



Application of Geophysical Techniques in CO₂ Sequestration

Mogali Veera Phaneendra

Andhra University

The major options under consideration for mitigation of green house gas emissions included switching to non carbon based sources of energy increased, energy efficiency, energy conservation and terrestrial or biotic sequestration of carbon dioxide. However, during the past several years the concept of capturing carbon dioxide from large point sources followed by injection and permanent storage in geological reservoir has gained increase prominent as an element of an overall strategy for mitigating the effects of anthropogenic emission of carbon dioxide. Carbon sequestration is the isolation of carbon dioxide from the earth's atmosphere.

Sequestration can play a significant role in preventing continual build up in the atmosphere.

Currently carbon dioxide emitted from electric power plants, cement kilns, and petroleum refineries etc. is captured by themselves, liquefied, and is stored. The storage is envisaged in deep geological formations, deep oceans, depleted oil and gas reservoirs, unmineable coal seams, saline filled basalt formations etc...

Geological formations considered for carbon dioxide storage are layers of porous rock deep under ground that are capped by a layer of non porous rock above them. Sequestration practitioners drill a well into the porous rock and inject pressurized carbon dioxide into it. The Carbon dioxide is buoyant and flows upward until it encounters the layer of non porous rock and becomes trapped. Deep saline formations are sites for geologic sequestration which are natural saline formations. These are salt water bearing porous and permeable rocks, occurring beneath the level of potable ground water. Saline formations are wide spread close to large carbon dioxide sources having large pore volumes available for injection use. In order to maintain the injected carbon dioxide in super critical phase (i.e liquid phase) the units must be approximately 2500 feet or greater in depth. Maintaining the carbon dioxide in liquid phase is desirable because as a liquid it takes up less volume than when in the gaseous phase. These sequestration depths also help insure there is an adequate interval of rocks

(confining layers) above the potential injection zones to act as geological seal. In these types of reservoirs, carbon dioxide is injected under pressure down especially constructed well into the reservoir where it displaces (hydrodynamic trapping) and mixes (solubility trapping) with saline water and fills the pore spaces between the mineral grains of the rocks in the reservoir and is trapped with in minerals in rock matrix. The injected carbon dioxide has a lower specific gravity and thus more buoyant than the natural formation fluids and will rise to top of the porous zones. Once injected carbon dioxide will migrate to the highest portion of the saline aquifer where it accumulates again the cap rock. Unmineable coal seams can be used to store carbon dioxide because carbon dioxide adsorbs to the surface of coal. The adsorption rate for carbon dioxide in coals is approximately twice that of methane; thus in theory the injected CO₂ would displace methane allowing for the potential of enhanced gas recovery. However, the technological feasibility depends on the permeability of the coal bed. Similarly abandoned gas or oil wells can also be used for CO₂ storage. The structures which favored these oil wells have sidewalls and cap rock non permeable and especially salt domes with greater depths and extended widths are immense sources for storage.

Another process for storage is ocean storage. Ocean storage is of two types. The dissolution type injects CO₂ by ship or pipeline into the water column at depths of 1000m or more and the CO₂ subsequently dissolves. The lake type deposits CO₂ directly onto the seafloor at depths greater than 3000m where CO₂ is denser than water and is expected to form a lake that would delay dissolution of CO₂ into the environment.

Another method of carbon sequestration is to bring naturally occurring magnesium and calcium containing minerals to react with CO₂ to form carbonates. This method has many unique advantages. Similarly carbonaceous shales act as seals for underlying reservoirs, as source rocks for oil and gas reservoirs, and are unconventional gas reservoirs themselves. It is believed the carbonaceous shale would adsorb the



"HYDERABAD 2008"

CO₂ into the shale matrix, permitting long term storage of CO₂, even at relatively shallow depths.

