Journal of CO2 Utilization 42 (2020) 101333

Contents lists available at ScienceDirect

Journal of CO2 Utilization

journal homepage: www.elsevier.com/locate/jcou

# A critical review to bridge the gaps between carbon capture, storage and use of $CaCO_3$

Why-Ling Tan [a], A.L. Ahmad [a], C.P. Leo [a,*], Su Shiung Lam [b,c]

[a] School of Chemical Engineering, Engineering Campus, Universiti Sains Malaysia, 14300, Nibong Tebal, Pulau Pinang, Malaysia
[b] Pyrolysis Technology Research Group, Institute of Tropical Aquaculture and Fisheries (Akuatrop), Universiti Malaysia Terengganu, 21030, Kuala Terengganu, Terengganu, Malaysia
[c] Henan Province Engineering Research Center for Biomass Value-added Products, School of Forestry, Henan Agricultural University, Zhengzhou, 450002, China

ARTICLE INFO

*Keywords:*
Carbon capture utilization and storage
$CO_2$ sequestration
Calcium carbonate
Carbonation
Polymorphs

ABSTRACT

Carbon capture, utilisation, and storage (CCUS) is a new strategy to combat climate change. $CO_2$ sequestration using calcium-rich wastes has been extensively studied since calcium carbonate ($CaCO_3$) can be produced for various. In this review, the gaps between carbon capture technologies and carbonation are thoroughly discussed. Direct carbonation which involves the carbonation of calcium rich particles using $CO_2$ should be integrated with adsorption, membrane gas separation and cryogenic separation. Wet carbonation should be integrated with absorption and further adjusted to control the particle size and polymorphs. Among the polymorphs, amorphous $CaCO_3$ nanoparticles have drawn great attention due to their large surface area. The modification of $CaCO_3$ was then reviewed for increasing demand of hydrophobic $CaCO_3$. There are technical gaps exist in CCUS using $CaCO_3$, but the current scientific studies proposed some practical strategies for its implementation at large scale with economic feasibility. Membrane technology and alternative absorbent can enhance gas absorption to meet the requirement of wet carbonation for process integration. The economy potential of $CaCO_3$ should be elevated through particle size reduction, surface area enlargement and chemical functionalisation.

## 1. Introduction

The United Nations Environment Programme report released in November 2019 stated that the global emission has increased significantly in the past decade. Carbon dioxide ($CO_2$) remains to be the major cause of global warming and climate change. The global $CO_2$ emissions reached 33.1 Gt in 2018 [1]. Temperature increment from 2 to 4 °C is expected by 2100 [2,3].

Carbon capture and storage (CCS) has been identified as the most important tactic to mitigate the global warming effects by $CO_2$ gas. According to the estimation by Leung *et al.* [4] based on worldwide data, an average geological storage site is able to store several ten megatons of $CO_2$. Geological storage of $CO_2$ at supercritical conditions involves trapping, which offers long-term storage up to 1 million years, while mineralisation further prolongs more than 1 million years [5]. However, the geological storage of $CO_2$ is still facing financial, technological, political and environmental hurdles [6]. Public and health organisations also have concerns about the negative effects of geological storage because it can contaminate the drinking water sources, causing more health problems or even death. Carbon capture, utilisation, and storage (CCUS) is the elevated mitigation strategy to improve $CO_2$ sequestration and reduce environmental impacts caused by the geological storage of $CO_2$. Since the end of 2018, Petra Nova and Boundary Dam CCUS projects have been operated at full scale and record carbon capture of up to 2.4 million tons each year via enhanced oil recovery (EOR) [7,8]. Boundary Dam $CO_2$ Capture demonstration plant alone can acquire 4 tons of $CO_2$ daily [9]. However, the total capture capacity is still far from the target of 2030 Sustainable Development Scenario, which is 350 million tons $CO_2$ per year [10]. More research works are required to reduce the cost of CCUS and broaden the implementation of CCUS. In recent years, mineral carbonation is extensively studied in CCUS research as it allows the conversion of $CO_2$ into thermodynamically stable carbonates using brine solution and other alkaline wastes such as fly ash, sludge ash and steel slag. Although mineral carbonation is

*Abbreviations:* $CaCO_3$, calcium carbonate; $CO_2$, carbon dioxide; CCS, carbon capture and storage; CCUS, carbon capture, utilization, and storage; EOR, enhanced oil recovery; CaO, calcium oxide; $Ca(OH)_2$, calcium hydroxide; MGA, membrane gas absorption; $HCO_3^-$, bicarbonate ion; $CO_3^{2-}$, carbonate ion.

* Corresponding author.
*E-mail address:* chcpleo@usm.my (C.P. Leo).

https://doi.org/10.1016/j.jcou.2020.101333
Received 29 June 2020; Received in revised form 30 September 2020; Accepted 30 September 2020
Available online 23 October 2020