Chemical Sequestration of CO₂ by CaCO₃ Dissolution

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The famous ‘Keeling Curve’

Atmospheric CO₂ at Mauna Loa Observatory

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We are conducting an experiment that is global in scale…
The long record of CO$_2$ and Temperature from Antarctic Ice Cores

![Graph showing atmospheric pCO$_2$ and temperature changes over calendar age (years).]
We know how the planet will do CO₂ Sequestration

The ocean and atmosphere will react to excess CO₂ emissions by reacting it with CaCO₃ sediments in the deep ocean. That is, the shells of dead plankton will buffer the CO₂ addition.

\[
\text{Ocean Sediment} + \text{CO}_2 = 2\text{HCO}_3^- + \text{Ca}^{2+}
\]

Archer et al., 1997
Close to Equilibrium the ‘Rate Law’ is Poorly Constrained

\[ \text{Rate} = k(1-\Omega)^n \]

\[ \Omega = \frac{([\text{Ca}][\text{CO}_3])_{\text{insitu}}}{([\text{Ca}][\text{CO}_3])_{\text{eq}}} \]

\[ \text{CaCO}_3 \rightleftharpoons \text{Ca} + \text{CO}_3 \]

Graph showing dissolution rate vs \( \Omega \) with different values of \( n \).
A New Approach to Measuring the Dissolution Rate

Seawater bag, $\Omega_{\text{seawater}} < 1$
The basic data output from an experiment
The calcite rate law is strongly curved
We Discovered a Catalyst that make the natural reaction go much faster

In the lab the enzyme carbonic anhydrase makes the reaction of CO₂ and CaCO₃ go almost 1,000 times faster

In a business, a reactor located at a power plant would greatly increase the speed of CO₂ sequestration, thus making it feasible to convert the gas into harmless dissolved inorganic carbon.
A simple reactor using freshwater and a limestone bed

A single catalyzed run

Carbon in the water (µmol/kg)

Carbon Difference (outflow-bottle)

Catalyzed
Uncatalyzed

Bottle
Outflow

Time (Hours)
Seawater flowing through a packed bed of Limestone in the la.

Uncatalyzed: 24,000 Factories
Catalyzed: 600 Factories

40 GT CO₂
Limestone Equivalent

Walmart-Sized Dissolution Factory

Catalyzed: 600 Factories
Uncatalyzed: 24,000 Factories
We hired Antonio Corradini, PE of Alternative Energy Systems Consulting Inc. to do a cost analysis for CO₂ sequestration at a power plant that already brings in large amounts of water for system cooling.
Basic Costs of Material Processing

Water Pump

$18.20/ton CO₂, assuming 500 μmol/kg carbon in water

CO₂ Blower

$3.29/ton CO₂, with 7 psi pressure

CaCO₃ Conveyor

$36.81/ton CO₂, limestone cost of $24.93/ton CO₂ and $11.88/ton rock rail transport 150km away

Total

$58.30 /ton CO₂

Does NOT include catalyst cost

all assume $0.05/kwh for power
How will our effluent interact with the ocean/river?

Seawater Version of No Harm

Freshwater Version of No Harm

USGS classifies anything below 60mg CaCO₃/L as soft. This is 1200µeq/kg alkalinity. We are going to make water of ~5000µeq/kg so a 5:1 dilution factor will put us into the ‘soft’ water category.
The ocean has a vast capacity to take up the effluent