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CARBON SEQUESTRATION IN THE OCEAN-AN ESCAPE ROUTE

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Abstract. The utilization of fossil fuels is releasing previously carbon stored in the various carbon pools of the earth and increasing the global concentration of Carbon dioxide from an initial 280 parts per million in the 1850s to above 400 parts per million today. This review takes a look at previous works on carbon sequestration; its feasibility, potential and process. Increased carbon emission has disrupted the fragile balance in carbon content between the atmosphere and ocean which took thousands of years to attain. Aftermath of which includes increase global temperatures as well as other environmental problems. It has been projected that from 2025 up-wards; we would have exceeded our carbon budget at our current emission rates. Curtailing fossil fuel utilization alone will not suffice to save the planet unless something more drastic is done. Capturing anthropogenically produced carbon gas and discharging it into the ocean at a depth of 3000m where it sinks into the bottom of the ocean is recommended. Here, the oceans are expected to store about 59 times the carbon gas carrying capacity of the atmosphere. The need to speed up the slow natural process of sequestrating carbon in the ocean depth has never been more expedient. Research is recommended into understanding the oceans as a variegated system of interactions compared to terrestrial ecosystems.

Keywords: carbon, carbon dioxide, sequestration, ocean, atmosphere, depth.

1. Introduction

The earth is a vibrantly changing system that has all its individual parts interconnected. No change occurs in isolation here; a change in one segment affects the normal functioning of the other segments as well. Land, water, air and living organisms are the four major elements subjected to this dynamic inter-play. Most of our interactions like travels, production and basic day–to-day routines take place either on land (lithosphere), air (atmosphere) and water (hydrosphere). The atmosphere is retained over the surface of the earth by the action of earth's gravity and naturally contains about 500 Petagrams (Pg) of gases including nitrogen, oxygen, argon and carbon dioxide among other inert gases (Balasubramanian, 2011). This data is without addition of anthropogenically produced gases like chlorofluorocarbons, halocarbons and other greenhouse gases.

Of great concern among atmospheric gases are carbon dioxide and other carbon infused gases like methane and chlorofluorocarbons. This is because as the foundation of life on our planet, carbon is a major constituent of our bodies; meals, our very civilization itself are all based on carbon. We want carbon and its affiliated products both natural (coal) and man-made

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(premium motor spirit), yet an external cost of utilizing these products is well spiked with what can be referred to as the major problem confronting us today; global environmental alteration. Up until now, natural configuration has saddled land plants and the seas with the task of taking up more than half of the carbon we have released into the environment while around 45 % has remained in the earth's atmosphere though this can be further reduced, nothing less than 20 % of this gas remains in the atmosphere for thousands of years (NASA, 2011).

The global carbon reservoirs have largely being in equilibrium before the unset of modern industrialization. The CO_2 exchange rate between the ocean and the atmosphere were relatively balanced even with the then prevailing large carbon flux exchanges between the atmosphere and the oceans and between the atmosphere and land, there were no net gains or losses from one reservoir to another. Following the industrial revolution however, tones of previously trapped carbon in various forms are now being liberated thus; disrupting the fragile equilibrium between the various carbon reservoirs. Fossil are now the global source of energy and as need for energy source grows, increasing quantity of CO_2 is being discharged into the atmosphere. This increase in atmospheric CO_2 from about 280 to more than 412.5 parts per million (ppm) over the last 271 years is causing noticeable global warming (Dlugokencky, 2020). Aftermaths of this rise in global temperature includes; sea-level rise, increased frequency and intensity of wildfires, floods, droughts, and tropical storms, changes in the amount, timing, and distribution of rain, snow, and run off as well as disturbance of coastal marine and other ecosystems. Another effect of global warming that is not frequently talked about is ocean acidification.The disequilibrium between the major carbon reservoirs has occurred due to the relatively slow rate of carbon assimilation by ocean. Other existing CO_2 uptake mechanisms are insufficient to offset the accelerating pace of emissions related to human activities as they also take time. According to the Union of Concerned Scientists (2020), annual carbon emissions from burning fossil fuels in China are 10.06 Petagram, while in the United States it is about 5.41 Petagram. Whereas annual uptake amounts in the United States is only about 0.5 Petagram, resulting in a net release of about 1.1 Petagram per year.

