2

REVIEW OF LITERATURE

The capture and storage of CO_2 in geological reservoirs is now considered to be one of the main options for achieving deep reduction in greenhouse gas emissions **(Rubin et al., 2005 and Connell, 2005).**Carbon capture and sequestration entails the capture of CO_2, at the site where it is generated, and the storage of CO_2 for periods sufficiently long to mitigate the impact of CO_2 on climate.

This chapter converses a detailed study on various aspects related to carbon sequestration network and its relevant literature work.

2.1 Economic incentive in storing carbon

One arena where CO_2 is pumped into reservoirs currently is in **enhanced oil recovery (EOR).** This provides a proving ground for a variety of techniques of relevance to CCS, and therefore it is necessary to discuss the role of CO_2-EOR in the development of CCS technologies.

In CO_2 - EOR, CO_2 is injected into depleted oil fields following the primary and secondary production methods for the purpose of recovering the fraction of the oil leftover in the field. The injected CO_2 dissolves in the oil, thus reducing its viscosity and forces the oil towards the productive well **(Meyer, 2007 and Moritis,1996).**

The CO_2-EOR industry has more than 35 years of experience in successfully transporting and injecting CO_2. Large-scale CO_2 injection is already underway at locations across the U.S and Canada as a part of the oil industry. In the US alone, several CO_2 - EOR wells are in operation injecting over 600million tonnes of CO_2 and producing about 245,000 barrels of oil a day through CO_2-EOR projects.

According to recent survey data by Koottungal (2010), there are 129 CO2-EOR projects operating around the world, with 114 of those in the U.S. Therefore, capturing and storage of CO2 in geologic formations is measured as an attractive opportunity because of the commercial value of CO2 and its value as an input into other industries.

Almost 3 million tonnes of CO_2 are captured each year from a coal gasification plant in North Dakota in a flagship project straddling the U.S-Canadian border, and it has been transported by means of pipeline to Weyburn in Saskatchewan where they are injected to enhance oil production.

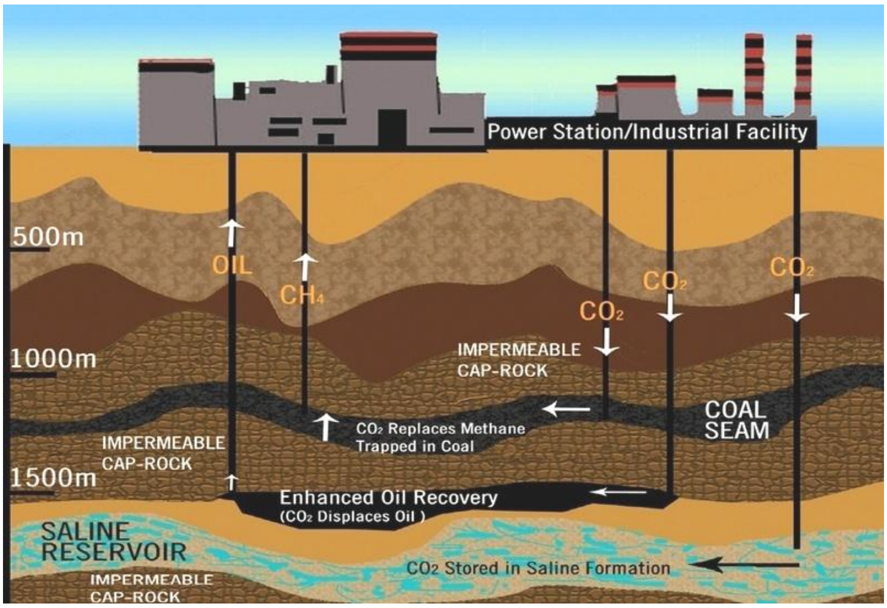

Figure 6. Underground injection of CO_2

CO_2 enhanced oil recovery (CO_2-EOR) offered significant potential for storing huge volumes of carbon dioxide while increasing domestic oil production. The recently completed study for DOE/NETL, examined the domestic oil resource amenable to CO_2-EOR, the size of the related market for CO_2, and the benefits to the power sector from CO_2 sales to the EOR industry. The study revealed that, depending on future oil prices and the costs for purchasing CO_2 from power plants and other industrial sources, from 39 to 48 billion barrels of oil could be economically recoverable with CO_2-EOR. In addition, the size of the market for CO_2 offered by the EOR industry would be in the order of 7,500 million metric tonnes between now and 2030. With the advancement in CO_2-EOR and storage technology, the economically recoverable oil resource would increase to 54 to 70 billion barrels .

