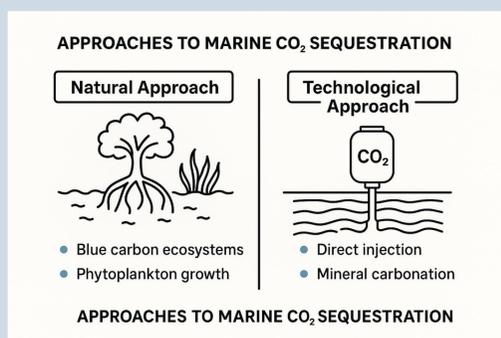


Carbon Sequestration Techniques in Marine Environments

To meet growing energy demands while reducing atmospheric CO₂, innovative carbon capture and storage technologies are essential. Three promising marine-based methods include:



Source: Created by Ance Erdmane, *Simplified conceptual comparison of natural and technological approaches to marine CO₂ sequestration*, 2025. This diagram provides a visual summary of marine CO₂ storage strategies.

- **Deep-Sea Injection:** CO₂ injected into deep-sea sediments (>3000 m) can remain securely stored for millennia due to high-pressure conditions and hydrate formation. Field studies suggest this method could offer long-term, low-maintenance storage with minimal ecological disturbance.
- **Mineral Carbonation:** CO₂ reacts with alkaline earth metals in basaltic rocks to form stable carbonate minerals. The CarbFix project in Iceland demonstrated that 95% of injected CO₂ can be mineralized within two years, making it a highly effective storage option.
- **Phytoplankton Enhancement:** Techniques like iron fertilization aim to stimulate phytoplankton growth, increasing CO₂ uptake via photosynthesis. While nature-based and scalable, this method carries ecological risks and requires careful oversight.

Introduction

The escalating atmospheric CO₂ levels driven by human activities call for innovative climate mitigation strategies.

Marine-based carbon sequestration, especially through "blue carbon" ecosystems such as seagrass meadows, mangroves, and tidal marshes, offers a powerful nature-based solution.

In parallel, engineered techniques—such as deep-sea CO₂ injection and mineral carbonation—are being explored to boost oceanic carbon storage capacity.

Protecting and restoring these ecosystems is essential for maximizing their role in climate regulation.

Conclusions

Marine CO₂ sequestration presents a multifaceted solution to mitigate atmospheric CO₂ levels.

While natural processes offer sustainable and ecologically harmonious methods, engineered techniques provide scalability and permanence.

Integrating these approaches necessitates addressing technological, regulatory, and ethical challenges.

Collaborative efforts among scientists, policymakers, and stakeholders are crucial to harness the full potential of marine-based carbon sequestration in combating climate change.

Methodology

A systematic literature review was conducted to explore innovative marine CO₂ sequestration strategies. Using databases like Web of Science, Scopus, and Google Scholar, we targeted peer-reviewed studies and reports published since 2000.

Keywords included "blue carbon," "marine CO₂ capture," and "mineral carbonation." Reference lists were also reviewed to expand the dataset.

This comprehensive method ensured a robust foundation for analyzing techniques such as deep-sea basalt injection and seaweed-based carbon uptake.

Key Findings / Policy Implications

Marine-based CO₂ sequestration offers promising climate mitigation potential.

Certain deep-sea geological formations have demonstrated potential for long-term, stable CO₂ storage with minimal ecological risk.

The conservation and restoration of blue carbon ecosystems are also critical, yet underutilized strategies.

Expanding research and closing knowledge gaps, especially on seabed carbon storage, is essential for informed climate governance.