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CARBON CAPTURE AND STORAGE IN AQUIFERS

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Abstract. Nowadays one of the main environmental problems is air pollution and a large number of harmful emissions in the atmosphere. Since CCS installations have been proven to be an effective technology for reducing harmful emissions this paper aims to analyze this process, its benefits and disadvantages. This paper carried out a detailed analysis of the capture, transport, injection, and storage of carbon dioxide in aquifers and also examined various methods of this process. Besides economic and environmental impacts have also been considered. The ecological impact of CCS in aquifers is also discussed, emphasizing the importance of monitoring, and preventing potential risks of leakage. The paper evaluates the cost-effectiveness of CO_2 storage in aquifers compared to other storage options. Such factors as a long-term monitoring of the storage facilities and liability have been taken into consideration to evaluate the total viability of CCS projects in aquifers.
Keywords: leakage, carbon capture and storage (ccs), aquifers, CO_2 storage

SULU TƏBƏQƏLƏRDƏ KARBONUN TUTULMA VƏ SAXLANMASI

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Xülasə. Hal-hazırda əsas ekoloji problemlərdən biri havanın çirklənməsi və atmosferə çoxlu sayda zərərli tullantıların atılmasıdır. CCS qurğularının zərərli emissiyaları azaltmaq üçün effektiv texnologiya olduğu sübut olunduğundan, bu sənəd bu prosesi, onun faydalarını və mənfi cəhətlərini təhlil etmək məqsədi daşıyır. Bu məqalədə karbon qazının sulu təbəqələrdə tutulması, daşınması, vurulması və saxlanmasının ətraflı təhlili aparılıb və bu prosesin müxtəlif üsulları da araşdırılıb. Bundan əlavə, iqtisadi və ekoloji təsirlər də nəzərə alınıb. CCS-nin sulu təbəqələrə ekoloji təsiri də müzakirə edilir, monitorinqin vacibliyi vurğulanır və potensial sızma risklərinin qarşısı alınır. Sənəd digər saxlama variantları ilə müqayisədə sulu təbəqələrdə CO_2 saxlanmasının səmərəliliyini qiymətləndirir. Sulu təbəqələrdə CCS layihələrinin ümumi həyat qabiliyyətini qiymətləndirmək üçün anbarların uzunmüddətli monitorinqi və öhdəlik kimi amillər nəzərə alınmışdır.
Açar sözlər: sızma, karbon tutma və saxlama (ccs), sulu qatlar, CO_2 saxlama

Introduction. Before considering the ecological impact of the Carbon Capture and Storage CCS it is necessary to understand what CCS is and where does this carbon come from. We are living in a rapidly developing world with its daily growing needs. Everything surrounding us from the clothes we wear to the technology we use directly or indirectly connected with the industrial processes. These are the processes that cause emissions (including CO_2). So, Carbon Capture and Storage is a separation of carbon dioxide from the emissions of industrial processes and its storage deep underground in general in depleted oil and gas reservoirs, saline formations, and basalt formations (onshore or offshore) prior release emissions into the atmosphere.

It has been proved that CCS is one of the most effective tools in decarbonization of the atmosphere. According to the International Energy Agency (IEA), CCS could contribute up to 13% to the required emissions reductions by 2060. But at the same tie it is very important to understand each level of CCS, all benefits, and risks and how it is impacting the environment. This paper aimed to assess mentioned above risks and goals of the Carbone Capture and Storage process.

Nowadays climate change and global warming turned out into a common problem that all countries involved all their efforts to find the solution. CCS is a working tool to reduce the greenhouse gas emissions (including CO_2) in the atmosphere. However, in order to provide its environmental sustainability, it is vital to estimate CCS ecological impact.

Overall, this paper contributes to the growing body of knowledge on CCS in aquifers, highlighting its potential as a sustainable solution for reducing carbon emissions and addressing climate change challenges [2].

Methods and materials. There are three steps in CCS process: a plant capturing carbon dioxide, transportation, and storage [3,4]. This paper aims to consider each stage in detail for better understanding. Here are some general ways of CCS: post-combustion, pre-combustion, oxy-fuel combustion, and direct air capture.