Furthermore, the World Population Prospect (2019) puts the current global population at around 7 billion and is expected to increase by 2 billion in the next 30 years meaning more resources will be explored particularly fossil fuels; the emission rate of CO_2 is not about to slow down. As the damning consequences of this keeps coming to bear, the world now searches for a way out on how best to salvage this situation. Schemas involving the capture of carbon dioxide and subsequent storage in geological formations, or in marine waters have generated a range of deliberations and considerations. The scale of some of these proposals is such that they will exert impacts of global connotation by their own rights. There is now a strong interest in stabilizing the atmospheric abundance of CO_2 and other Green House Gases so as to curtail the risks of global warming (Kerr, 2007). An overview of the merits/demerits and feasibility of capturing and storing carbon in a various natural vessels particularly in ocean depths is crucial in reaching a logical conclusion on the subject matter.

1.1. Carbon and Carbon dioxide (CO_2)

Carbon is unique in its chemical properties because it forms a number of components superior to the addition of all the other known elements in combination with each other. It forms more compounds than all the other elements combined especially as it is a chief constituents of Green House Gases and is incorporated into every layer of the Earth system (Kelemen, Manning, 2015). Carbon dioxide (CO_2) occurs naturally in the earth's lithosphere, hydrosphere, and atmosphere and is produced via the combustion of fossil fuels or vegetable matter among other processes. During combustion, liberated carbon from the fossil fuels reacts with oxygen in atmosphere to form CO_2. There are other processes that both produce CO_2 and use it up; these processes are in fragile equilibrium (Topham, 2000). Plants and algae utilize CO_2 for photosynthesis during which they release the oxygen we need for respiration. It is naturally stored in the ocean through natural chemical processes as a dissolved gas or eventually as sediments infused with carbon on the seafloor (Eric, Colder, 2008).

An estimated 5.588Pg of CO_2 is bound in the earth's crust in various forms like carbonates of metals like calcium, magnesium and as a constituent of many organic compounds. All igneous rocks emit a mixture of gases under certain conditions of high temperature and pressure, the chief constituent of which are usually carbon dioxide, water and hydrogen. Carbon dioxide is also present in the earth's atmosphere at a level of about 0.03 % by volume. The exact level is not constant as it varies with; the exact location where the sample is taken, the quantity of vegetation present, and the time of day. The total amount of carbon dioxide in the atmosphere is about 2.3276Pg. While that in the seas and oceans also vary widely but average five volumes of gas per ten thousand volumes of water. CO_2 content in all water bodies is about 1.4196Pg according to (Tppham, Susan, 2000).

1.2. Global Atmospheric Carbon Budget

The global carbon budget has to do with the total allowance or carrying capacity that the environment has for carbon. It refers to the mean, variations, and trends in the perturbation of CO_2 in the environment commencing from the beginning of the Industrial Era (Friedlingstein, O'Sullivan and Jones, 2020). It is also referred to as the amount of carbon that we can emit into the atmosphere without causing a two-degree Celsius temperature change (Thomas and Rudiger, 2010).

According to the International Energy Agency's Greenhouse Gas R&D Programme (2007), the world's hydrocarbon reservoirs have a pooled storage capacity of roughly 800Pg of CO_2. While the Inter-Governmental Panel on Climate Change (IPCC) has placed this budget at approximately one thousand Petagram. From 1860 to 2011 we emitted an estimated 515Pg of carbon, leaving around 500Pg left in our budget eight years ago. Present day estimates leaves us with values ranging from 250Pg to 485Pg of carbon before we overshoot our budget and catastrophically format the earth. If our current annual emissions stay constant at 36PgCO_2 (9.8Pg Carbon) then we have only around 25 to 50 years before reaching the tipping point (David, 2018).

1.3. Global Carbon Cycle

Carbon naturally moves or cycles between the various spheres of the earth; from the atmosphere to the biosphere, lithosphere, and hydrosphere over time scales ranging from years to millennia or even geologic time scales; the reason why carbon never diminished or disappears from the earth. Burning of fossil fuels and clearing of forests/vegetation cover have increased the transfer of carbon in the form of CO_2 to the atmosphere. Although some of this anthropogenic CO_2 is removed from the atmosphere by the natural uptake processes in the carbon cycle, the atmosphere still retains most of it which leads to an increase in atmospheric CO_2 concentrations (United State Geological Survey, 2008). Changes in the carbon cycle impact each carbon reservoir, excess carbon in the atmosphere prevents heat from escaping thereby warming the planet and helping plant growth on land while in the ocean, it makes the water increase in acidity (NASA, 2011).

The carbon cycle in the ocean is defined by interactions between physical, chemical and biological processes. These processes are understood in individual terms to varying lengths, but the interactive aspects are subject to extremely large uncertainties yet to be comprehended (Falkowski et al., 2000). Fig. 1 illustrates the various processes leading to the continuous availability of carbon in our world otherwise known as the carbon cycle.

