OnLine Journal of Earth Sciences 13 (1): 10-14, 2019
ISSN: 1991-7708

Carbon Capture and Sequestration Technique as a Feasible Solution to the Problem of Climate Change

K.O. Rabiu
Department of Civil Engineering, Osun State University, Osogbo, Nigeria

Abstract: Climate change is a major problem that the world is facing today and this problem can be attributed to the excessive burning of carbon into the atmosphere. Carbon Capture and Sequestration (CCS) technique has been proven to proffer solution to this problem. CCS is the process of capturing CO_2 emission from power plant, compressed, transport and storage in geological formation for a significant period of time. Carbon dioxide can remain trapped underground by a number of mechanisms such as structural trapping in which CO_2 is trapped beneath the confining layer (caprock); retention as an immobile phase trapped in the pore spaces of the storage formation; dissolution in the in-situ formation fluids and adsorption onto organic matter in coal and shale. Additionally, it may be trapped by reacting with the minerals in the storage formation and caprock to produce carbonate minerals. Also, the criterial for site selection during geological carbon sequestration were discussed. Moreover, the CO_2 monitoring techniques and simulators for modelling CO_2 sequestration were also explained.

Key words: Climate change, carbon, geological formation, dissolution, carbonate

INTRODUCTION

The continuous use of fossil fuels has become a major concern because of associated CO_2 emissions and effect on climate (Metz *et al*., 2005). Consequently, a number of studies have been undertaken to assess the possibility of utilising carbon capture and sequestration technique as a mitigation measure to reduce the rising of CO_2 emissions (Metz *et al*., 2005). Carbon Capture and Sequestration (CCS) technique is a process of reducing the emitting CO_2 into the atmosphere by capturing CO_2 from major stationary sources such as power plant, transporting it usually by pipeline and injecting it into suitable geological formations on a timescale (Metz *et al*., 2005). The capture step requires dissociating CO_2 from other gaseous products such as nitrogen, sulphur and oxygen. The transportation of CO_2 involves the capturing of CO_2 to a suitable storage site located at a distance from the CO_2 source. CO_2 emission storage methods include injection into underground geological formations such as saline aquifers, depleted hydrocarbon reservoirs, coal beds and basalts, also the injection into the deep ocean. The three existing and well function commercial projects that link CO_2 capture and geological storage are the offshore sleipner natural gas processing project in Norway, the Weyburn Enhanced Oil Recovery (EOR) project in Canada and the in Salah natural gas project in Algeria. Other existing pilot and commercial projects are well explained from previous studies(Metz *et al*., 2005; Rabiu *et al*., 2017).

Worldwide capacity of CO_2 storage in deep underground is enormous (Metz *et al*., 2005). For example, deep saline aquifers are foreseeable to have a storage capacity of at least 1000 $GtCO_2$, in addition, depleted hydrocarbon basins are evaluated to have a storage capacity of 675-900 $GtCO_2$. Unminable coal formations capacity is uncertain and their estimations range from about 3-200 $GtCO_2$ (Metz *et al*., 2005). All these aquifers can conveniently sequester all the CO_2 emission in the atmosphere but however, more studies are needed on suitability of these aquifers.

MATERIALS AND METHODS

Properties of CO_2: It is paramount to know the main properties of carbon dioxide in order to study its behaviour during CO_2 sequestration. CO_2 is a colourless, odourless and non-combustible gas; it is in gaseous state under ambient pressure and temperature conditions (Nelson *et al*., 2005). CO_2 canoccur in four different phasesgas, liquid, supercritical and hydrate (Fig. 1). CO_2 occurs in asupercritical phase at temperatures >31.1°C and pressures >73.9 bar (critical point). Below the mentioned temperature and pressure, CO_2 will exist is gaseous, liquid or solid states. CO_2 is generally, store in supercritical conditions; at this condition ithas a higher density than gaseous CO_2 and consequently significant amount of CO_2 can be stored (Voormeij, 2004).

