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Potential impacts of effluent from accelerated weathering of limestone on seawater carbon chemistry: a case study for the Hoping power plant in northeastern Taiwan

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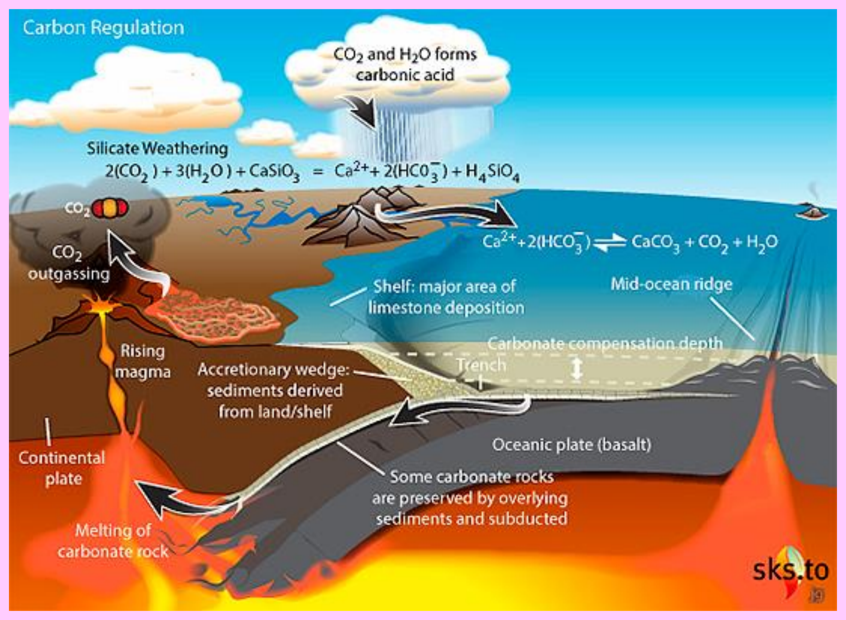
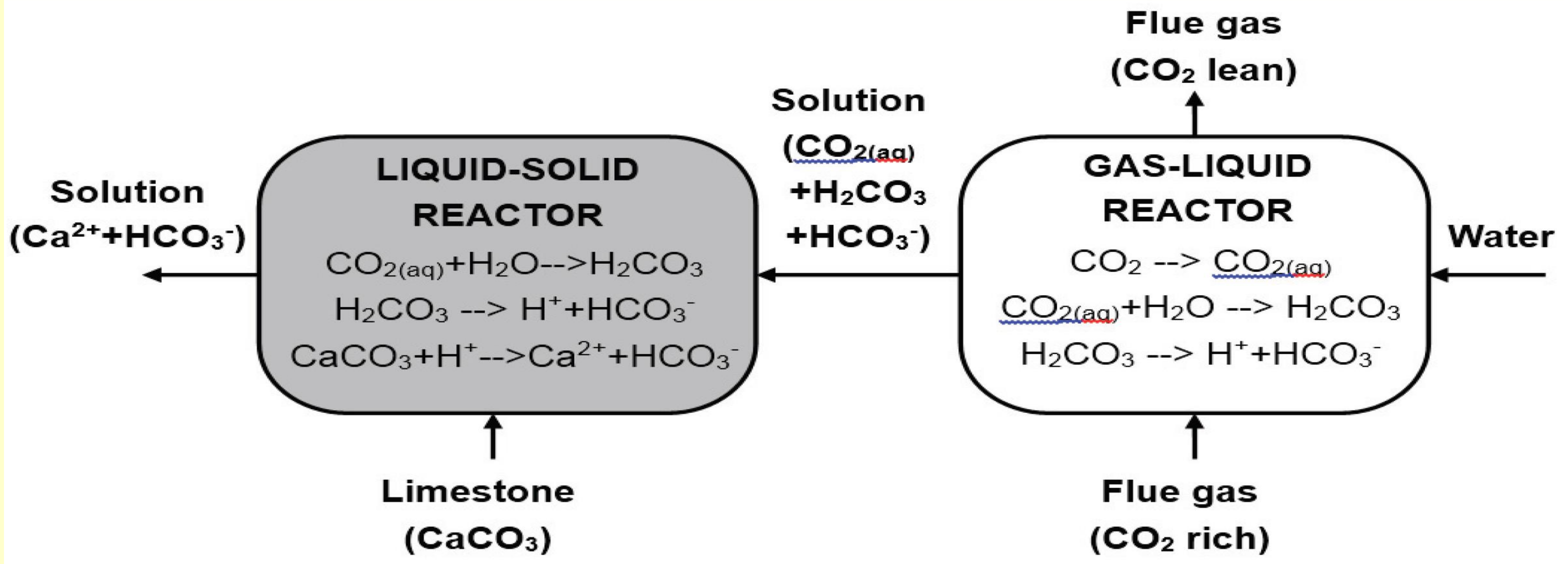
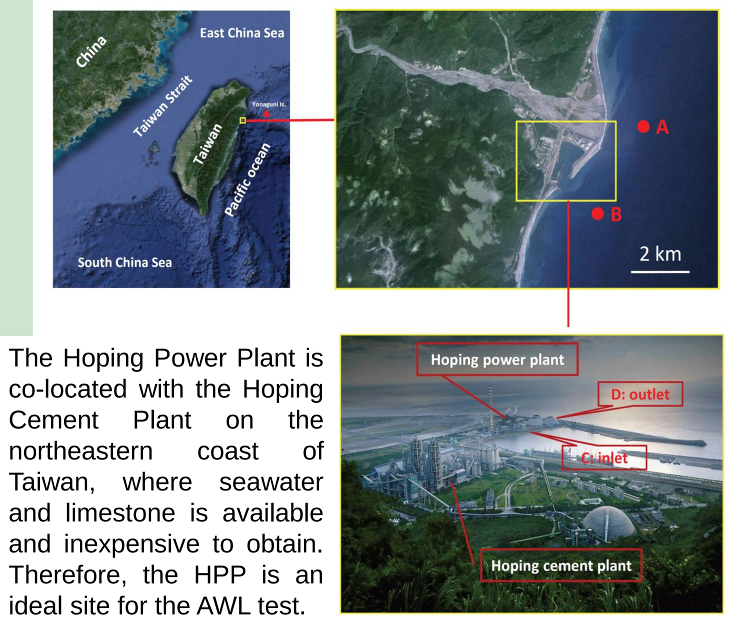
AWL mimics nature's own CO_2 mitigation mechanism: accelerated weathering of limestone (AWL) has been proposed as an alternative method for reducing CO_2 emissions. The basic concept of AWL is simple; the process involves accelerating the natural CO_2 sequestration process, i.e., carbonate and silicate mineral weathering, which is a major consumer of excess atmospheric CO_2. Because such a process essentially mimics nature's own CO_2 mitigation mechanism, it is thought to be able to effectively sequester CO_2 in a safer and more energy-saving fashion than conventional Carbon Capture Storage.