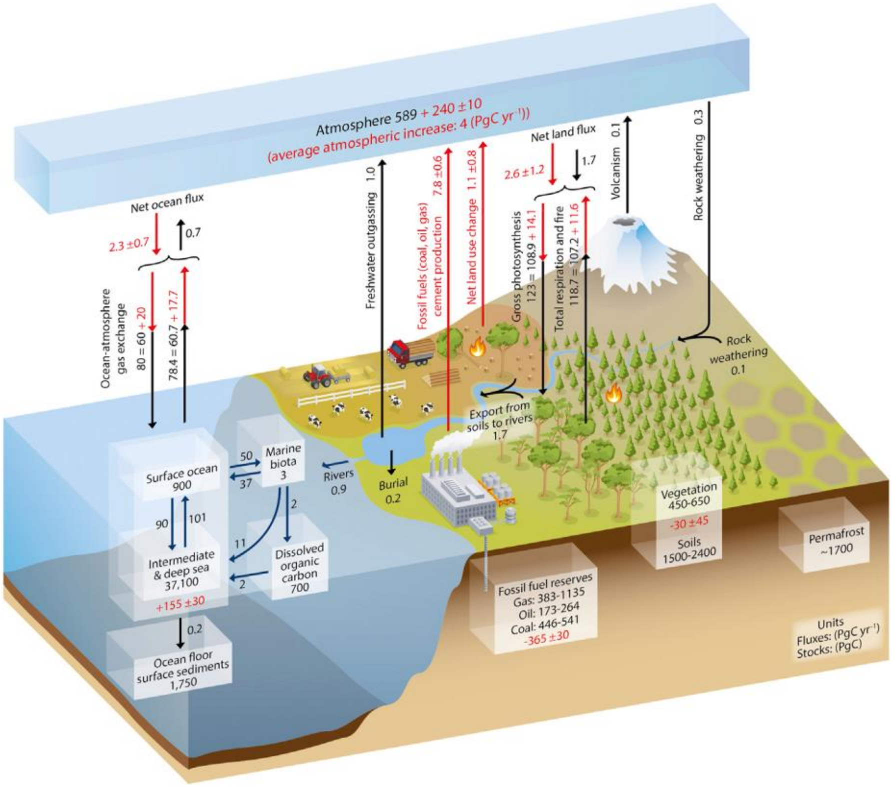

Fig. 1. The Global Carbon Cycle. The numbers are in petagrams of carbon, which is the same as gigatonnes of carbon. Source: Stocker, 2013

2. Helping Nature

Helping ourselves by helping nature puts it succinctly; when nature is stable, our survival is guaranteed. As a dynamic system, nature has always found a way to counter and resolve environmental challenges but in this present scenario, natural processes are unable to keep up with the pace at which environmental problems manifest, nature needs a helping hand. We need to pull CO_2 out of the atmosphere and store it away in places where it will do less harm.

Artificially speeding up natural processes is not peculiar to carbon sequestration alone. Bioremediation of polluted soil/water and afforestation measures are instances where man has come to nature's aid. The goal of deliberate carbon sequestration is to decrease the amount of CO_2 in the atmosphere by capturing and sequestering carbon in the oceans, vegetation, soils, and porous rock formations. Marchetti (1977) made the first submission on storing carbon in ocean depth about 44 years ago. In his proposal, he sought to introduce CO_2 into the outflow of the Mediterranean Sea, where the relatively dense seawater would cause the CO_2 to sink as it entered the Atlantic Ocean.

Our oceans flours are not only rich in mountain ranges that can dwarf Mount Everest; they are also potential earth savers due to their immense carbon storage capacity. Oceans occupy more than 70 percent of our planet, and roughly three-quarters of it has a depth of more than 3.000 meters (NOAA, 2018). This can be explored and used to store excess carbon dioxide released by man into the environment. This opens up a vast amount of storage locations in the deep ocean. Appraisals of the capacity of ocean storage range from 4.000Pg CO_2 to 10,000Pg CO_2 (Bert et al., *2005*). Other natural carbon sink serving similar purpose are terrestrial plants, soil, and marine algae. The oceans absorb 25 percent of the atmospheric CO_2 we emit each year making them one of the largest carbon sinks on the planet (NOAA, 2018).