The leakage of CO_2 after storage into atmosphere is risky because it can lead to casualties among both living organisms and man. Human being with normal cardiovascular, pulmonary-respiratory and neurological functions can bear the risk of exposure between 0.5-1.5%

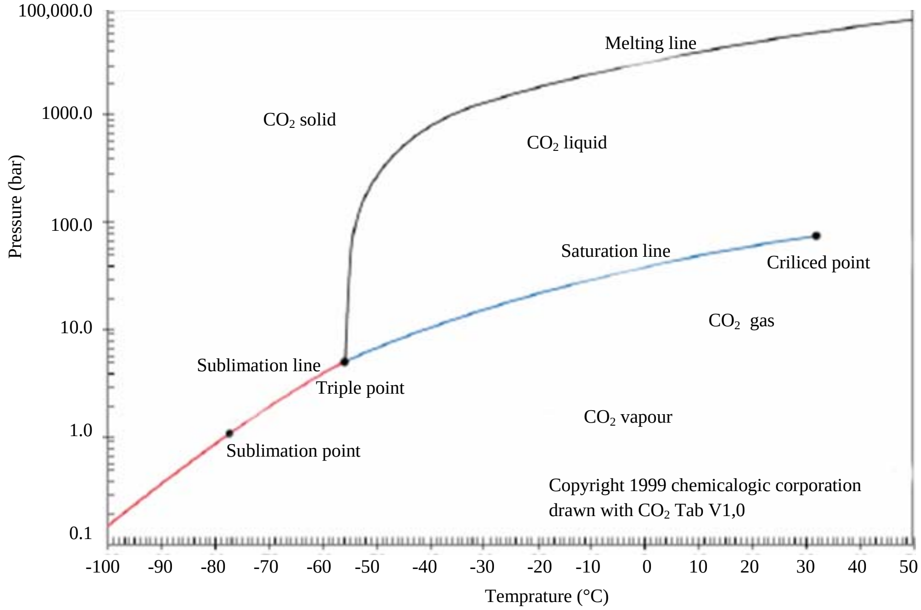

Fig. 1: Existence of CO_2 in various phases (Solomon, 2006) (Carbon dioxide: temperature-pressure diagram)

CO_2 for several hours without causing harm. Longer exposure of CO_2 can significantly affect health. High concentration of more than 1.5% can lead to increased heart rate, discomfort and unconsciousness. The worst scenario is the exposure to CO_2 concentrations at or above 3% which may be connected to a serious health related issue for example, hearing loss and visual disturbances occur above 3% CO_2. The exposure of CO_2 concentrations at above 20% can resulted into death (Solomon, 2006).

RESULTS AND DISCUSSION

Sources of CO_2: The emission of CO_2 is mainly from the combustion of fossil fuels used in power generation, transportation, industrial processes, residentials and commercial buildings (Metz *et al*., 2005). Studies have shown that about 60% of the current global CO_2 emissions are from power and industry sectors. The CO_2 emissions in these sectors are generated by boilers and furnaces burning fossil fuels and are generally emitted from large exhaust stacks (Metz *et al*., 2005; Solomon, 2006).

Multiphase flow in the reservoir-flow of the $scCO_2$ phase: The study of flow between the CO_2 phase and water phase is very important in the context of geological carbon sequestration. Reservoir models forecast that the injected CO_2 phase rises upwards due to buoyancy force and is stopped by the caprock (Iglauer 2011; Metz *et al*., 2005). Flow in the sedimentary basin is affected by changes in rock morphology and wettability which can result in changes of capillary pressures and relative permeabilities of CO_2 and water. Capillary pressures and relative permeability are strongly influence multi-phase fluid flow in the reservoir (Iglauer, 2011).

Geological storage: This section examines various types of geological formations which store CO_2 for long period of time. Examples are deep saline aquifers, oil and gas reservoirs, basalts and unminable coal beds. In each case, geological storage of CO_2 is by injecting supercritical CO_2 into a rock formation beneath the Earth's surface (Metz *et al*., 2005). Saline aquifer is enormous, i.e., it is available worldwide and the formation does not have any economic values for instance it can not be used for drinking and at the same time it cannot be used for irrigation. Therefore, CO_2 can be sequestered into the formation. Depleted oil and gas reservoirs can be use for enhanced oil recovery, also it can be used for carbon sequestration. However, depleted oil and gas reservoirshave limited capacity in comparison with saline aquifers. other important geological formations are coal seams and basalts Table 1.

CO_2 Trapping mechanisms: The trapping mechanisms of CO_2 in geological formationcan occur by either physical or chemical trapping mechanisms. Four types of trapping mechanisms control the movement and leakage potential of the CO_2 injected into geologic formations Fig. 2 (Metz *et al*., 2005). These trapping mechanisms are explained in the following sections.

