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Types and Methods of Carbon sequestration : A Review

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ABSTRACT
Most of the energy that is used to meet human needs is directly or indirectly derived from the burning of fossil fuels (natural gas, oil, and coal), which releases carbon to the atmosphere, primarily as carbon dioxide (CO_2) Greenhouse gases including this CO_2 are increasing in the atmosphere. This is a major cause of climate change. Studies predict that increases in atmospheric CO_2 will adversely affect life on Earth by trapping solar heat and causing average surficial temperature of the Earth to rise in response. International concern about potential global climate change has initiated discussions about limiting the amount of CO_2 and other greenhouse gases released to the atmosphere. Scientists and policy makers are trying to determine how to decrease and possibly reverse the emission of carbon dioxide (CO_2). Carbon sequestration, a process where CO_2 is taken from the atmosphere and stored for an indefinitely, may be one way to slow or reverse the accumulation of CO_2 in the earth's atmosphere. It involves accumulating CO_2 into long-lived global pools within the forest, oceanic, biomass and geological strata to reduce the net rate of increase in atmospheric CO_2. These techniques have potential to mitigate the climate change risks however, there is a need to analyse the costs associated and the benefit delivered by each of the proposed solutions for carbon sequestration.
Key words: *Carbon sequestration, Climate change*

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INTRODUCTION

Greenhouse Gases

Greenhouse gases include carbon dioxide, water vapour, methane, nitrous oxide, hydro fluorocarbons, fluorocarbons, and sulphur hexafluoride. The gases are both naturally occurring and caused by human activities. When sunlight hits the earth's surface, some of it is re- radiated back to space as infrared radiation (heat). Greenhouse gases absorb infrared radiation and the heat is trapped within the earth's atmosphere. Rising levels of greenhouse gases is contributing to what is known as the greenhouse effect [2].

Greenhouse Effect

The greenhouse effect is a natural phenomenon that helps regulate the earth's temperature. Greenhouse gases, such as carbon dioxide and methane act like an insulating blanket, trapping solar energy that would otherwise escape into space. Without this natural "greenhouse effect," temperatures would be about 60°F lower than they are now, and life as we know it today would not be possible. However, human activities, such as the burning of fossil fuels and clearing of forests, have enhanced the natural greenhouse effect, causing the earth's average temperature to rise [1].

Carbon Cycle

Carbon dioxide (CO_2) is a gas made up of one atom of carbon and two atoms of oxygen.
CO_2 is both naturally occurring and caused by human activities. CO_2moves through the earth's atmosphere, biosphere, geosphere, and oceans in a naturally occurring process known as the carbon cycle. Humans and animals breathe in oxygen and breathe out CO_2;

plants take in CO_2 during photosynthesis and release oxygen. Since the industrial revolution, the amount of CO_2 in the atmosphere has increased due to human activity, such as burning of fossil fuels and land use conversion. CO_2 is a greenhouse gas and contributes to global warming. The carbon cycle is the process in which carbon is exchanged between living things, the earth's crust, the oceans and the sky; or the biosphere, geosphere, hydrosphere and the atmosphere. Carbon is continuously cycled through these systems by being taken up and released in several ways. Carbon is taken up from the atmosphere by plants during photosynthesis and by the cooling of the oceans. Carbon is released to the atmosphere by decomposition of living things, volcanic eruptions, and the heating of the oceans and burning fossil fuels. Burning fossil fuels has knocked the carbon cycle out of balance, resulting in increasing levels of CO_2 in the atmosphere.

Carbon - Cutting Strategy

There are a suite of strategies that could potentially stabilize atmospheric CO_2 concentrations. Scientists at Princeton University have proposed a stabilization model composed of seven "wedges," with each wedge representing a carbon-cutting strategy to reduce carbon emissions in the short term future. The wedges include ways in which energy is made and/or used. In addition to carbon sequestration technologies, increased transportation efficiency, increased efficiency of electricity production, and renewable energies are ways in which atmospheric CO_2 levels can be reduced and potentially stabilized.

Objectives

Following are the objectives of this research paper:

1. To discuss different available techniques for carbon sequestration
2. To review and discuss the global strategies for carbon sequestration
3. To review the Indian scenario regarding carbon sequestration

RESEARCH METHODOLOGY

This research paper is created on the basis of research journals, books, websites and various reports with the help of secondary data. This study reviews the current material related to carbon sequestration. The present study is of analytical and exploratory nature using available literature.