2.1. Carbon Transfer in the Sea

According to Ormerod, Freund and Smith (2002), transfer of CO_2 in the sea takes place at the air-sea interface and is accelerated when strong winds causes the breaking up of waves and air bubbles are carried along in the wind-mixed layer. The dissolvability of CO_2 in seawater is greater than in fresh water because the alkalinity of sea results in the following equilibrium being pushed to the right:

$CO_2 + H_2O \Leftrightarrow H_2CO_3$ (*carbonic acid)*

$H_2CO_3 \Leftrightarrow H^+ + HCO_3^-$ (*bicarbonate ion*)

$HCO_3 \Leftrightarrow H+ + CO_3^{2-}$ (*carbonate ion*)

In seawater, only 1 % of the CO_2 remains as molecular CO_2 the remainder exists in the form of bicarbonate ion. Dissolved Inorganic Carbon (DIC) is the collective term for all forms of carbon present in the sea with the exception of molecular carbon. Sea surfaces are relatively warmer and so they can hold more CO_2 than the colder waters of the deep ocean.

To this end, the deep waters of the world's oceans are unsaturated and so have enormous under-utilized capacity to dissolve CO_2. This is so because even though the ratio of solubility of CO_2 in these deeper to surface waters is 2:1, the concentration of DIC however is only 12 % higher in deep water. This highlights considerable capacity for storing carbon in deeper ocean water. Furthermore, the high DIC content of the oceans (38.000PgC) would only be slightly affected even if it were to receive all the carbon trapped in known fossil fuel reserves (about 4.000Pg C) as it already contains an estimated 40.000Pg C compared with about 800Pg C in the atmosphere and 2,200Pg C in the land biosphere.

As a result, the amount of carbon that would cause a doubling of the atmospheric concentration would only change the ocean concentration by about 2 %. In addition, default chemical equilibration between the atmosphere and ocean ensures that about 80 % of present day carbon emissions ultimately end in the ocean. In fact, the total dissolved inorganic carbon in the oceans is approximately 59 times that of the atmosphere (Falkowski, 2000). Deliberately discharging CO_2 directly to the ocean would accelerate this slow, natural process, and serve to reduce both peak atmospheric CO_2 concentrations and rate of increase (Adams and Caldeira, 2008).

Another related strategy of sequestration in ocean depth is by enhancing biological sink using nutrients such as iron to inseminate portions of our oceans and stimulating phytoplankton growth in the process. This will increase the rate of biological uptake of CO_2 by phytoplankton which will also be transported to the ocean depth upon death of the organism. The indirect introduction of CO_2 to the ocean from the atmosphere is also handy. Ocean surfaces have been becoming more acidic even before the industrial revolution with a drop in pH of about 0.1 units from an initial surface pH of about 8.2 (Abbasi, Abbasi, 2011).

2.2. Natural Process of Carbon Capture and Sequestration

The gushing in of research on the feasibility of oceanic carbon sequestration plummeted only after scientists uncovered the enormous work being done by the ocean in sequestrating thousands of Petagram of carbon with no engineering or scientific input. Ocean currents naturally circulate surface waters to the deep and bring it back to the surface. This mixing effect is well pronounced near the surface and mostly decreases with depth. For seawater in the deep reaches, it can take between 300 to 1000 years for seawater to go through a complete circulation (Bert et al., 2005). There are two unassisted mechanisms that 'pump' CO_2 accumulated in the atmosphere to deep waters:

I) Solubility Pump

CO_2 is highly soluble in the cold, dense water which in high latitudes, hence it can sink to the bottom of the ocean. 'thermohaline circulation' of seawater is a result of this sinking activity where by cold North Atlantic deep water ladened with CO_2 is 'conveyed' southwards to Antarctica before surfacing in the Indian Ocean and in the Equatorial Pacific. There, CO_2 escapes to the atmosphere again to continue the carbon circle. In the same vein, deep Antarctic waters circulate around Antarctica before resurfacing. The timeframe for the sinking and resurfacing of carbon is roughly around 1000 years.

II) Biological Pump

This natural pumping mechanism is powered by biota in the ocean. Photosynthesis by oceanic plants like phytoplankton in the ocean utilizes the CO_2 dissolved in the surface waters. The rate of phytoplankton growth and reproduction is determined by nutrient availability. Their size range is from 1mm to 5mm in size and like in a typical food chain, phytoplankton occupy the first level and are rapidly grazed upon by zooplankton, which are in turn consumed by larger marine animals such as fish (Jiao et al., 2010).

Over 70 % of this organic matter is recycled in surface waters but the balance is transported to the deep ocean waters, majorly by settling down or sedimentation of particulate organic matter. The biological pump therefore transfers CO_2 from the surface waters and effectively domiciles part of it in the deep ocean (Jiao *et al*., 2010). Most of this organic material is re-mineralized by bacteria back to CO_2, ultimately returning to the surface waters. Again the time taken for the sequestered CO_2 to resurface from the deep ocean can reach millennia. Considering the large time scale for these natural carbon uptake mechanisms to complete their circle, we can say that most of humanity will be wiped out by the aftermaths of global warming before a natural sequestration circle completes.

