CHEMICAL ECONOMICS - CARBON DIOXIDE DISPOSAL

One of the main hopes for continuing the use of fossil fuels is that carbon dioxide resulting from combustion can be deposited in deep geological strata - so called carbon geo-sequestration. In past issues of *Chemistry in Australia* I have described the technology and economics of removing carbon dioxide from gas streams in the hydrocarbon processing industry and how these produce a concentrated stream that can be geo-sequestrated. In another issue, I described the difficulties and costs of extracting carbon dioxide from flue gases, particularly from gas and coal power generating facilities. In this paper I will discuss technology and cost issues concerning carbon dioxide disposal in storage facilities that will maintain their integrity for hundreds of years.

The basic theory of carbon geo-sequestration comes from work in enhanced oil recovery (EOR) using carbon dioxide. In one method of EOR, carbon dioxide is injected into an oil reservoir where it dissolves in the oil, lowering its viscosity allowing freer flow of oil to the producing well. For this to work there has to a source of carbon dioxide and this is often obtained from remote process plants and piped to the oil-field over long distances. This practice gives some reassurance that carbon dioxide pipelines and pipeline networks can be constructed safely and carbon dioxide transmitted over long distances. This is an important demonstration because most carbon dioxide emissions are remote from geological structures suitable for disposal.

An EOR project at Weyburn in Canada obtains carbon dioxide from a large lignite coal to gas plant in Dakota in the USA (Dakota Gasification Company). The EOR gas also contains hydrogen sulphide which is also injected and disposed in the EOR project. The pipeline system for this is over 300km long. This project demonstrates that pure carbon dioxide is not required for geo-sequestration. Table 1 lists the methods that have been considered for long term carbon dioxide disposal together with the typical pressure required to maintain it in the liquid state.

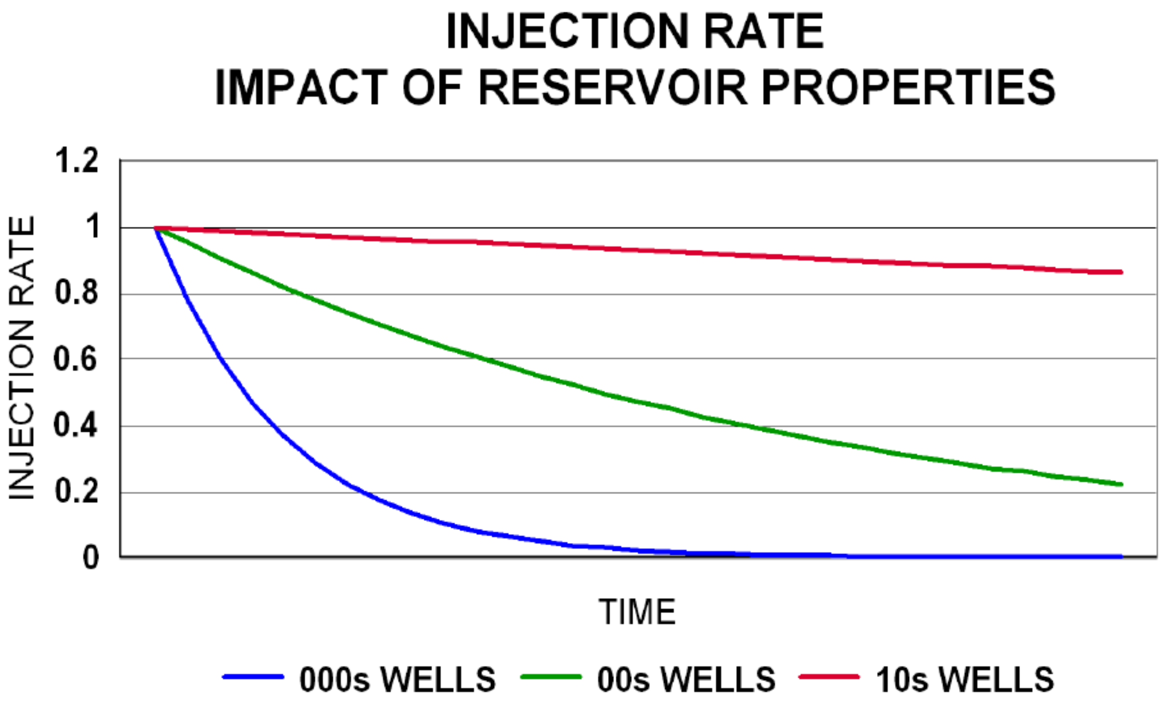
Table 1: Methods for long term carbon dioxide disposal (after Saxena and Flintoff, Hydrocarbon Processing, December 2006)

