BIOTRANS
LA ROCHELLE 2023

N°520 / PC
TOPIC(s) : Industrial biocatalysis / (Chemo)enzymatic strategies

Enzyme-assisted CO2 capture from industrial emissions using mine tailings as co-sequestrating agents

AUTHORS

Io ANTONOPOULOU / BIOCHEMICAL PROCESS ENGINEERING, DIVISION OF CHEMICAL ENGINEERING, LULEÅ UNIVERSITY OF TECHNOLOGY, PORSÖN CAMPUS, LULEÅ
AYANNE DE OLIVEIRA MACIEL / BIOCHEMICAL PROCESS ENGINEERING, DIVISION OF CHEMICAL ENGINEERING, LULEÅ UNIVERSITY OF TECHNOLOGY, PORSÖN CAMPUS, LULEÅ
ULRIKA ROVA / BIOCHEMICAL PROCESS ENGINEERING, DIVISION OF CHEMICAL ENGINEERING, LULEÅ UNIVERSITY OF TECHNOLOGY, PORSÖN CAMPUS, LULEÅ
PAUL CHRISTAKOPOULOS / BIOCHEMICAL PROCESS ENGINEERING, DIVISION OF CHEMICAL ENGINEERING, LULEÅ UNIVERSITY OF TECHNOLOGY, PORSÖN CAMPUS, LULEÅ

PURPOSE OF THE ABSTRACT

Global temperatures are expected to rise by at least 2.6 °C by the end of the century, even if all signatory states effectively carry out the commitments set in the 2015 Paris Agreement, targeting global mean temperatures below 2 °C by 2100 [1]. It is evident that achieving net zero emissions would need significant emission reductions, which will make necessary the investments in novel and technologically advanced solutions as a large share of the reductions will come from technologies that are currently at the demonstration or prototype phase.

The mining industry has a high potential for Carbon Capture and Storage (CCS). Enhanced weathering, where the natural reactions between CO2 and silicate minerals that produce dissolved bicarbonate ions are accelerated, has the potential to remove substantial amounts of CO2 from the environment. The global mining industry produces huge volumes of waste that could be utilized as feedstock for enhanced weathering. The annual global enhanced weathering potential of mined metal commodity tailings from silicate-hosted deposits is estimated to 31 and 125% of the industry's primary emissions. However, current knowledge suggests that dissolution rates of many minerals are relatively slow, such that only a small percentage (3–21%) of this potential may be realized on timescales of <50 years. Thus, methodologies for accelerating weathering reactions, must be developed [2].

Carbonic anhydrase (CA) is one of the fastest enzymes in nature, catalyzing the hydration of CO2 to bicarbonate [3]. Integrating carbonic anhydrase in a natural weathering process, will boost bicarbonate formation which is key for further carbonate dissolution to form bicarbonate. The liquid bicarbonate solution, which is a temporary storage form for captured CO2, could subsequently be pumped into old or mined-out mine shafts/drifts to facilitate carbonation of the bedrock and thereby storing atmospheric carbon dioxide. Thus, formation of bicarbonate is strongly urged in order to provide both an efficient CO2 capture step and easy transportation for further permanent storage.

Aim of this work is to assess a novel evolved CA from Desulfovibrio vulgaris [4,5] for its potential to enhance the weathering of mine tailing waste. Preliminary results showed that, by adding CA into an aqueous solution of mine tailing waste, the silicate dissolution rate was increased 16.45 times at the first 40 min of reaction, while the CO2 capture yield was improved 2.29 times. The CA was also characterized for its stability towards potential inhibitors found in mine tailings (e.g. sulfates, carbonates). Further optimization will elucidate the potential of enzymatic CO2 hydration towards Carbon Dioxide Removal (CDR) practices to achieve the Paris Agreement ambition and mitigate climate change. This work is supported by the Swedish Energy Agency funded project TAILOR-MADE (Use of mine tailings to carbonate minerals by a symbiotic CC and DAC bio-strategy, Dnr number P2022-01123).

FIGURES

FIGURE 1

FIGURE 2

KEYWORDS

CO2 capture | Carbonic anhydrase | Mining tailings | Climate change

BIBLIOGRAPHY

1. IPCC (2022) Climate Change 2022: Impacts, Adaptation and Vulnerability. https://www.ipcc.ch/report/ar6/wg2/.

2. Bullock et al. Global Carbon Dioxide Removal Potential of Waste Materials From Metal and Diamond Mining. Global Carbon Dioxide Removal Potential of Waste Materials From Metal and Diamond Mining. Front. Clim. 3:694175 (2021).

3. De Oliveira Maciel, A., Rova, U., Christakopoulos, P., Antonopoulou I. (2022). Carbonic anhydrase to boost CO2 sequestration: Improving carbon capture utilization and storage (CCUS). Chemosphere, 299, 134419.

4. Alvizo, O., Nguyen, L.J., Savile, C.K. et al. (2014). Directed evolution of an ultrastable carbonic anhydrase for highly efficient carbon capture from flue gas. PNAS, 111(46), 16436-16441.

5. Sjöblom, M., Antonopoulou, I., Giménez, I.G., de Oliveira Maciel, A., Khokarale, S.G., Mikkola, J.-P., Rova, U., Christakopoulos, P. (2020). Enzyme-assisted CO2 absorption in aqueous amino acid ionic liquid amine blends. ACS Sustainable Chemistry & Engineering, 36(8), 13672-13682.