



Reuse Carbon Dioxide Emissions via Accelerated Carbonation

Imagine a technology that could capture atmospheric carbon dioxide, reduce carbon dioxide emissions, reduce the alkalinity of industrial waste, and generate useful materials — all in one process. You don't need a vivid imagination to envision this scenario. The National Energy Technology Laboratory (NETL) and other research labs have already developed technologies referred to as accelerated carbonation or carbon mineralization that do all of those things.

Accelerated carbonation is a technique to sequester large amounts of carbon dioxide as carbonates, often by reacting CO_2 with silicate minerals in aqueous solutions or with industrial waste streams that contain calcium or magnesium. The magnesium and calcium carbonates produced by this reaction are thermodynamically stable solids that could be used as construction materials or in other applications. The technology has been gaining popularity.

The two methods for performing carbonation are *in situ* and *ex situ* mineral carbonation. *In situ* mineral carbonation involves injecting CO_2 into geologic formations containing minerals such as olivine (Mg_2SiO_4 or Fe_2SiO_4), wollastonite (CaSiO_3), and serpentine ($\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4$). The geothermal gradient, pressure of the CO_2 , and groundwater present provide the necessary conditions for carbonation to occur naturally over time. This method has the potential to sequester on the order of thousands of gigatons (Gt) of carbon per year.

Conversely, *ex situ* mineral carbonation takes place in controlled engineered environments. The CO_2 is mixed with highly reactive industrial alkaline waste that has a high concentration of calcium and/or magnesium, such as coal flyash, steel and stainless steel slag, waste cement, lime kiln dust, or red mud. Because there is far less of these types of waste than natural minerals available, only about 200–300 megatons (Mt) of carbon is sequestered annually

using this method. *Ex situ* mineral carbonation has additional advantages over the *in situ* alternative, including reducing the alkalinity of the feed wastes and producing materials that can be used in construction. Alkaline industrial waste such as mine tailings, which contain calcium and magnesium, could benefit from *ex situ* accelerated carbonation.

The cement industry and the construction industry are large emitters of carbon dioxide and could benefit from carbon mineralization to reduce their waste output and carbon footprint. In their position paper, “Electrochemical Conversion of CO_2 — Opportunities and Challenges, Research and Innovation,” researchers N. Sridhar and D. Hill state that by using carbonates in 10% of building materials, carbon emissions can be reduced by 1.6 Gt/yr. However, mechanical properties, long-term environmental safety, and net reduction in carbon emissions should be considered when deciding whether to use carbonates as a material of construction.

In addition to reducing the alkalinity of the wastes, carbonation can make industrial wastes safer by immobilizing chromium and other toxic heavy metals, depending on the chemical composition of the waste. For various types and amounts of toxic heavy metals, different chemical conditions are required for immobilization.

Accelerated carbonation research aims to optimize reaction conditions, including temperature, pressure, and reaction time. Researchers must possess a fundamental understanding of the chemistries behind the CO_2 -to-carbonates conversion reaction, such as the formation of boundary layers containing silicon and iron that limit mass transfer and the effect of impurities like sulfur dioxide in the gas streams. Energy requirements for preprocessing materials, cost, feedstock availability, electricity vs. heat as an energy source, and conversion routes still require more research to advance accelerated carbonation technology.

AIChE's Center for Energy Initiatives (CEI) is encouraging discussion and knowledge sharing among researchers in this field through its Accelerated Carbonation for Environmental and Material Engineering (ACEME) conference series. ACEME conferences aim to promote research and development activities related to accelerated carbonation at an international level by serving as a forum for discussion on future development and implementation in the field. Processing conditions, product properties, and (online) analysis at the lab, pilot, and full scales are the major themes of the conferences. The last ACEME conference was held in 2015 in New York, NY, and plans for the next ACEME conference in New Castle, Australia, are underway.

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▲ Cement plants are large emitters of carbon dioxide that could use carbon mineralization to curb emissions.