DISCUSSION

What is carbon sequestration

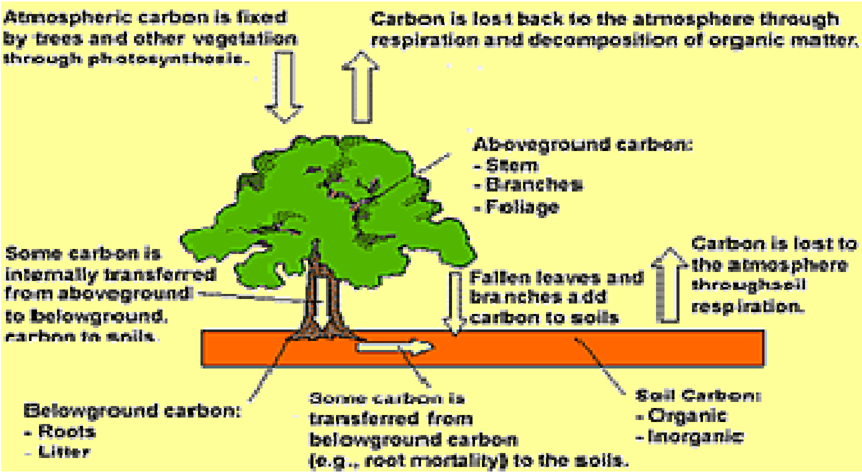
It is the removal and long-term storage of CO_2 from the atmosphere into carbon reservoirs or carbon sinks.

Types of carbon sequestration

There are three types of carbon sequestration viz., *i.* Terrestrial sequestration, *ii.* Geologic sequestration and *iii.* Carbon sequestration in the oceans. This is also known as carbon, capture and storage i.e. CCS. In terrestrial sequestration, the carbon can be stored in forests or in the soils of farm land and range land. In geologic sequestration, the carbon can be stored underground in depleted oil and gas reservoirs, coal seams, basalt rocks and saline aquifers. Ocean sequestration is enhancing the net uptake of carbon from the atmosphere by the oceans.

1. Terrestrial Sequestration

Terrestrial carbon sequestration is the process through which carbon dioxide from the atmosphere is absorbed by trees, plants and crops through photosynthesis, and stored as carbon in biomass (tree trunks, branches, foliage and roots) and soils. The term "sinks" is also used to refer to forests, croplands, and grazing lands, and their ability to sequester carbon. Agriculture and forestry activities can also release CO_2 to the atmosphere. Therefore, a carbon sink occurs when carbon sequestration is greater than carbon releases over some time period



Source: https://www.nrs.fs.fed.us/niacs/carbon/forests/carbon_sequestration/

Terrestrial activities sequesters CO_2

Terrestrial sequestration can be enhanced by land use practices and land management decisions that increase the amount of carbon stored in croplands, soils, and forest environments. Diversified rotation cropping, no-till farming, reducing summer fallow, planting cover crops (i.e. wheat, rye) or high residue crops (i.e. corn, grain sorghum), and vegetation buffers are ways in which carbon is stored in cropland environments.Additional terrestrial sequestration activities include converting marginal agricultural lands to grasslands or forests, selecting hybrid crops with high carbon storage capacities, and other land use practices that minimize soil tillage, erosion, and the removal of carbon from the land.

2. Geologic Sequestration

Geologic sequestration of CO_2 involves a three step process that includes capturing the CO_2, transporting the CO_2, and storing it into a deep underground reservoir.

A. Capture

CO_2 that is produced by power plants is captured by mainly through Flue-gas (or exhaust gas) separation, Oxy-fuel combustion and Pre-combustion method.

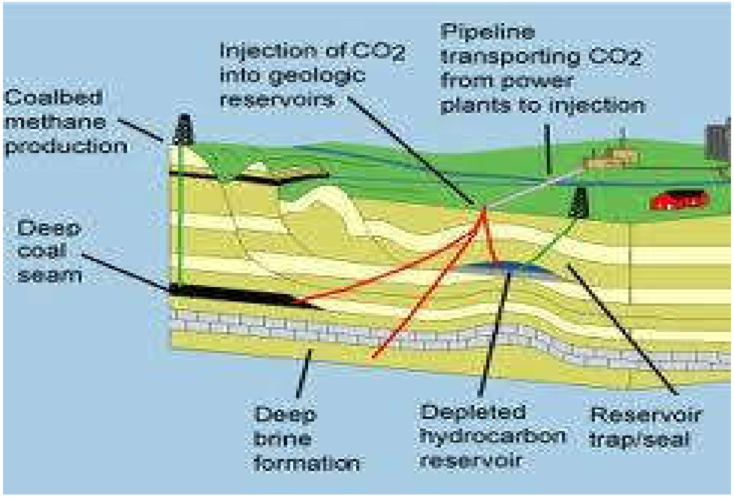
1. Flue-gas (or exhaust gas) separation removes CO_2 with a solvent, strips off the CO_2 with steam, and condenses the steam into a concentrated stream. Flue gas separation renders commercially usable CO_2, which helps offset its price.
ii. Oxy-fuel combustion burns the fuel in pure or enriched oxygen to create a flue gas composed primarily of CO_2 and water.
iii. Pre-combustion capture removes the CO_2 before it's burned as a part of a gasification process.

