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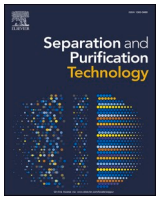

Review

Review on CO_2 removal from ocean with an emphasis on direct ocean capture (DOC) technologies

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ABSTRACT

Carbon dioxide (CO_2) capture and removal are pivotal in addressing climate change. Beyond capturing CO_2 directly from industrial emissions, the scope of greenhouse gas control has been extended to include technologies designed to remove CO_2 from the atmosphere. Recent developments focus on maturing promising Carbon Dioxide Removal (CDR) technologies that remove and permanently store CO_2. This article specifically examines a subset of CDR technologies referred to as ocean-based negative emission technologies (ONETs). The technologies under review involve modifications to seawater chemistry aimed at maximizing the ocean's potential as a CO_2 sink. Specifically, electrochemical ocean capture (EOC) and ocean alkalinity enhancement (OAE) are discussed.

There is a growing interest towards electrochemical ocean capture (EOC) utilizing different approaches, such as bipolar membrane electrodialysis (BPMED), three-chambered electrolytic cation exchange module (E-CEM), electrochemical hydrogen looping (EHL) and asymmetric chloride-mediated electrochemical process. The literature review shows that recent developments have up to 91% CO_2 capture efficiency and a record-low electricity consumption in the electrodialysis process of 2.4 GJ/tonneCO_2 with an EHL system and up to 87% CO_2 capture efficiency with an electricity consumption of 2.8 GJ/tonneCO_2 in the asymmetric chloride-mediated electrochemical process. Potential industrial and environmental challenges and solutions for the successful large-scale implementation of ONETs for greenhouse gas removal are discussed.

1. Background

Ever since the first anthropogenic CO_2 was generated from fossil fuels, humans have released substantial amounts of CO_2 to the atmosphere where a large fraction of these emissions have been absorbed by the oceans. It has been estimated that over the period from year 1750 to 2000, the oceans have absorbed approximately one-third of the anthropogenic CO_2 emissions. This has dropped the overall ocean alkalinity and the biggest changes have been seen in the ocean surface where the pH has decreased from 8.2 to 8.1 [1]. However, despite being a thermodynamically favourable process, oceans cannot completely offset all anthropogenic CO_2 emissions, even though oceans cover more than 70 % of Earth's surface. This limitation arises from the slow kinetics and mass transfer involved in the CO_2 solubilization, coupled with a diminishing driving force. Consequently, the concentration of CO_2 in the atmosphere has been steadily increasing over the past centuries.

According to the IPCC report [2], aggressive mitigation measures should be taken to reduce CO_2 emissions by 100 – 1000 Gt CO_2 before the end of the 21st century to avert the worst consequences of climate change. However, aside from capturing CO_2 directly from industrial emission sources, the technology toolbox is now extended to develop technologies to capture CO_2 directly from the environment. These technologies are also referred to as climate-positive or carbon dioxide removal (CDR) technologies. The objective of climate positive technologies is twofold: to abate unavoidable CO_2 emissions and to remove already-made emissions. It must be remarked that climate positive technologies are not to be considered as competitive substitutes for Post-Combustion CO_2 Capture (PCCC) technologies; instead, they are complementary.

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