Structural trapping: The geologic sink for hydrodynamic trapping is a porous rock layer capped by an essentially impermeable rock layer. Other terms that

Table 1: Capacity of various CO_2 sink (Mariyamma *et al*., 2015)

Formations	CO_2 capacity ($GtCO_2$)	Comments
Saline aquifers	>1,000	Available worldwide
Depleted oil and gas recovery	675-900	Limited CO_2 capacity
Unminablecoalbed	3-200	Very limited capacity
Marine sediments and sedimentary rocks	60,000,000-100,000,000	Largest capacity for CO_2 sequestration

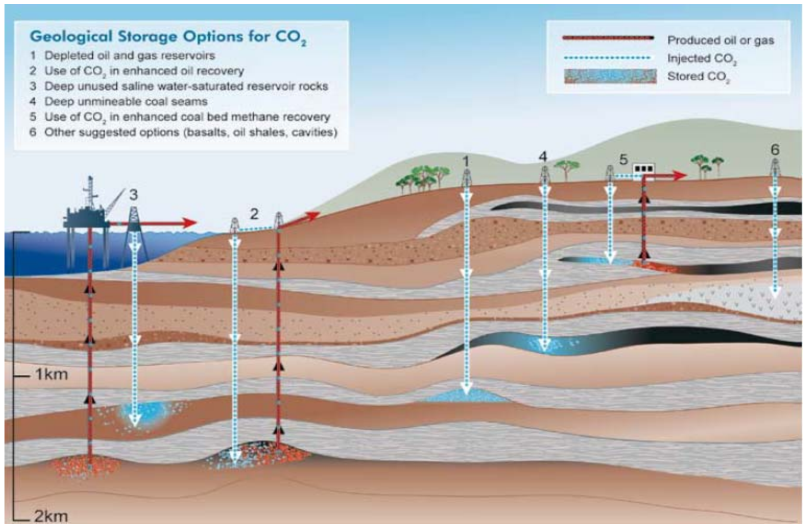

Fig. 2: Options for storing CO_2 in deep underground geological formations (Metz *et al*., 2005)

are sometimes used to describe this type of trapping mechanism are structural and stratigraphic trapping (Nelson *et al*., 2005).

Solubility trapping: In solubility trapping, the dissolution of CO_2 and water occur and form carbonic acid and other aqueous carbonate species. Solubility trapping also takes place during CO_2 flooding in Enhanced Oil Recovery (EOR).

Capillary trapping: Capillary pressure is also called residual-phase trapping and this occurs as a result of hysteresis, i.e., the different between drainage and imbibition. The injection of CO_2 displaces water in the subsurface and the process is called drainage on the other hand, after the injection stops, the CO_2 tends to move up due to buoyancy force and displace some water; during the process, some CO_2 got trapped by capillary pressure. This trapping mechanism tends to be effective and efficient and the process takes place with in shortest period of time in comparison with mineral trapping which take millennia before permanently trapped. However, more research is needed in capillary trapping for permanent storage.

Mineral trapping: This occurs as a result of dissolution of CO_2, water and silicate minerals rich in Ca, Mg and Fe, resulting in the formation of a solid carbonate mineral phase. Mineral trapping is arguably the most stable, permanent form of geologic CO_2 sequestration. However, it takes millennium before the conversion takes place (Nelson *et al*., 2005). More research is required in this area. Over time, the physical process of residual CO_2 trapping and geochemical processes of solubility trapping and mineral trapping increase (Metz *et al*., 2005) (Fig. 3).

Site selection criteria for geological carbon sequestration: The characterisation of the potential carbon sequestration site is the most paramount step required before any injection started. Some of the major areas to be focus are faults, thickness, quality, distribution of cap and reservoir rocks. The movement pattern and behaviour of carbon dioxide plume, designing, positioning and management of injection bore holes needed to be studied using model and plume simulations (Metz *et al*., 2005; Rabiu *et al*., 2017). Computer programmes that model underground CO_2 movement are used to support sitecharacterization and selection activities (Metz *et al*., 2005). Generally, geological storage sites should have enough storage capacity, fault free cap rock and geological environments to contain the integrity of the storage site (Mariyamma *et al*., 2015).