B. Transportation

The captured CO_2 is transported via pipelines to a suitable storage location selected by a team of geologists, engineers, project managers, and many others.

C. Storage

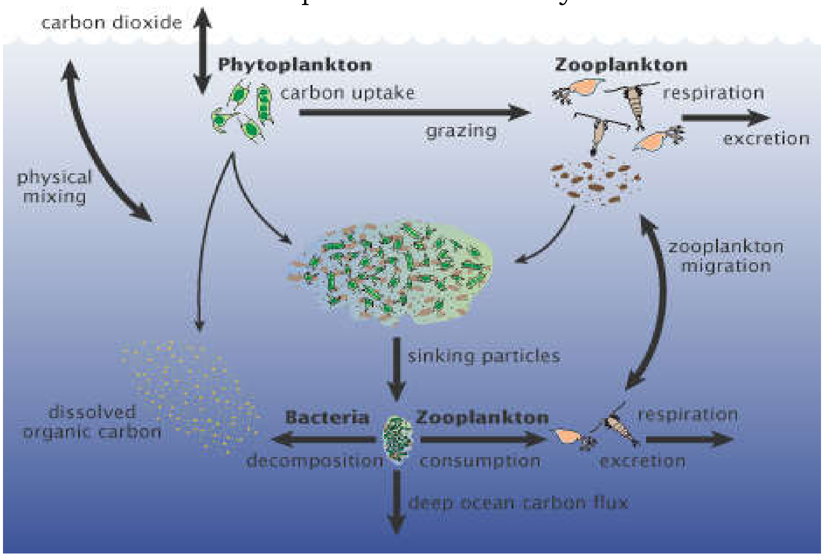
The CO_2 is injected into deep underground rock formations that have high porosity and permeability. Porosity refers to the amount of pore space between rock particles. The CO_2, once injected, will be located within these spaces. Permeability describes how well connected the pores are to each other. High permeability allows injected CO_2 to ‘flow’ through the rock, making the injection process much faster, and thus less expensive. The rock formation that the CO_2 is injected into is called the reservoir. The reservoir also must have a low porosity rock formation, called a cap rock, directly above it to keep the CO_2 from escaping. There are many types of reservoirs that can hold CO_2 such as deep saline aquifers, depleted oil and gas reservoirs, and unmineable coal seams. The well is properly sealed after the CO_2 is injected into the reservoir and the area is monitored long term to detect CO_2 leaks of any kind.



Source: https://pubs.usgs.gov/fs/fs026-03/fs026-03.html

3. Carbon Sequestration in the Oceans

Enhancing the net uptake of carbon from the atmosphere by the oceans, through fertilisation of phytoplankton with nutrients and injecting carbon dioxide to ocean depths great than 1000 meters. All of these options are commonly known as carbon "sinks".



Source:https://earthobservatory.nasa.gov/features/Phytoplankton/page2.php

Farmers who can verify that they have sequestered more carbon in their soil than they emitted with their equipment etc. have earned a 'carbon credit'. The carbon sequestered in the soil can be used to offset emissions from fossil fuel combustion, cement making or other carbon-emitting activities. At the same time it improves soil quality and long-term agricultural productivity. Globally, farm lands can offset 30% of annual global emissions of CO_2 from burning fossil fuels. Preparing soil carbon offset credits for market requires governments to determine who owns the carbon (landowners, operators, governments), who will need to buy carbon offsets, who will not, how long contracts should be, how sequestration is verified and what penalties for fraud or breach of contract should be.

Monitoring, verification, and accounting (MVA) is a component of carbon sequestration that ensures the permanence and safety of carbon dioxide storage. Monitoring and verification encompasses the ability to: measure the amount of CO_2 stored at a specific site; monitor it for leaks; track the location of the CO_2 underground; and verify that the $CO_2$is stored in a way that is permanent and not harmful to the environment. Mitigation is the ability to respond to risks such as CO_2 leakage or any damage in the unlikely event that a leak should occur [16].