2.3. Carbon Pools of the Earth

According to Haigh (2017), Carbon dioxide has been in existence on our planet since the earth's formation following it's consolidated from a chunk of hot gases and subsequent arrangement from the scattering of a gigantic star around five billion years. The earth then mostly consisted of nitrogen, CO_2 and water fume, which leaked through cracks in the formed solid surfaces in the same fashion various components will escape from volcanic emissions in our present day.

As the planet continued cooling, a portion of the water fume consolidated out to frame seas and they broke down fragments of the CO_2 that was present in the air in large amounts. The only living things on the earth then were those microorganisms that could survive in this premier environment. Photosynthetic plant emerged about 2.5 billion years ago. These plants flourished in their ability to photosynthesize, making glucose and oxygen from CO_2 and water in the presence of light from the Sun.

This extraordinarily configured the earth's atmosphere via the consumption of CO_2 as following the evolution of life which brought down the ratio of molecules of CO_2 present in every one million molecules of air to 3:10. By this activity, excess carbon dioxide was sequestered in what will now be known as the "Biotic Carbon Pool". Though presently the smallest global carbon pool in terms of capacity among the global carbon pools, it has the capacity of 560Pg. Other carbon pools with their carbon carrying capacities also exist. Carbon temporarily resides in these pools were going through its cycle; these pools vary in their storage capacities and composition. With an estimated capacity of 40.000Pg increasing at the rate of 2.3Pg C per year the oceanic pool towers above them all (Lal, 2008).

Following the oceanic pool is the geological pool comprising fossil fuels with a storage capacity of 4.130Pg of which 85 % is coal, 5.5 % is oil and 3.3 % is gas. Established reserves of fossil fuel in this pool include 678Pg of coal (3.2Pg per year of production), 146Pg of oil (3.6Pg per year of production) and 98Pg of natural gas (1.5Pg per year of production)**.** Currently, utilization of coal and oil account for approximately 40 % of global CO_2 emissions (Schrag, 2007). Thus, the geological pool is steadily receding at a rate of 7.0Pg C per year through fossil fuel exploration and exploitation.

The IPCC foresees a doubling of the atmospheric concentration of CO_2 in the next 100 years should our fossil usage and CO_2 emission rates continue unchecked (Albritton and Dokken, 2001). The third largest pool is pedologic estimated at 2500Pg to 1m depth. Two distinct sup-pools within this pool are: Soil Organic Carbon (SOC) pool estimated at 1550Pg and Soil Inorganic Carbon (SIC) pool at 950Pg (Batjes, 1996). The SOC pool includes highly active humus and relatively inert charcoal carbon (Schnitzer, 1991). The SIC pool includes elemental carbon and carbonate minerals such as calcite, dolomite and gypsum, and comprises primary and secondary carbonates.

The fourth largest pool is the atmospheric pool comprising 760Pg of CO_2–C, and increasing at the rate of 3.5Pg C per year (yr^{-1}) or 0.46 % yr^{-1}. The pedologic and biotic C pools together are called the terrestrial C pool estimated at approximately 3060Pg. The atmospheric pool is also connected to the oceanic pool which absorbs 92.3Pg $yr^{-1}$and releases 90Pg $yr^{-1}$with a net positive balance of 2.3Pg C yr^{-1}. The oceanic pool would have absorbed approximately 5Pg C yr^{-1} by the year 2100 (Orr et al., 2021). On the scales of millennia, the oceans determine the atmospheric CO_2 concentration, not the other way round (Falkowski et al., 2020).

2.4. Oceanic Carbon Sequestration

According to Flux and Year (2008), carbon sequestration describes any natural or deliberate process by which CO_2 is either removed from the atmosphere or diverted from point source of emission and stored in the ocean, terrestrial environments and geologic formations towards slowing down the increasing rate of CO_2 emission into the atmosphere. Other schemas for removing CO_2 from the atmosphere includes; reducing the global energy use, developing low and no-carbon fuel. This idea of capturing CO_2 from the air and then transporting and storing it in a manmade ‘sink’ that is separated from the atmosphere is referred to as carbon capture and sequestration/storage (David, 2018). Fig. 2 shows some techniques in carbon sequestration among which are iron fertilization, cloud seeding, pumping CO_2 into the ocean, as well as adding chemicals to save the ozone.

Wide scale adoption of ocean storage is viewed as escape route from the eminent transient high peak of atmospheric CO_2 predicted for the next few centuries that will accompany projected future emissions (IPCC, 1996). There are several ways of utilizing natural carbon reservoirs to reduce the impact of anthropogenic CO_2 emissions into the atmosphere. Currently, however, it is the atmospheric reservoir that is receiving the full brunt of fossil fuel CO_2 emissions, triggering anxieties about climate change. The idea of CO_2 mineralization in oceans at the Petagram scale is attractive because the reaction $CO_2 + H_2O \Leftrightarrow H^+ + HCO_3$ is exothermic and hence does not require energy input (Majumdar, Deutch, 2018).

