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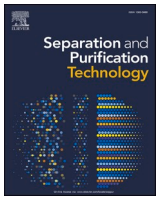

Recent advancements in carbonic anhydrase immobilization and its implementation in CO_2 capture technologies: A review

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ABSTRACT

Currently, amine-based solutions are considered as benchmark absorbents for CO_2 capture. However, there are severe environmental concerns as well as high energy consumption. A viable option is CO_2 capture utilising water as absorbent, via a biomimetic approach by the enzyme carbonic anhydrase (CA), with high selectivity, upmost performance, and environmental friendliness. However, the employment of the free form of CA in industrial applications is not rational due to the considerable amounts of enzyme required, instability and non-reusability. The immobilization of CA has attained significant interest, appearing as a promising approach to solve the problems associated with free CA. In this context, different immobilization strategies and supports have been developed to ameliorate the activity, stability, and reusability of CA enzyme, lowering the cost and increasing the process efficiency in large-scale applications. CO_2 capture has been studied using immobilized CA in various technologies such as absorption columns, selective membranes, and membrane contactors. In this state-of-the-art review, the scientific literature regarding the immobilization of CA and carbon capture technologies using immobilized CA are analyzed, highlighting the benefits, issues, and limitations of processes. Moreover, modelling approaches describing the absorption of CO_2 in packed-bed and membrane bioreactors with immobilized CA are presented, as well as the impact of operating parameters on bioreactors performance. The techno-economic analyses carried out on enzymatic capture processes are reviewed as well, to assess their feasibility in an industrial context. Finally, concluding remarks are made with a recommended perspective on open challenges and research priorities.

1. Introduction

Today, global warming is imposed as challenging problem on the earth due to the huge emission of greenhouse gasses (GHGs) through human activities. Uncontrolled emission of CO_2 in the atmosphere from various industries such as power generation, automobiles and burning of fossil fuels are steadily rising, which is the primary cause of global warming and significantly contributed to climatic change. As a result, preventing excessive emissions or developing new technologies to reduce CO_2 concentration became imperative [1,2]. Carbon capture and storage (CCS) is recommended as main technology to capture the CO_2 from main sources, transport and store it by geological storage or under the ocean [3]. There are several applications for reusing CO_2 such as mineral carbonation, enhanced oil recovery, food and beverage industry, algae growth, medical application, generation of useful biomass, freezing and pH control in several industrial processes [1,4–6]. Three technological concepts can be used to capture CO_2: post-combustion, oxycombusion, and pre-combustion [7]. Among these, post-combustion capture is a well-known method, as it can easily be adapted to existing industrial systems. Chemical absorption using amine-based absorbents is the most widely used and reported separation process for post-combustion CO_2 capture, due to its great efficiency, low cost, and maturity [1,8–11]. However, due to negative features of amine-based absorbents (significant energy and electricity consumption, CO_2 emissions related to the amines production process, high toxicity, degradation products, volatility and corrosivity) there is an ongoing search for more appealing technologies for CO_2 removal [1,11]. In the last decades, CO_2 capture using carbonic anhydrase (CA) has been developed as eco-friendly and economic viable technology [4,12].

CA is a metalloenzyme catalyst, generally with zinc in the active site, which usually exists in nature (mammals, plants, algae, archaea, vertebrates, and bacteria). It regulates biological processes in human and other living organisms and according to the Enzyme Commission (EC), it is defined by EC 4.2.1.1 [4,13–15]. CA converts CO_2 into bicarbonate

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