Another interesting concept of carbon dioxide sequestration is pumping carbon dioxide gas into the depleted hydrocarbon reservoir to increase the hydrocarbon recovery. This is called enhanced oil recovery (EOR). In this process some of the oil that remains in reservoirs after production is recovered by injecting carbon dioxide that repressurizes the reservoir, displaces and drives the remaining oil to a recovery well.

The main constraint in ocean storage is that large concentrations of carbon dioxide kill ocean organisms. The carbon dioxide that is dissolved, would eventually equilibrate with the atmosphere making storage temporary. Acidity of ocean water increases due to increase of carbonic acid. Leakage of carbon dioxide back into the atmosphere may be a problem in saline water aquifer.

Geophysical Monitoring:

Monitoring of the sequestered carbon dioxide is important to warn the public safety concerns in case of reservoir leaks. For his images of the space time distribution of injected carbon dioxide to aid optimization of injection and storage are necessary. Geophysics offers a variety of methods that operate over a wide range of geologic environments, reservoir scales and depths. The challenge is to track the flow of carbon dioxide while simultaneously monitoring for leaks in a growing sub surface volume. More over, a thorough description and predictive simulations of the monitoring capacity may be required for the safety cases. Developed models that estimate the change in bulk rock fluid properties with injected carbon dioxide. The considered geophysical methods are seismic, electrical, magnetic, electromagnetic, gravity etc...

Seismic and electrical techniques will be used to map the movement of carbon dioxide in the sub surface and to establish that the storage volume is being efficiently utilized and the carbon dioxide is being safely contained with in a known region. Seismic methods provide the most effective and universal applicable technology for subsurface monitoring for the various geologic storage scenarios of coal beds, deep saline aquifers and depleted oil and gas fields

In seismic monitoring, the changes we may detect or changes in velocity, reflectivity and possibly attenuation. The bulk of the velocity changes resulting from saturation effects occur with only a small carbon dioxide in the pore space. For this reason seismic monitoring will be very useful in leak detection and for monitoring carbon dioxide migration. Seismic monitoring should be able to detect thin layers of carbon dioxide, under favorable circumstances carbon dioxide migration paths thus should show up in a reflection survey and the

presence of carbon dioxide in overlying zones should be easily detectable. The acoustic velocity of fluids under most reservoir conditions is typically above 1000m/s, where as the velocity of carbon dioxide is considerably less. Early detection of carbon dioxide plume injection by seismic techniques should provide an early warning about the failure of storage site.

On the other hand resistivity surveys are the simplest assessing subsurface conductivity. Introduction of carbon dioxide caused a significant increase in resistivity of the formation. Another option is cross well electromagnetic measurements. At the low frequencies necessary to propagate EMwaves across field scale distances. The resolution is fairly low and the measurements are strongly effected by the conductivity structure near the source and receiver. Gravity monitoring is only suitable for making very low resolution mass balance measurement and that to in shallow formations as signal falls off inversely with distance squared. Geodetic techniques measured displacement or displacement gradient at the earth surface. These techniques can also be used in carbon dioxide sequestration under certain conditions. In a stable tectonic environment, measured deformation over a sequestration site should only be the result of induced pressure changes at depth due to fluid injection.

Also the gravitational attraction of the bodies in the solar system causes tidal deformation of the earth, and the pore pressure of the geological reservoir changes in response to such tidal phenomena. The pressure fluctuations can be retrieved from the continuous pressure data obtained at the monitoring well. The diurnal and semidiurnal features of the pressure fluctuations can be explained by the earth tides, and it is possible to estimate the poroelastic parameter, a function of the carbon dioxide saturation in the pore space.

Hence geological carbon sequestration is an excellent process to divert the harmful carbon dioxide gases emission into a relatively safe environment. Monitoring the sequestration, early warning systems for the prevention of destruction if any is of due important. In this context geophysical techniques are excellent tools to aid the operations. But reliable and cost effective monitoring techniques are required to ensure safe and effective geological sequestration of carbon dioxide. Effective techniques for determination of proper storage characteristics have to be derived. This monitoring should give advanced models which can further substantiate proper site selections.