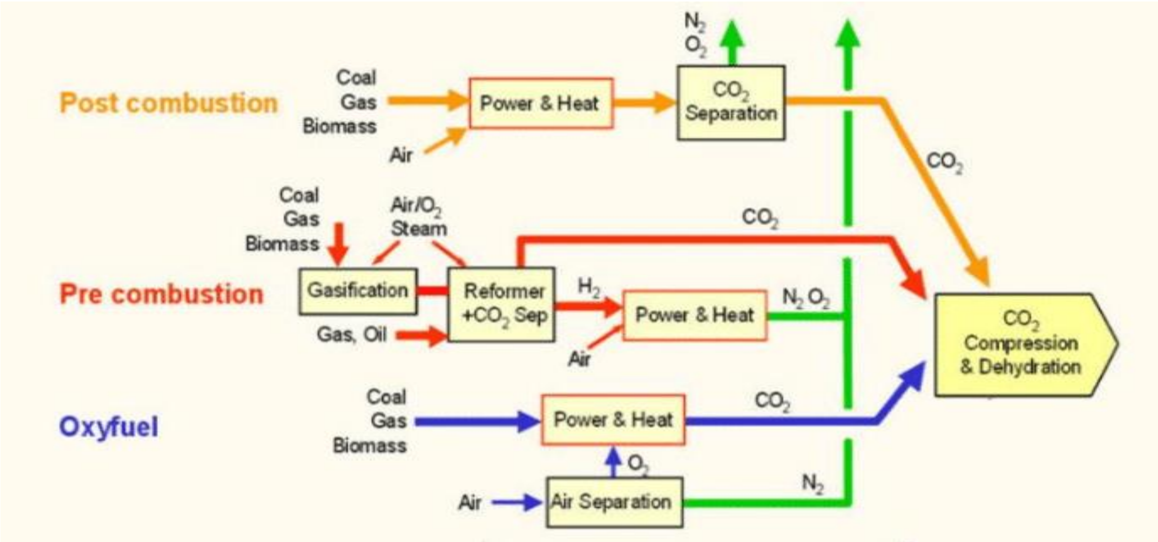

Fig. 1. Combustion types [4]

Post-combustion method includes carbon capture by usage of a large number of amine-based solvents. While the process pollution control system captures separately carbon dioxide (i.e., getting in contact with solvents, CO_2 molecules are attracted by them). Then the gas is heated in a special column in order to separate CO_2 from the solvents. The separated carbon then compressed to the liquid state that make it easier to transport to the storage reservoirs. The advantage of this method is that separated and captured CO_2 can be easily transported by adding a pipe to the already existing system. But on the other hand, the percentage of the captured carbon is significantly low (4-15 %) despite the pricey equipment and solvents. Another disadvantage is the solvent leakage may be harmful for the environment (Rochelle, 2009).

Pre-combustion method means to separate carbon dioxide prior the combustion. There are 3 stages of pre-combustion:

1. Hydrocarbon fuel is converted into hydrogen and carbon monoxide to form a synthesis gas;
2. CO is converted into CO_2 by water gas shift reaction;
3. Carbon dioxide is extracted from hydrogen. Then it can be combusted completely. The captured CO_2 will be compressed into liquid and transported to a storage site (Basile, Morrone, 2011).

The benefits of this method are high percentage of the captured emissions (90-95%), can be applied to the gas and coal IGCC, less risk, possibility of producing H_2. The disadvantages are the cost of this process [5].

Geological Storage of Captured Carbon Dioxide: Types, Locations, and Operations The average temperature on Earth rose by 0.99°C (1.78°F) in 2016 according to a combined report from the National Oceanic and Atmospheric Administration (NOAA) and National Aeronautics and Space Administration (NASA). It has been proven that carbon dioxide is one of the main greenhouse gases that leads to global warming. This is the reason for many researches about implementing carbon capture and storage technology and worldwide attempts to increase the number of installed CCS plants.