Carbon sequestration simulators: All the codes used in simulation are dependent on the types of numerical

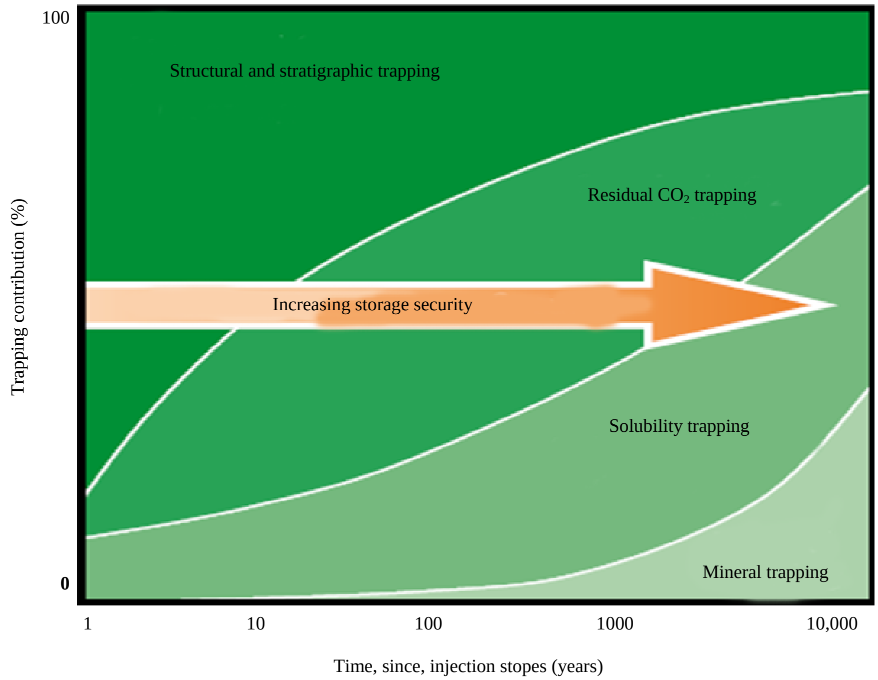

Fig. 3: Storage security depends on a combination of physical and geochemical trapping

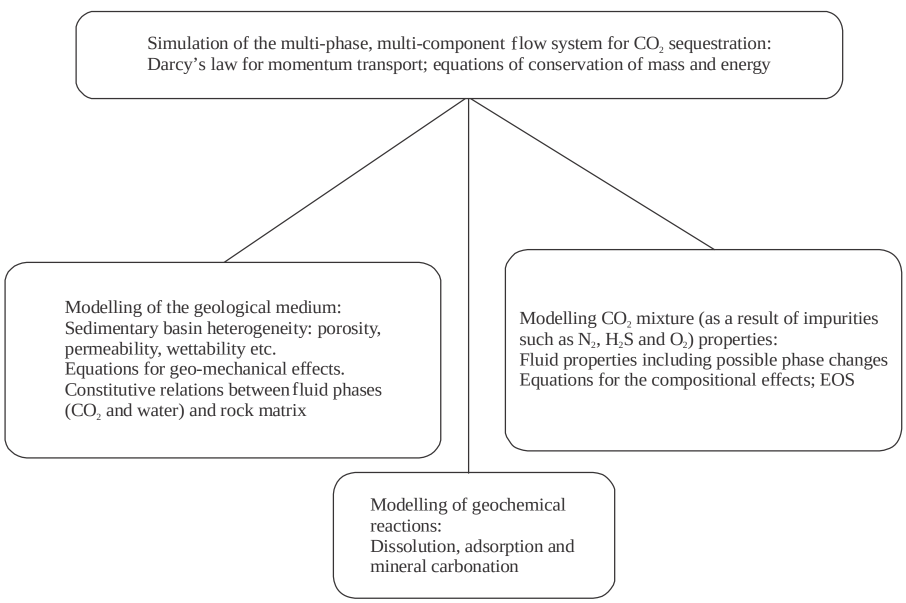

Fig. 4: Schematic of the physical modelling of geological carbon sequestration (Jiang, 2011)

methods used to convert the governing equations into a finite form, appropriate for computational manipulation and analysis. The most commonly used numerical methods can be classified intofinite difference, finite element and finite volume methods. The intricacy of the simulators depends majorly on the number of fluid phases and the number of components considered as well as the discretisation methods used. The codes developed in the oil and gas industry are the existing simulators presently using for geological carbon storage (Jiang, 2011). Figure 4 shows the schematic of the physical modelling of geological carbon sequestration.