Method	Pressure required
Deep un-minable coal beds	80 to 100 bar
Enhanced oil recovery	150 to 160 bar
Deep saline aquifers	150 to 180 bar
Abandoned oil and gas wells	150 to 180 bar
Deep sea disposal	310 bar (3km water depth)

The methods listed are considered viable methods for disposing of carbon dioxide. In deep coal beds, the carbon dioxide is absorbed by the coal. In EOR some of the carbon dioxide returns via the producing well dissolved in the oil but since the carbon dioxide is a valuable commodity, it is recovered and re-injected. Carbon dioxide can also be disposed of in deep sea trenches of static water and the like where the gas will be dissolved and remain in the cold water.

Deep saline aquifers and abandoned oil and gas facilities are the most studied. There are several issues to be considered. As noted above the best sites are often remote from the emissions point requiring a gas transmission pipeline and since carbon dioxide is a heavy suffocating gas, worries over leakage, especially near urban areas, will be of concern. Another issue is the dissolution of minerals causing, in the long term, caving and potential collapse and leakage from the storage site. The main worry is limestone (a very common mineral) but other minerals could also be attached over the long times required for storage.

One of the main difficulties is identifying potential sites. For a greenfield site that is required to geo-sequestrate the emissions from a large coal fired power station, the rate of carbon dioxide injection may be over 10 million tonnes per year, furthermore, this rate will be constant for the life of the power station. The rate of injection may be quite high on a newly drilled well but as more carbon dioxide is pushed down the well, resistance will build up and the rate will fall. This is illustrated in Figure 1. The top line shows an ideal situation where the rate of injection falls little with time but the more likely situation is with the lower lines. For a geological structure which is tight (highly compacted), resistance to injection may increase dramatically with time and in order to maintain a constant high injection rate thousands of wells may have to be drilled over the life of the project (lower line). This is analogous, but the inverse of, the production of gas from tight reservoirs or shale where many wells have to be drilled to maintain a constant overall production rate because the production rate of the individual wells falls dramatically with time.



The middle line is the intermediate case where increasing resistance can be overcome by drilling less but still hundreds of wells over the course of a major project. The geology will determine if a few or many wells will have to be drilled but whatever the case it is certain that a geo-sequestration project will require an extensive area if large volumes of carbon dioxide from major power generating facilities are to be disposed; some estimates are in the thousands of square kilometres

So for a carbon dioxide geo-sequestration project assuming the costs of carbon dioxide extraction and compression is paid by the emitter (EOR experience indicates that this may be at least

$20/tonne) the additional costs will be for transmission to the geo-sequestration site, possibly further compression costs at the injection site, and the cost of the well (typically $2 to 5 million each).

As can be deduced from the above, a major demonstration of this aspect of the carbon geo-sequestration will be costly. In a small project in Australia, the CO2CRC has demonstrated the injection of 65,000t of carbon dioxide in a depleted natural gas reservoir in the Otway basin in Victoria. The project has gone on to inject carbon dioxide into saline formations and to monitor movement of the gas in the underground reservoirs. A commercial carbon dioxide gathering system and pipeline network has been proposed for Victoria in the LaTrobe Valley (known as CarbonNet) with carbon dioxide being geo-sequestrated in depleted oil and gas reservoirs in Bass Strait.

One of the largest projects is by Chevron in the Gorgon LNG project in NW Australia. The LNG facilities on Barrow Island use gas from the offshore Gorgon gas field which contains about 14% carbon dioxide. This is extracted prior to LNG production and is injected to a depth of two kilometres under the island using three compressor stations and nine injection wells supplemented with six water production/injection wells and two wells for surveillance. The project is said to dispose of 3.4 million tonnes of carbon dioxide per year when fully operational. However, this will only dispose of 40% of the facility emissions; most of the rest probably being emitted in flue gas from power generation facilities to drive the refrigeration plant.

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