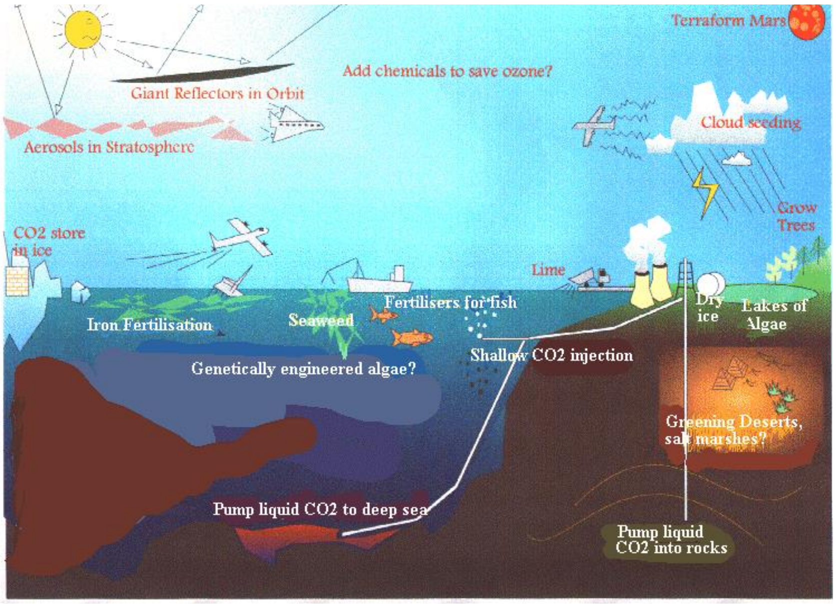

Fig. 2. Schematic representation of various proposals which have been made to mitigate anthropogenic climate change through planetary engineering projects. Source: Matthews 1996

3. Major Arguments about Oceanic Carbon Sequestration

The general idea of sequestrating CO_2 in ocean depths is a noble quest with a lot of promises and potentials yet to be verified. This concept however has not settled down well with individuals of varying viewpoints. There are those who express their reservations regarding the idea certain via questions and arguments which mostly stems from the absent of on-going long term CO_2 direct-injection experiment in the ocean which creates a knowledge gap on the following issues.

Carbon dioxide is constantly exchanged between the ocean and atmosphere. Each year the ocean and atmosphere exchange about 350PgCO_2, with a net ocean uptake currently of about 8PgCO_2. This raises questions regarding the effectiveness of ocean sequestration in terms of keeping the CO_2 permanently out of the atmosphere (John, Steved, 2009).

I) Secondly, people argue that in future, with or without human intervention, the equilibrium that will be attained in CO_2 concentration in the ocean and that of the atmosphere will still be the same. Such postulates are premeditated on the fact that it is possible to capture and transport CO_2 emitted from most of the world's power stations for injection into deep water (GESAMP, 1997).

II) Thirdly, according to David (2018), it seems counter-intuitive to put more CO_2 into oceans as they are already becoming more acidic due to excess CO_2 residing in it.

III) The question of whether ocean carbon storage constitutes a regulated activity or not under the various sustainable environmental conventions and protocols (Johnston and Santillo, 2002).

Notwithstanding the above arguments, there are those who have welcomed the idea and who think that the idea of carbon sequestration in the ocean makes logical sense. To be objective, this is not a solution to climate change, but perhaps a way to avoid the worst of it (David, 2018).

3.1. Methods of Injecting Carbon into the Ocean

There are three general methods that could be used to directly inject carbon dioxide into the ocean for storage as shown in Figure 3 (David, 2018). First, would involve running a pipe from shore to the ocean depths. This pipe will serve to receive a stream of carbon dioxide from a capture or intermediary storage facility on the coast and then direct it off-shore for long-term storage. In the dispersal by ship method, CO_2 stored on board the vessel would be ejected at great depths using a long hose or pipe towed behind the vessel, promoting rapid diffusion of the CO_2 into seawater. The third method would be to use a stationary vessel or platform to inject CO_2 to a fixed location at or near the ocean bottom (Kling et al., 1994; Clarke, 2001).