Existing CO_2 storage projects: The three major existing CO_2 storage projects are sleipner project in the North sea, the Weyburn project in Canada and the in Salah project in Algeria. Almost 3-4 $MtCO_2$ were captured and stored annually in geological formations. Other storage projects are listed in Table 1. Metz *et al*. (2005) explored that "in addition to the CCS projects currently in place, 30 $MtCO_2$ is injected annually for EOR, mostly in Texas, USA where EOR commenced in the early 1970s. Most of this CO_2 is obtained from natural CO_2 reservoirs found in western regions of the US with some coming from anthropogenic sources such as natural gas processing. Much of the CO_2 injected for EOR is produced with the oil from which it is separated and then reinjected. At the end of the oil recovery, the CO_2 can be retained for the purpose of climate changemitigation, rather than vented to the atmosphere".

CO_2 monitoring techniques: Existing monitoring methods include pressure monitoring, chemical tracers, chemical sampling, surface and borehole seismic analysis, electromagnetic and other geotechnical instruments (Metz *et al*., 2005). Successful remote sensing for the detection of CO_2 leakage and land surface deformation is expected to need high-resolution mapping techniques for tracking migration of sequestered CO_2 (Shukla *et al*., 2010).

CONCLUSION

The problem of climate change continues to be a source of concern to all stakeholders and this problem can be attributed to excessive burning of CO_2 into the atmosphere. Carbon Capture and Sequestration (CCS) technique has been proven to proffer solution to this problem. CCS is the process of capturing CO_2 emission from power plant, compressed, transport and storage in geological formation for a significant period of time. Carbon dioxide can remain trapped underground by a number of mechanisms such as structural trapping in which CO_2 is trapped beneath the confining layer (caprock); retention as an immobile phase trapped in the pore spaces of the storage formation; dissolution in the in-situ formation fluids; and adsorption onto organic matter in coal and shale. The review also shed more light on CO_2 monitoring techniques and also the simulators used in modelling CO_2 sequestration.

REFERENCES

Iglauer, S., 2011. Dissolution Trapping of Carbon Dioxide in Reservoir Formation Brine-A Carbon Storage Mechanism. In: Mass Transfer-Advanced Aspects, Nakajima, H. (Ed.). InTech, New York, USA., ISBN: 978-953-307-636-2, pp: 234-362.

Jiang, X., 2011. A review of physical modelling and numerical simulation of long-term geological storage of CO2. Applied Energy, 88: 3557-3566.

Mariyamma, P.N., S. Yan, R.D. Tyagi, R.Y. Surampalli and T.C. Zhang, 2015. CO2 Sequestration and Leakage. In: Carbon Capture and Storage: Physical, Chemical and Biological Methods, Surampalli, R.Y., T.C. Zhang, R.D. Tyagi, R. Naidu and B.R. Gurjar et al. (Eds.). American Society of Civil Engineers, Reston, Virginia, USA., ISBN: 9780784413678, pp: 113-157.

Metz, B., O. Davidson, H. Connick, M. Loos and L. Meyer, 2005. IPCC special report on carbon dioxide capture and storage. Working Group III of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, New York, Chapter 7, pp: 319-338.

Nelson, C.R., J.M. Evans, J.A. Sorensen, E.N. Steadman and J.A. Harju, 2005. Factors affecting the potential for CO2 leakage from geologic sinks. Technical Report Plains CO2 Reduction Partnership, National Energy Technology Laboratory, Pittsburgh, Pennsylvania, USA. https://undeerc.org/pcor/newsandpubs/pdf/FactorsAffectingPotential.pdf

Rabiu, K.O., L. Han and D.B. Das, 2017. CO2 Trapping in the Context of Geological Carbon Sequestration. In: Encyclopedia of Sustainable Technologies, Abraham, M.A. (Ed.). Elsevier, Amsterdam, Netherlands, pp: 461-475.

Shukla, R., P. Ranjith, A. Haque and X. Choi, 2010. A review of studies on CO2 sequestration and caprock integrity. Fuel, 89: 2651-2664.

Solomon, S., 2006. Criteria for intermediate storage of carbon dioxide in geological formations. Bellona Foundation, Oslo, Norway. https://bellona.org/publication/criteria-intermediate-storage-carbon-dioxide-geological-formations

Voormeij, D.A., 2004. Carbon dioxide sequestration options for British Columbia and mineral carbonation potential of the Tulameen ultramafic complex. M.Sc. Thesis, University of Victoria, Victoria, Canada. http://dspace.library.uvic.ca/handle/1828/619