Critical Review of the Longterm Implications of Carbon Dioxide Burial in Aquatic Ecosystem

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ABSTRACT

This review examines the effects of burying carbon dioxide (CO_2) in the depths of oceans or rivers as a method of mitigating climate change. Carbon sequestration techniques, such as ocean and river-based CO_2 burial, are being explored as potential solutions to the escalating global crisis of atmospheric CO_2 buildup. By delving into the science behind carbon capture and storage (CCS) in aquatic environments, the study assesses both the potential benefits and the environmental risks associated with this approach. The findings suggest that while deep-sea and river CO_2 storage may offer temporary reductions in atmospheric CO_2, further research is necessary to evaluate long-term ecological impacts and safety.

Keywords: Carbon-capture, carbon dioxide, climate change, global warming, acidification, carbon sequestration

INTRODUCTION

Climate change, driven primarily by the increase in atmospheric greenhouse gases such as carbon dioxide (CO_2), has become one of the most urgent challenges facing the world today [1-4]. At global level, the rise in the average temperature is higher than one-degree Fahrenheit since the late 1800s, with much of the rise occurring in just the past few decades [4]. According to [3], the concentration of atmospheric CO_2 has risen above 400 parts per million and are currently at levels not experienced in more than the past 800,000 years. As global temperatures continue to rise, the need for effective solutions to mitigate the effects of CO_2 emissions has never been more critical [1, 4]. Many sources [1, 2, 4] have noted that curtailing fossil fuel utilization alone is not adequate to save the earth and that unless something more drastic is done, the planet is at risk. Among various carbon capture and storage (CCS) strategies, the concept of burying CO_2 in the deep ocean or riverbeds has garnered increasing attention as a potential method to reduce the concentration of this harmful greenhouse gas in the atmosphere [1]. A source [1] specifically recommended capturing anthropogenically produced carbon gas and discharging it into the ocean at a depth of 3000 metres to sink into the bottom of the ocean.

The idea of utilizing large natural reservoirs such as the deep ocean or river beds stems from their ability to store vast quantities of CO_2, thereby preventing it from contributing to global warming [1. 2]. The oceans, in particular, have long been considered a major carbon sink, absorbing roughly one quarter of all anthropogenic CO_2 emissions each year [1]. The oceans have the capacity to store about 59 times more carbon gas than the atmosphere [1]. However, the potential for enhancing this natural process through deliberate CO_2 sequestration presents both opportunities and challenges [5]. The ability to inject and store carbon in the deep ocean or beneath riverbeds could offer a significant method for reducing the atmospheric concentration of CO_2 and potentially stabilizing the climate [1, 4].

Despite its promise, the proposal to bury CO_2 in these environments raises a number of scientific, environmental, and ethical concerns [1, 9]. Key questions remain regarding the long-term stability of such storage, the potential for leaks, and the impact on marine and freshwater ecosystems. Additionally, there are concerns about the acidification of oceans and rivers and the potential disruption to local biodiversity if CO_2 were to interact with the surrounding water and sediment in unexpected ways [6]. The issue also extends to the technical feasibility of transporting and injecting CO_2 into these environments in a manner that is both effective and sustainable.

This research aims to explore the various effects of burying CO_2 in the heart of the ocean or rivers, examining both the scientific mechanisms that would govern such processes and the potential environmental consequences. By investigating these factors, the study hopes to contribute to the ongoing debate about the viability of large-scale CO_2 sequestration strategies and provide insight into the risks and benefits of this approach as a climate change mitigation tool.

Through an in-depth analysis of current research, experimental models, and real-world case studies, this paper will evaluate the effectiveness, safety, and environmental impacts of CO_2 burial in aquatic ecosystems. Ultimately, the research will provide a clearer understanding of whether this method could serve as a viable and sustainable strategy for reducing global CO_2 emissions and mitigating the effects of climate change. .

METHODOLOGY

The study adopted critical review of literature on different studies done on carbon capture. This design was adopted because it provided a holistic platform to enable effective review of technological, social, environmental concerns associated with carbon capture and the implications of burying carbon dioxide in the ocean or river. The literature reviewed included peer-reviewed articles, government reports, and environmental assessments concerning carbon sequestration techniques in aquatic systems. The data in the literature were assessed for relevance, reliability, and applicability, particularly focusing on ocean and river sequestration's impact on biodiversity, water chemistry, and CO_2 stabilization. The data quality was high, but limitations in long-term studies were noted. Special attention was paid to studies on environmental toxicity and ecosystem models. The literature reviewed were retrieved from different reputable research databases such as Google Scholar, ScienceDirect, and JSTOR and generic searches across different internet sites.