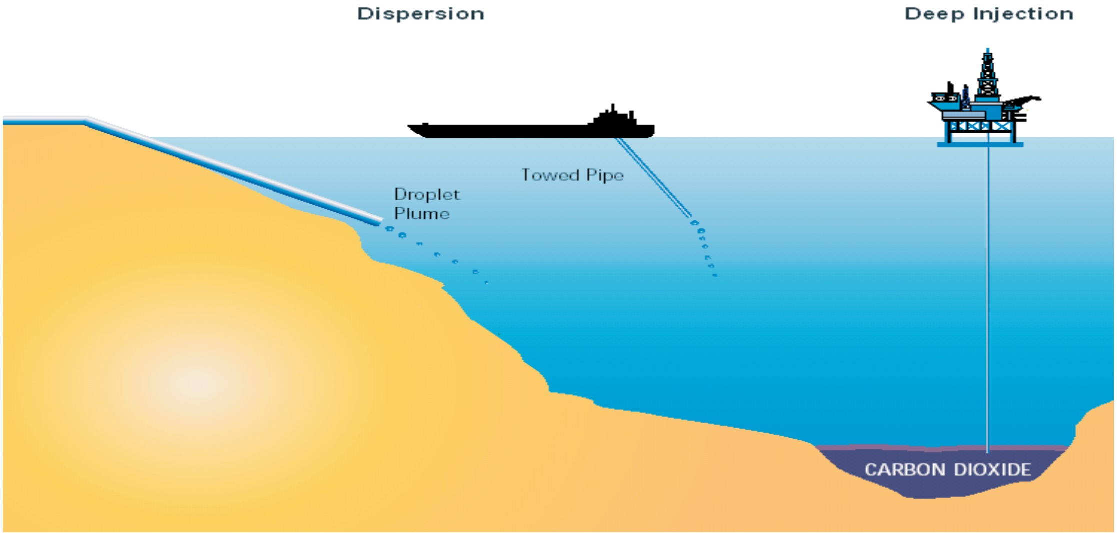

Fig. 3. This illustrates methods of dispersing CO_2 and injecting liquid at depth. Source+: Ormerod, Freund and Smith, 2002

3.2. Process of Carbon Sequestration in the Ocean

All scenarios involving the capture and storage of carbon dioxide either in ocean systems or geological formations have in common the capture phase of operations followed by liquefaction and then transport (Department of Trade and Industry, 2000). At normal ocean pressures and temperatures, pure CO_2 would be a gas above a depth of 400–500m and a liquid below same depth. Liquid CO_2 is more compressible than seawater and would be positively buoyant down to about 3000m, but negatively buoyant below that depth. At about 3700m, the liquid becomes negatively buoyant compared to seawater saturated with CO_2. In seawater CO_2 systems, CO_2 hydrate (CO_2 _ nH_2O, n ~5.75) can form below 400m depth depending on the relative compositions of CO_2 and H_2O. CO_2 hydrate is a solid with a density about 10 % greater than that of seawater (Herzog, 1998).

The concept of a CO_2 lake is based on a quest to minimize leakage to the atmosphere and risk to biota. Successful sequestration of CO_2 in the ocean depends on its phase state and the depth at which it is injected. Since pressure increases with depth; depending on pressure and temperature, carbon dioxide can exist as a gas, liquid, solid, or solid hydrate. By technically injecting anthropogenic CO_2 into the deep ocean, the surface-to-deep mixing timescale of 300-1000 is effectively circumvented. Thus, increasing the effectiveness and diminishing the environmental implications of intentional storage of carbon dioxide in the ocean (Adams, Caldeira, 2008).

3.3. Legal Implications

On the basis of available data, it appears that the oceans and saline aquifers present the greatest opportunities for storage of anthropogenically derived CO_2. The advocates of such global engineering schemes assert that such approaches resonates with the United Nations Framework Convention on Climate Change (UNFCC) which "specifically" mentions the need for using sinks and reservoirs as one module of a more comprehensive collection of strategies for reducing greenhouse gas emissions (Adams et al., 2002). It has however cautioned concerned parties to use these sinks in a sustainable manner.

Despite the seeming endorsement of the usage of oceans and saline aquifers as CO_2 sinks by most global parties, there exist some legal mechanisms which specifically impinge upon this programme. On an international basis, certain conventions like the London Convention (1972) prohibit the dumping of industrial waste at sea or in sub-sea bed formations. While the OSPAR Convention (1992) reinforces and extends the provisions of the London Convention within like the North East Atlantic area (Paul and Santillo, 2002). The London Convention, 1996 protocol permits dumping only 'approved' substances from ships or platforms. Then, the United Nations Convention on the Law of the Sea places an obligation on coastal states to monitor discharges from pipelines inside their areas of jurisdiction (Economic Exclusion Zone). Moreover, a stern application of the 'precautionary principle' prevents an environmental option whose potential hazards haven't being established from been adopted. This further places constraint on CO_2 sequestration in the ocean, which is not unrelated to the complexity of ocean ecology (Heinze et al., 2015).