In India it is planned to inject CO_2, captured from a gas plant for EOR into Ankleshwar oil fields after secondary recovery methods. **(Kale, 2007).**

The technology and practices used in handling and injecting CO_2 in the CO_2-EOR industry is a valuable resource for future CO_2 sequestration projects. Use of CO_2 for EOR is capable of sequestering a large quantity of CO_2, resulting in a net reduction in CO_2.

2.2 Enhanced coal bed methane recovery (ECBM)

The use of coal beds as a reservoir rock for storing CO_2 is novel. In coal beds there are considerable amounts of methane gas adsorbed in the coal which is called coal bed methane (CBM). By injecting CO_2 into these coal beds, the CO_2 is adsorbed in the coal pore matrix, releasing the methane (**Gunter et al., 1998).**It is interesting to note that storage of CO_2 in the depleted oil reservoirs or deep coal seams enhances oil recovery or produce methane thus providing economic incentive to store carbon. The use of CO_2 for CBM recovery would have the same effect as enhanced oil recovery and is classified as an **enhanced coal bed methane recovery (ECBM).** The bulk of the world's coal bed methane resource occurs in China, the Asian portion of Russia, Kazahkstan and India **(Kelafant et al., 1992).**

2.3 Feasibility and Global storage potential of CO_2

The captured CO_2 may be stored in deep geologic formations, such as depleted oil and gas reservoirs, Unmineable coal seems, and deep saline aquifers (**Bachu 2008, Benson and Cole 2008, Bickle 2009, Plasynski et al., 2011).**

Sequestered CO_2 can be stored in **saline aquifers,** safely below the drinking water table. A deep saline formation provides the largest potential volumes for geological storage of CO_2 since they contain highly mineralized brines, which has no benefit to humans. The salinity of water present in such formations ranges from 5,000 to over 350,000 mg/L **(Kharaka and Hanor, 2007).**Carbon-dioxide disposal into low permeability, deep aquifers in sedimentary basins has been shown to be technically feasible as geologic sinks and offers the largest potential for the landlocked areas of the world since it contains high salinity water and could host large amounts of CO_2.

Based on the comprehensive survey published by the U.S Department of Energy, North America has sufficient underground capacity in depleted oil and gas fields, saline aquifers and uneconomic coal seams to store up all its CO_2 emissions for the next 600 years.

The total CO_2 storage capacity of the United States is 1.8-20.4 trillion tonnes, compared with annual emissions of just 3 billion tonnes in U.S which is sufficient to last for hundreds of years if not thousands of years.

In IIlinois, Archer Daniels Midland is building a project that may capture 1 million tonnes of CO_2 from an existing ethanol distillery, and sequester it in a nearby saline aquifer.

2.4 CO_2 Storage potential in India

Estimates for the geological storage in India are in the range of 500-1000Gt of CO_2, Including on-shore and off-shore deep saline formations (300-400 Gt), basalt formation traps (200-400Gt), unmineable coal seams (5Gt) and depleted oil and gas reservoirs (5-10Gt) (**Singh et al., 2006).**

Deccan Volcanic Province, the basalt rock region in the northwest of India, is one of the largest potential areas for CO_2 storage. There is considerable potential for CO_2 storage in deep saline aquifers, mainly at the coast and on the margins of the Indian peninsula, particularly in Gujarat and Rajasthan.

India, as one of the largest developing countries, has significant low-cost coal resources and also growing electricity needs. Implement of CCS technology, could definitely constitute an important foundation block for future GHG mitigation strategies in India. The Government of India has planned to develop nine Ultra Mega Power Projects (UMPPs), each of 4,000 MW capacities, through private competitive request. In India, it is widely expected that the CCS technology will reach maturity in the interval 2020-2030, during the operational lifetime of India's new UMPPs **(Mott MacDonald, 2008)**.The IEA Energy Technology Perspectives (ETP) report of 2006 says that CCS would be the second largest potential contributor to CO_2 emission reductions by 2050.

2.4 Oil and Gas Production -Metallurgy

NACE **- National Association of Corrosion Engineers was established in 1943 by eleven corrosion engineers from the pipeline industry. Since then it has become the global leader in developing corrosion prevention and control standards, certification and education. Headquartered in Houston, Texas, it serves nearly 30,000 members in 116 countries and is recognized globally as the premier authority for corrosion control solutions. It offers technical training and certification programs, conferences, industry standards, reports, publications, technical journals, government relations activities and more to fulfill its mission of "**Protecting people, assets, and the environment from the effects of corrosion".