After capturing carbon dioxide, it is compressed into a liquid phase and transported to storage locations. It can be injected into porous rock formations deep underground. There are three main types of geological storage for CO_2: oil and gas reservoirs, deep saline formations, and un-minable coal beds.

CO_2 can be trapped under a sealed rock layer or in the rock pores. Besides it can be chemically trapped by dissolving in water and reacting with the surrounding rocks. In this case leak risk is is significantly small. CO_2 storage in geological formations is cheap and the most ecologically friendly. This paper aims to highlight the different types of geological storage, their locations, and the operational processes involved.

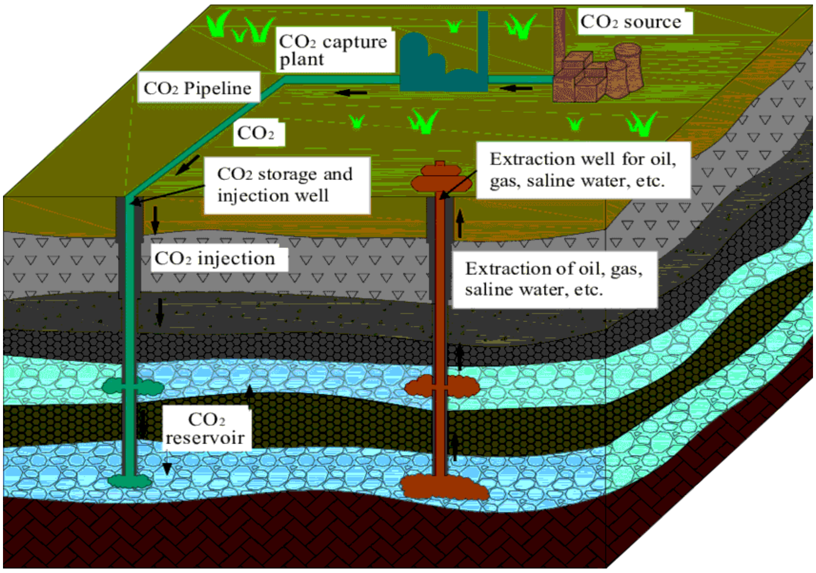

Fig.2. Overall schematic of carbon capture and storage concept [5]

Types of Geological Storage.

- *Depleted Oil and Gas Reservoirs.* This is the most reliable option for carbon dioxide storage. Since while oil and gas production all formations data have been collected. Besides formations have previously held hydrocarbons and possess suitable characteristics for carbon dioxide storage, including a rock layer above that prevents CO_2 upwards migrating and escaping into the atmosphere (Benson, & Cole, (2000). Pore presence also makes these reservoirs favorable for CO_2 storage (Yu, & He, (2017). In addition, there is exact information about the reservoir capacity. thus, sufficient CO_2 volume may be injected and accommodate within the reservoir (Bachu, (2015).

It also should be noted that depleted reservoirs have the infrastructure i.e., injection wells, surface facilities that significantly reduce storage costs.

- *Saline Aquifers.* deep underground formations also considered as a storage for CO_2. There are several and main factors for this. First, in comparison with the other geological formations saline aquifers has the larger storage capacity (Bachu, (2015). From the other side brine and CO_2 do not readily mix, that minimizing the risk of CO_2 dissolving and contaminating the brine (Metz, et (2005). Wide geographical distribution is increasing the accessibility of the CO_2 storage on saline aquifers(International Energy Agency (2023). But the biggest disadvantage of using saline aquifers is the infrastructure absence (i.e., Injection wells and pipelines). This leads to large investments requirement.