Global initiatives in Carbon Sequestration [3, 4]
In addition to the U.S. Department of Energy's Regional Partnerships, there are several existing international carbon capture and storage programs. Some of the largest sequestration projects are located in Europe, such as in Norway, Germany, and the Netherlands. Other CCS projects have been implemented in Australia, Canada, and Algeria and sequestration opportunities are being explored in China and India. The Global CCS Institute keeps a database of sequestration projects throughout the world.
A Cap and Trade system is a means to limit the release of CO_2 to the air to curb and reverse climate warming. In an emissions trading system, governments around the world get together and set a global cap on carbon releases and agree on what share of that cap each country will have. Then governments allocate the cap for their country to businesses and utilities in their country. Firms that want to expand, must reduce the CO_2 they release per unit of production or buy carbon credits from farmers or others with credits to sell to expand their cap. That credit can only be used once at a time, so the total cap is not changed. With growth, the value of credits and carbon reducing technologies increases. The trade is in carbon dioxide equivalents so methane for example is more costly per ton than CO_2. The system is based on the principle that industries that exceed their allowed (capped) carbon emissions would pay farmers (or others) for credits earned by adopting carbon sequestering practices, such as no-till. Farmers would be paid by private firms to use carbon sequestering methods; and industries could meet their greenhouse gas reduction targets**.**
Some critics have suggested that carbon credits would be prohibitively expensive. In practice they add about 2% to the cost of an airline ticket or a computer. But trucking costs and electricity from coal might increase in cost by 20%. In 2005, the European Union Greenhouse Gas Emission Trading Scheme (EUGGETS) began operation as the world's first multi-country, cap-and-trade system. According to the European Commission, the EUGGETS will help the EU to achieve its carbon reduction targets under the Kyoto Protocol at a cost of 0.1 % of GDP. Despite unstable beginnings, the system has been a success, opening a door for other countries like Canada to follow.

INDIAN SCENARIO
In India the C emissions from deforestation are estimated to be nearly offset by C sequestration in forests under succession and tree plantations. India has nearly succeeded in stabilizing the area under forests and has adequate forest conservation strategies [17]. Long-term role of crop residue C inputs to soil in SOC sequestration and also the critical value of C inputs for maintenance of SOC across five different rice-based cropping systems [15]. With a large land area and diverse ecoregions, there is a considerable potential of terrestrial/soil carbon sequestration in India. Many workers have pointed out the SOC sequestration and suggested its methods [1, 2, 1-14, 5, 6, 8, 18].
The forestry sector can not only sustain its carbon but also has the potential to absorb carbon from the atmosphere. To meet the ever growing demand, we not only need to sustain our forest biomass but should also aim at increasing it by implementing massive afforestation programmes in the coming years. The ongoing anthropogenic increases in CO_2 in the atmosphere can also be sequestered by increasing the rate of afforestation. The present rate of afforestation in the world is 10.5 Mha per annum. This is only marginal in comparison to the rate of forest degradation and deforestation. [14]. The management systems [7], cropping systems [11, 8] play important role in removing carbon dioxide from the atmosphere.
India's carbon market is one of the fastest growing markets in the world and has already generated approximately 30 million carbon credits, the second highest transacted volumes in the world. The carbon trading market in India is growing faster than even information technology, bio technology and BPO sectors. Nearly 850 projects with an investment of Rs 650,000 million are in the pipeline.
In India various efforts are being made towards carbon sequestration. Department of Science and Technology (DST) has set up the National Program on Carbon Sequestration (NPCS) Research in 2007, with a view to competing with other countries in this area with respect to both pure/applied research and industrial applications. Various other organizations like ONGC, National Aluminium Company (NALCO) are planning to set up

carbon capture units. Indian Institute of Technology Bombay (IITB) has been carrying out a study for Cyanobacteria which can be developed as an excellent microbial cell factory that can harvest solar energy and convert atmospheric CO_2 to useful products. Indian Institute of Petroleum (IIP) has been working on developing new adsorbents for post-combustion CO_2 capture.

A breakthrough in the race to make useful products out of planet-heating CO_2 emissions has been made in southern India. A plant at the industrial port of Tuticorin is capturing CO_2 from its own coal-powered boiler and using it to make baking soda. ONGC has received 121207 *carbon credits* by the United Nations body on Climate Change to its 51 MW wind power project at Bhujin Gujarat. The Shri Pandurang Sahakari Sakhar Karkhana (SSK) from Solapur has earned *carbon credits* (certified emission reduction - CER). Jindal Vijaynagar Steel, Powerguda in Andhra Pradesh, Handia Forest in Madhya Pradesh are some of the examples earning huge through Carbon credits.

CONCLUSION

Carbon sequestration is a vital part of complete and comprehensive strategy for mitigation of climate change by offsetting carbon emissions globally even undoing some of the harm done by previous emission. Measures undertaken to increase carbon sequestration could also be used to conserve soil and reduce erosion. Research to enhance sequestration methods could lead to significantly practical systems which could be implemented globally as early as next twenty years. While not a solution onto themselves for the global climate change problem, these practices could help "buy time" for other methods of sequestration and clean power systems to be researched and rolled out. It would also delay further requirement of dramatic decreases in global emission. Concurrently, we require the development of an understanding of the global carbon cycle which continues to drive global changes and can impact the efficacy of sequestration options in natural systems. While the large scale sequestration of carbon seems more practical than ever as a technological task, we still need to know much more of the long term impact of these systems on the biosphere and its components including ourselves.

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