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Beyond Photosynthesis: The Rise of Dark Oxygen in the Ocean Abyss

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ABSTRACT

Scientists have recently identified an unexpected process producing oxygen in the deep ocean, termed 'dark oxygen.' This discovery is significant as it provides a new understanding of marine ecosystems and potential oxygen sources in areas where photosynthesis cannot occur. The phenomenon was observed in the abyssal zone, particularly in the Clarion-Clipperton Zone, a region noted for its high concentration of polymetallic nodules. One hypothesis suggests that these nodules may generate oxygen by splitting water molecules through electric charge transport. However, the exact mechanism remains unclear. This finding has implications for deep-sea mining, as the removal of polymetallic nodules could harm ecosystems that depend on dark oxygen. India is among the countries pursuing deep-sea mining opportunities, highlighting the importance of balancing resource extraction with environmental conservation.

INTRODUCTION

Oxygen production in the ocean has traditionally been associated with photosynthetic organisms in the sunlit upper layers, where sunlight enables these organisms to convert carbon dioxide and water into oxygen and glucose. This process sustains much of the marine life by supplying essential oxygen. However, recent discoveries have challenged this understanding by revealing the presence of an unexpected increase in oxygen concentrations in the abyssal zone (Sweetman *et al*., 2024).

Researchers have termed this phenomenon 'dark oxygen,' referring to a novel oxygen production process independent of light. The discovery of dark oxygen suggests the existence of unknown biochemical or geophysical mechanisms and previously uncharted ecosystems capable of supporting marine life in extreme conditions. This breakthrough highlights the complexity and dynamism of deep-sea environments, which remain among the least explored and understood regions of the planet (Sweetman *et al*., 2024). The findings have opened new avenues for scientific inquiry into the processes sustaining life in the deep ocean and their implications for global ecological and climate systems.

Compliances and Suppositions

The presence of dark oxygen was linked to the Clarion-Clipperton Zone (CCZ), off the west coast of Mexico. This region, notable for its abundance of polymetallic nodules, displayed localized increases in oxygen concentration (International Seabed Authority, 2023). These nodules, composed of iron, manganese hydroxides, and rock, are hypothesized to play a part in oxygen production. One potential explanation is that the nodules transport electric charges capable of splitting water molecules to release oxygen. However, the energy source driving this process remains undetermined (Sweetman *et al*., 2024).

Environmental Implications

The discovery of dark oxygen highlights the ecological significance of deep-ocean environments and raises concerns about the impacts of human activities like deep-ocean mining. Polymetallic nodules, a focus of deep-ocean mining, are also critical to the oxygen generation process in these ecosystems. Disturbing these nodules could disrupt the balance of benthic ecosystems that rely on dark oxygen (Ministry of Earth Sciences, 2017).

A study published in November 2023 revealed that deep-ocean mining could harm marine species such as flatfish by creating sediment plumes that interfere with nutrient cycles and reproductive processes (Sweetman *et al*., 2024). Given the limited scientific understanding of benthic ecosystems, the potential long-term consequences of mining remain uncertain.

Agriculture and Deep Oxygen

The discovery of dark oxygen, while primarily applicable to marine ecosystems, could have indirect implications for agriculture. Oxygen plays a pivotal role in maintaining the balance of global nutrient cycles, particularly nitrogen and carbon cycles that impact soil fertility. By providing insights into alternative oxygen sources, dark oxygen could enhance understanding of deep-earth biogeochemical processes, which might intersect with nutrient dynamics in terrestrial ecosystems (Sweetman *et al*., 2024). Furthermore, understanding deep-ocean oxygen production could inform strategies to address agricultural challenges such as soil degradation, anaerobic conditions, and declining fertility in certain regions. This discovery also highlights the interconnectedness of marine and terrestrial systems, emphasizing the importance of conserving oceanic resources for the overall health of the planet.

Deep-Sea Mining Practices and Concerns

Deep-ocean mining involves extracting valuable minerals and metals from the ocean floor, with three primary methods:

1. Removing polymetallic nodules from the seabed.

2. Mining massive seafloor sulphides.
3. Extracting cobalt crusts from underwater rock formations (International Seabed Authority, 2023).

These resources contain materials such as nickel, cobalt, and rare earth elements, which are essential for renewable energy technologies and consumer electronics. As demand for these resources grows, deep-ocean mining is anticipated to become a major industry. However, the environmental risks of such activities require careful consideration and regulation (Ministry of Earth Sciences, 2017).

India's Role in Deep-Sea Exploration

India has been actively pursuing deep-ocean mineral exploration, particularly in the Central Indian Ocean Basin (CIOB). Key milestones include:

- Receiving 'Pioneer Investor' status in 1987, granting exploration rights to 1.5 lakh sq. km in the CIOB (International Seabed Authority, 1987).
- Extending exclusive rights for polymetallic nodule exploration in 2017 for five years (Ministry of Earth Sciences, 2017).
- Applying in 2024 for rights to explore the Indian Ocean seabed, including the cobalt-rich Afanasy Nikitin Seamount (Ministry of Earth Sciences, 2024).

India's Ministry of Earth Sciences is leading the Deep Ocean Mission, which includes developing a submersible vehicle under the Samudrayaan Mission to facilitate resource exploration and extraction (Ministry of Earth Sciences, 2024).

CONCLUSION

The discovery of dark oxygen marks a breakthrough in understanding deep-ocean ecosystems and their potential contributions to marine life. However, it also underscores the need for responsible exploration and conservation, particularly as deep-ocean mining becomes a more prominent activity. Balancing economic interests with ecological preservation will be critical to ensuring the sustainability of these unique and largely unexplored environments.

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