3.3. Compromise

CO_2 constitutes an industrial waste which needs to be resolved in the shortest possible time. There are understandable reservations concerning the prospect of using the oceans to store waste materials. Dumping hazardous substances in the ocean, such as nuclear waste has been banned. But using the oceans to sequester more CO_2 is a different case entirely because even though CO_2 is a waste, the oceans has since be sequestrating it long before the industrial revolution and already holds vast quantities of CO_2. In short, what is being proposed with ocean sequestration of CO_2 is merely speeding up of an already existing natural process which has even far reaching implication for man and the environment (Ormerod, Freund, 2002; Savacool, 2008)

3.4. Engineering Uncertainties

According to the National Academy of Engineering and National Research Council (2003), it is now almost 40 years since we made our first measurements of carbon dioxide in seawater, and the knowledge has changed immensely within this time. The deep ocean is not well understood in fact according to NOAA (2018) 80 percent the ocean floor remains unmapped, unobserved, and unexplored.

For the most part, while the technical feasibilities of sequestrating carbon in the ocean have been widely explored, we cannot say same for their ecological implications. Interference in oceanic microbiological processes and ruining of benthic ecosystems, including restricted biomass is widely viewed as having great potential of incurring serious impacts. Furthermore, the impacts of any CO_2 leakage to surface need to be considered too (Cowen *et al.*, 2003). A known referent is the instance of Lake Nyos, a volcanic crater lake in Cameroon, Africa which out gassed large quantities of carbon dioxide resulting in 1.700 human mortalities and loss of livestock up to 25km from the crater (Kling et al., 1994; Clarke, 2001).

More CO_2 in the ocean will almost certainly lead to a lower pH in various amounts and specific locations. A sharp decrease in pH creates havoc for marine creatures. Carbon dioxide in seawater leads not only to the formation of carbonic acid but also to usurping of the carbonate ions present in marine organisms such as lobsters, phytoplankton, and corals. These organisms rely on carbonate ions to form their exoskeletons and these protective shells are fundamental to their survival (David, 2018).

3.5. Ecological Effects

Recent findings have indicated that diverse micro-flora exists in the ocean basin crust consisting of organisms linked with known nitrate and sulphate reducers along with heterotrophic organisms. The general ecological roles of these deep microbial communities are yet to be established and are thus a subject of notable debate (Kerr, 2007). Impacts upon these fragile ecosystems due to CO_2 storage could be substantial but the magnitude of the consequences fundamentally unknown. The use of very small organisms allows resolution of physical impacts over only small areas. It is however not clear on how this technique would translate to the much bigger areas likely to be impacted by deep ocean storage of CO_2. Furthermore, the overall lack of general baseline information on deep-sea ecosystems and their likely responses to perturbation, along with the difficulties inherent in working with such systems, present a highly important conglomeration of uncertainty and indeterminacy (Roberts, 2002).

The formation carbonic acid; a precursor of acidification is not the only aftermath of storing carbon dioxide in seawater. Another effect is the usurping of the carbonate ions present in marine organisms such as lobsters, phytoplankton, and corals. These organisms rely on carbonate ions to form their exoskeletons and shells that are fundamental to their continued existence. Some of these animals form the footing of the marine food web; their collapse could have multiplier effects of dire consequences (David, 2018).

4. Conclusion

This review explored the gains and pains of sequestrating carbon in the ocean of which the benefits outweighs the harm both in the short and long-run. The call for carbon sequestration in the ocean depth couldn't be more expedient because of the increasing rates of population growth and fossil fuel utilization as well as the damning effects it poses to our planet and humanity. The feasibility of ocean storage as a greenhouse gas extenuation option hinges on social, political, regulatory as well as technological considerations. In view of public precaution toward the ocean, the strategy will require that a conglomeration of all parties be included in ongoing research and discuss. Though some laws and conventions seem to kick against sequestrating carbon in the ocean, the United Nations Framework Convention on Climate Change (1992) gives this proposal its right of way. Direct injection of Carbon dioxide into the deep ocean has the possibility of curtailing the adverse impacts of global warming presently being experienced in different parts of the globe though with yet to be ascertained alteration to aquatic life. Looking into the future however, a sustainable solution to the problem of climate change will ultimately make a demand on us all too to drastically reduce usage of products that release CO_2 into the environment. The seemingly limitedness of ocean body ecologies and bio-data provides limitless opportunities for research in the area oceanic carbon sequestration which can be explored to provide location and organism specific outcomes of this proposal

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