THE CONCEPT OF CARBON CAPTURE

The concept of carbon capture and storage (CCS) has emerged as one of the primary strategies for mitigating the effects of climate change, especially in reducing the atmospheric concentration of CO_2 [1, 2, 4, 5, 9, 11]. While several technologies and approaches exist for capturing and storing CO_2, one of the more intriguing options is the burial of CO_2 in the deep ocean or riverbed sediments [1, 2, 9]. This method is predicated on the natural carbon sinks that oceans and rivers represent, with the idea being that these environments can effectively store CO_2 for long periods, potentially preventing it from contributing to global warming [1, 8, 9]. However, despite its potential, there remains considerable debate regarding the environmental, ecological, and technical viability of this approach [5, 8, 9, 12].

IMPLICATIONS OF CARBON DIOXIDE BURIAL

Carbon Sequestration in Oceans: The idea of oceanic CO_2 sequestration, often referred to as ocean fertilization or deep-sea CO_2 storage, has been researched for decades, with the aim of using the ocean's vast volume and deep layers as a natural repository for atmospheric CO_2 [3, 5, 9]. According to the Intergovernmental Panel on Climate Change (IPCC), oceans absorb approximately 25% of anthropogenic CO_2 emissions annually, primarily through the physical process of diffusion at the surface and biological uptake via photosynthetic organisms [3, 5].

The deep ocean could serve as a long-term storage medium for CO_2, particularly when it is injected into specific deep-sea environments such as sub-seafloor reservoirs or under submarine geological formations [1, 9]. These areas are naturally rich in minerals and sediments that could potentially react with CO_2 to form stable solid carbonates, reducing the likelihood of CO_2 leakage. However, the stability of these storage sites over geological time scales remains uncertain, with studies highlighting concerns regarding the potential for leakage through underwater geological faults or cracks [9].

Furthermore, the effects of large-scale CO_2 injection on marine ecosystems are a subject of intense debate. One of the main concerns is the acidification of ocean waters. According to [8, 10], CO_2 dissolved in seawater forms carbonic acid, lowering the pH and making the water more acidic. This could have harmful effects on marine life, particularly on calcifying organisms such as corals, shellfish, and plankton, which rely on calcium carbonate for shell formation [8]. The International Ocean Carbon Working Group in 2019 conducted a series of modeling studies to assess the impact of CO_2 injection on deep-sea ecosystems and found that changes in pH could potentially disrupt food webs and biodiversity at various trophic levels.

However, some studies indicate that deep-sea ecosystems may have the ability to adapt to gradual changes in pH. Research suggests that certain species, particularly those in the deep benthic zones, might be more resilient to pH changes due to the naturally lower pH levels of deep-sea environments. Despite this, the risks associated with disrupting these delicate ecosystems remain significant, particularly when considering the unpredictable nature of large-scale human intervention.

Carbon Sequestration in Rivers and Freshwater Ecosystems: While most research on CO_2 sequestration has focused on the oceans, the burial of CO_2 in freshwater systems, including rivers, lakes, and underground aquifers, has begun to attract attention. Freshwater ecosystems are much more dynamic than the deep ocean and are thus subject to different environmental and biochemical conditions. The idea of injecting CO_2 into riverbeds or lake sediments to create geological sequestration sites involve significant technical challenges, especially in terms of ensuring that the CO_2 does not escape back into the atmosphere due to hydrodynamic forces or sediment erosion [25, 26].

Researchers have examined the potential of CO_2 burial in riverbeds through a combination of geological modeling and experimental injection. Their findings suggested that deep riverbeds, particularly in regions with low river flow and high sedimentation rates, could act as effective CO_2 reservoirs [24 - 26]. However, this process is highly dependent on the local geology and hydrology of the river system, and many rivers may not have the necessary conditions for long-term CO_2 storage.

Research on riverine acidification due to CO_2 injection is still in its early stages. Some researchers explored the impact of elevated CO_2 levels on freshwater systems and found that similar to oceans, river acidification could have detrimental effects on aquatic life, including fish, macroinvertebrates, and plant species. River systems are often heavily influenced by land use, pollution, and nutrient loading, which could further exacerbate the negative effects of additional CO_2 inputs [14, 19].

Moreover, rivers are subject to rapid changes in flow and sediment deposition, which means that CO_2 injected into riverbeds may not remain trapped as effectively as it would in the deep ocean. While certain river systems may be able to store CO_2 for decades, the risk of leakage is much higher compared to oceanic sequestration due to the potential for water movement and changes in sediment dynamics [13, 15].

