski-Lauriol; 2003).

Small earthquake and accelerating natural earthquake

The CO_2 migrant mechanism helps in identifying best storage location and is depending on fault lithological (A, Annunziatellis., 2008) and lithology controlled the injected seal quality for many years (Zhou et al., 2004). The seismic data has been collected in from of P and S - wave inversion. The investigation shows that the pore pressure and CO_2 degree of saturation have been changed in reservoir zone (D.J, White., 2011). The application of inversion procedure is indicated by (Cole, S et al., 2002) and (Lumley, D et al., 2003). The impedances is inverted instead of travels time and amplitudes (Meadows, M., 2008). Migrating gas can result in seismic responses (Schroot., 2003). In sandy sea bed sediments gas emerges as bubbles (Hovland., 1985), Under low permeability condition CO_2 looses more energy than compare to high-permeable cases and also lower CO_2 viscosity leads to higher injection pressure (Andreas., 2008) this process under saturated condition reduced subsoil liquefaction resistance it means that the CO_2 leakage is an element accelerated liquefaction phenomenon and also increasing CO_2 temperature helps in acceleration uplift force. According to Lindeberg., (2003) and thermal conductivity may changes with CO2 degree of saturation during injection (Hilke., et al. 2010). Under the applied geological constraints, effective storage capacity of the reservoir increases with increasing heterogeneity, whereas the injectivity decreases. (Lengler et al., 2010). Where fluid moves from the reservoir to the wellhead, both pressure and temperature decrease and changes in the fluid chemistry (Quattrocchi et al., 2006b), and the Geomechanical stress decreases as pore fluid pressure decreases.

Thermal stress-strain modelling

Development model for geological storage and numerical codes helps to problem description (Class., 2009) The permanent temperature monitoring in gas-hydrate bearing sediments at around 1200 m depth has been investigated (Henninges., 2005). And also temperature monitoring in the subsurface fiber-optic distributed temperature sensing (DTS) cables can be used (Bielinski., 2008).

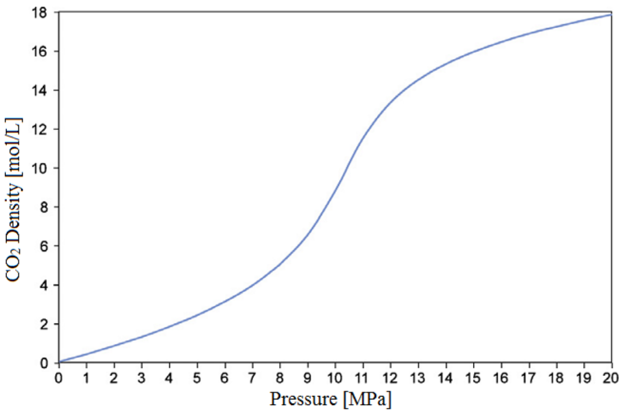

Fig. 3. Variation of CO_2 density in mol/L with pressure between 0 and 20 MPa. (Lemmon et al., 2010).

3. Methodology

- Application of geophysical methods to create experimental data.
- Analyzing potential CO_2 leakage using finite element model, soil mineralogy and lithology.
- Numerical and analytical modeling for assessment CO_2 behavior when fault is subject to seismic wave and CO_2 confide stress.
- Finalize to bring a new method for gas storage

4. Objective

- To monitoring CO_2 injection, storage and behavior in deep in seismic zone.
- To analysis effect of CO_2 on seismic wave propagation for estimate liquefaction magnitude.
- Assessing CO_2 confide durability due to earthquake and materials properties.
- Possibility of small earthquake or accelerating

natural earthquake because of CO_2 injection.

- Analyzing geological stress-strain behavior in concern to CO_2 behavior and possibility of ground movement level as well as facture or fault activation.
- Analyzing potential leakage of CO_2 due to failure of seal under dynamic or static stress
- Create extensive bridge between different branch of science.

5. Scope of study

- Maintain environment by using green building.
- Proposing a method to stop or minimize CO_2 leakage due to earthquake.
- The injection optimize level of CO_2, it is acceptable level based on region geological characteristics.
- The CO_2 storage up to time can be used in industry like other natural resources.

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