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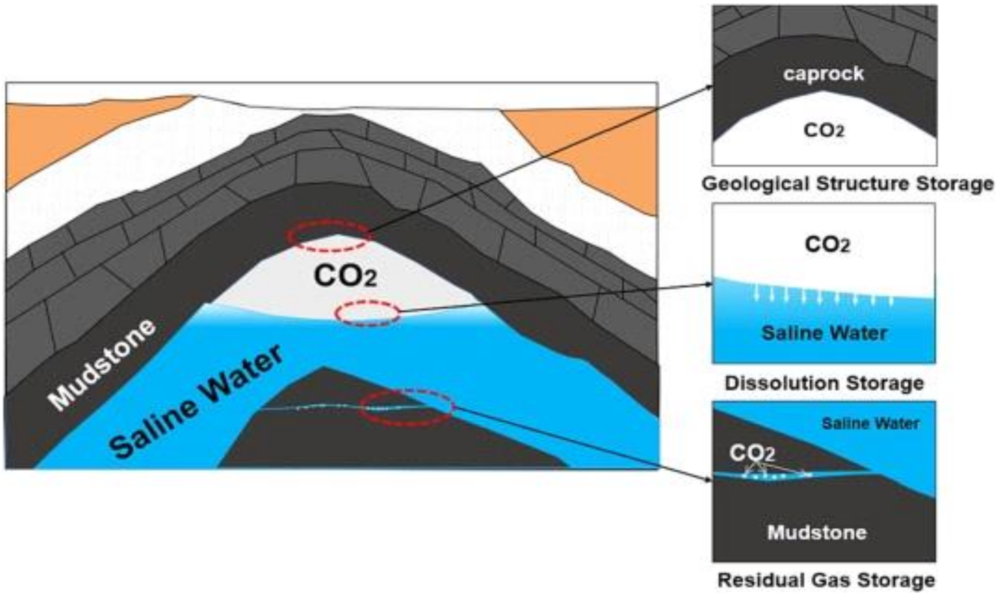

Fig.3. Captured Carbon Dioxide storage in saline aquifers [6]

PVT behavior of Carbon dioxide. It is known that Carbon dioxide has three states that may change under certain conditions of pressure and temperature. The understanding of each phase behavior of carbon dioxide is crucial during CCS especially in transport and injection. While CO_2 pipeline transport two processes play an important role here: the cooling of the CO2 in the pipeline and the well pressure between the well head and the storage reservoir. These processes have a significant impact on the CO_2 phase behavior. They require a thorough understanding and precautionary measures to ensure that the CO_2 enters the reservoir at the right pressure and temperature. Otherwise, density changes can have a major impact on the ability to inject CO_2 into the reservoir (Firoozabadi, (1999.) Hence this paper aims to find out PVT behavior of carbon dioxide and phase diagram of CO_2.

PVT Behavior of CO_2: Carbon dioxide is a compound that demonstrates different phase behavior in different pressure and temperature conditions. For example, CO_2 is a gas at low pressures and temperatures, while at high pressures and temperatures it transforms into a liquid or a supercritical fluid.

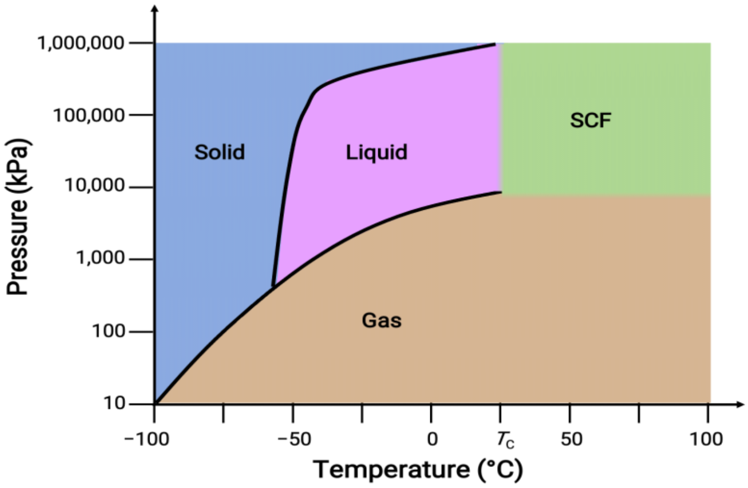

Fig.4. Phase diagram of carbon dioxide CO_2 [7]

The diagram above shows how CO_2 behaves in different pressure and temperature conditions. It consists of parts representing gas, liquid, and supercritical phase of CO_2. The phase boundaries, known as the vapor pressure curve and the critical point, separate these regions (Span, (1992).