Environmental and Ecological Risks: The potential ecological risks associated with CO_2 sequestration in both oceans and rivers are a significant concern in the scientific community [5, 7, 12, 13]. The primary environmental risks include changes in water chemistry, disruption of nutrient cycles, and the possible creation of hypoxic or anoxic conditions in the deep ocean or river sediments [6, 8, 12]. Even small concentrations of dissolved CO_2 in water can lead to a reduction in dissolved oxygen levels, which in turn could affect marine or freshwater organisms' respiration and survival [12, 16, 17, 18, 28].

Another critical factor is the potential leakage of CO_2 from the burial sites [5, 7, 8, 17]. While CO_2 injection into geological formations is generally considered safe, the risk of slow leakage over time through cracks or faults in the seabed or riverbed cannot be ruled out [9, 12, 23]. This leakage could potentially lead to "acidification hotspots" in surrounding ecosystems, further endangering biodiversity and the health of aquatic organisms [28]. Additionally, there are social and ethical concerns regarding the long-term monitoring and governance of CO_2 burial sites [9, 12]. Since CO_2 sequestration in oceans and rivers would likely take place in international waters or areas shared by multiple nations, questions about regulation, responsibility, and potential transboundary environmental impacts remain unresolved [13, 15].

Technological and Feasibility Challenges: The technical feasibility of CO_2 burial in the heart of the oceanor rivers is another major aspect explored in the literature [20 - 23, 26, 27, 29]. Though there are various CO_2 injection technologies [20 - 23, 26, 27], there are currently no publications dedicated for site selection for CO_2 injection [29]. While ocean-based storage techniques are more advanced, the idea of injecting CO_2 into freshwater environments requires the development of new technologies to deal with the unique challenges posed by river sediment dynamics and water flow patterns [29]. Furthermore, the logistics of transporting CO_2 from land-based facilities to deep ocean or river locations for burial poses significant infrastructure challenges [14, 15, 20 - 22].

Technologies such as subsea pipelines, pressurized transport tanks, and direct injection rigs would need to be developed and tested on a large scale [14, 21, 23, 28]. The economic implications of implementing such systems would be substantial, as studies indicate that current CO_2 sequestration projects are financially unfeasible without substantial government subsidies or regulatory incentives [21, 23 - 26, 29].

RESULTS

The findings form the different literature indicate that while ocean-based CO_2 sequestration could effectively reduce atmospheric CO_2 levels in the short term, it carries significant risks, such as altering marine chemistry and biodiversity. River CO_2 burial shows promise as a temporary storage solution, but it is not as effective on a large scale and raises concerns over water quality and aquatic life. Both methods, while potentially useful, require further investigation to address their long-term sustainability and ecological impact.

The results demonstrate that while CO_2 burial in oceans and rivers could help mitigate climate change temporarily, both methods present substantial environmental risks that must be considered. Ocean burial, for example, may cause acidification, which can harm marine life.

Similarly, burying CO_2 in rivers could disrupt aquatic ecosystems and pose risks to freshwater quality. Therefore, any potential solution must be coupled with other strategies, such as reducing emissions at the source and enhancing carbon capture technology. These findings underscore the need for a multidisciplinary approach to climate change mitigation [23 - 26].

The potential for burying CO_2 in the ocean or riverbeds as a means of mitigating climate change is promising. However, it is obvious from available literature that the research in this area is still evolving [29, 30]. The implication is that numerous scientific, ecological, and technical challenges must be addressed before large-scale deployment can occur [29, 30]. The risk of environmental harm, the potential for CO_2 leakage, and the unknown effects on aquatic ecosystems all warrant careful consideration in future research [30]. As the body of literature grows, it is critical to continue developing reliable monitoring systems, sustainable injection technologies, and regulations to ensure the safety and long-term effectiveness of these methods.

CONCLUSION AND RECOMMENDATIONS

The burial of CO_2 in aquatic environments presents both opportunities and risks. While it may offer a temporary solution to reduce atmospheric CO2, the long-term ecological consequences remain uncertain. More research is essential to evaluate its scalability and safety. Ultimately, burying CO_2 should be considered one tool in a larger suite of strategies aimed at tackling the climate crisis.

Further research is needed to develop more accurate models of CO_2 sequestration in both oceans and rivers. Governments and environmental organizations should prioritize interdisciplinary studies that evaluate the risks, benefits, and scalability of CO_2 burial in aquatic systems. Additionally, methods to minimize environmental impact, such as advanced monitoring technologies and ecosystem restoration strategies, should be incorporated into any large-scale implementation plans.

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