Hence papers presented in NACE International Conferences on the **Advancements in Materials Technology for use in Oil and Gas Industry (T-1F)** under the technical head C**orrosion Control in Petroleum Production** from 1996-2000 and **Specific Technology Group 32 – Oil and Gas Production-Metallurgy** from 2001-2011 were reviewed. The composition of materials used in Oil and Gas industry has been collected and spread in excel sheets.

2.5 Corrosion issues due to CO_2 in oil and gas pipelines

CO_2 is one of the main corrosive agents in the oil and gas production systems. CO_2 mixes with the water forming carbonic acid, making the fluid acidic (reducing the pH value). Carbonic acid corrosion of carbon steels has been recognized for years as a major source for “sweet gas” corrosion causing damage in oilfield equipment and gas pipelines.

CO_2 corrosion in oil and gas industry causes failure on the equipment especially the main downhole tubing and transmission pipelines and thus disrupts the oil/gas production.

CO_2 corrosion is influenced by temperature and its pH value. At elevated temperatures, Iron carbide (Siderite) scale is formed on the material as a protective scale and thereby reducing the corrosion rate. The metal starts corroding under these conditions and various forms of CO_2 corrosion such as ringworm corrosion, mesa corrosion and pitting corrosion occurs. It is important to realize the term CO_2 corrosion and the effect of CO_2. A large number of CO_2 dependent chemical, electrochemical and mass transport processes occur simultaneously on and close to the corroding steel surface. It depends mainly on CO_2 partial pressure, temperature, water chemistry, flow and other operational parameters.

2.6 Corrosion investigation of Carbon Steel for CO_2 transportation

The transportation of CO_2 from source to storage site is possible mainly through pipelines. To a large extent pipelines can be made in carbon steel as pure, dry CO_2 is essentially non-corrosive.

Sufficient drying (water removal) of carbon dioxide (CO_2) in transport pipelines is required to prevent breaking-out of free water and consequent excessive corrosion rates. However, there is a possibility of increased corrosion rates in supercritical CO_2 phase with water vapor (below its solubility level) in the presence of oxygen (O_2) and sulfur dioxide (SO_2).

2.7 Corrosion investigation of Stainless Steel for its application in CO_2 atmosphere

Increased green house gas emissions are expected to cause significant environmental and climatic changes. One of the important concerns in these efforts is that most of the CO_2 generation sites are not necessarily close to the storage sites and this will require a network of pipelines for the transportation of the super critical CO_2 to storage sites.

The development of the pipeline infrastructure for the transport of supercritical CO_2 would play an important role in enabling carbon capture and storage (CCS) to be an integral part of power generation and reduction of green house gas emissions **Ramgopal Thodla et al. (2009).**

In the year 1998 costs for corrosion in USA were estimated to be about 276 billion US-$. Even if the complete corrosion costs cannot be avoided, by choosing the right corrosion control technology including better materials of construction, these costs can be reduced by 25 to 30%.One way to reduce this gigantic amount of money is to use components constructed out of high alloy **stainless steels**.

2.8 Corrosion problems in gas treat systems

CO_2 is separated from the flue gas by passing the flue gas through a continuous scrubbing system. Gas Treating Units are an integral part of gas processing plant's operation. An amine was generally used as a solvent to absorb hydrogen sulfide (H_2S) and carbon dioxide (CO_2) from sour gas. However, these units experienced accelerated corrosion with complex damage mechanisms to varying extent due to various factors. Corrosion in new plants could be efficiently addressed by appropriate design and material selection, cost effective control of accelerated corrosion in the plants **Saleem, M.A and Hulaibi, A.A (2008).**

Glycol and amine systems are widely used in both refineries and gas processing plants for the removal of contaminants such as water, hydrogen sulfide and carbon dioxide. Since the majority of the piping and vessels in these plants are fabricated from carbon steel and the amines are in aqueous solution, there would be a high potential for corrosion **Mark A. Moore et al. (2008).**

2.9 Effect of Impurities on Corrosion of Steel in Supercritical CO_2

There is a strong need to better understand the relation between the water content and the highest acceptable concentration of impurities in the dense phase CO_2 to transport in the CCS pipelines.

Over the decades a plenty of research has been carried out to find the corrosion behavior of various metals in oil and gas pipeline operations. Adequate knowledge which exists in the oil and gas industry can be applied for the CO_2 capture and storage.

Clearly, at present, there is a lack of scientific data based on which confident decision about the behavior of metals during the injection and storage of CO_2 could be made. More data are necessary to comment on the safe use of metals without serious corrosion problems.

Based on the literature survey carried out, the present work is designed to have a clear idea on the integrity of few types of pipeline materials like carbon steels of various compositions (Carbon steel-I, 5LX42 and 5LX60) and 304 and 316 stainless steel and influence of solvent impurities in carbon sequestration network.