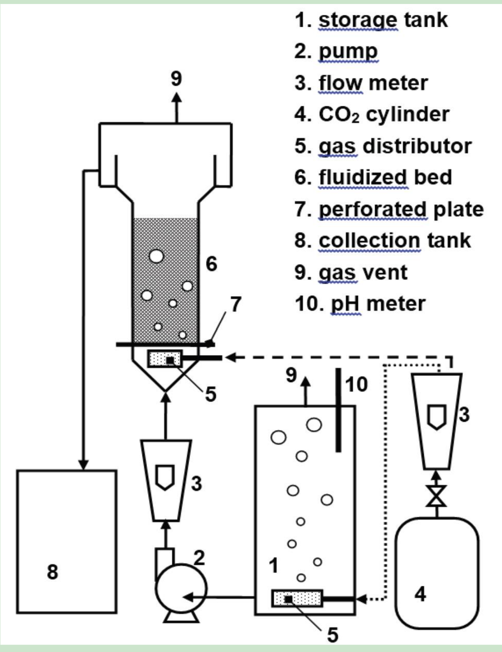
From http://www.skepticalscience.com/weathering.html

The process of AWL:
(1) CO_2–rich flue gas is hydrated with water to form carbonic acid
(2) The resulting carbonic acid reacts with limestone, thus converting the original CO2 gas to calcium bicarbonate in solution. The dissolved calcium bicarbonate solution can then be disposed of in the ocean.



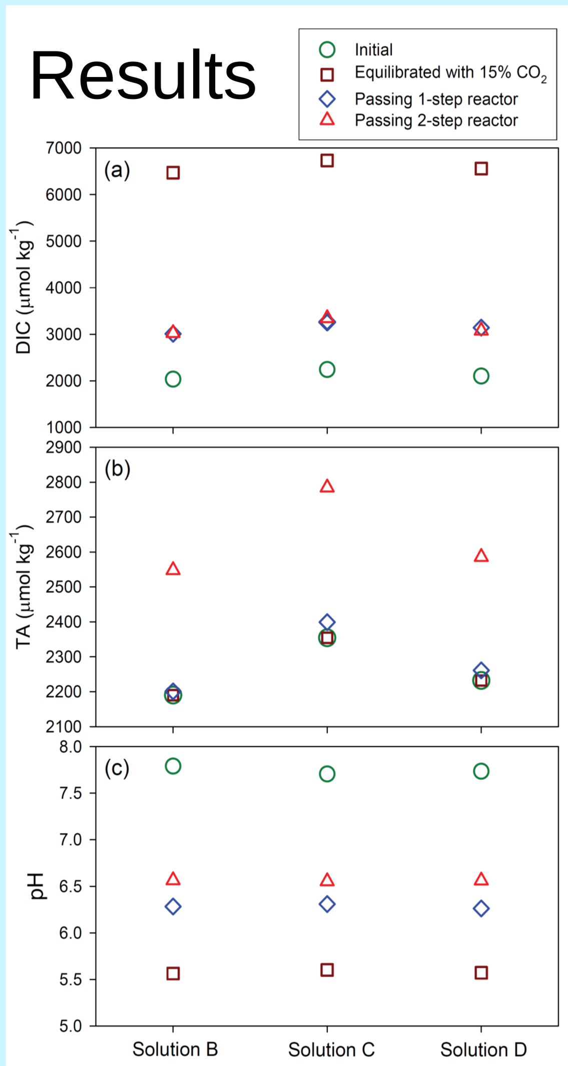


The Hoping Power Plant is co-located with the Hoping Cement Plant on the northeastern coast of Taiwan, where seawater and limestone is available and inexpensive to obtain. Therefore, the HPP is an ideal site for the AWL test.

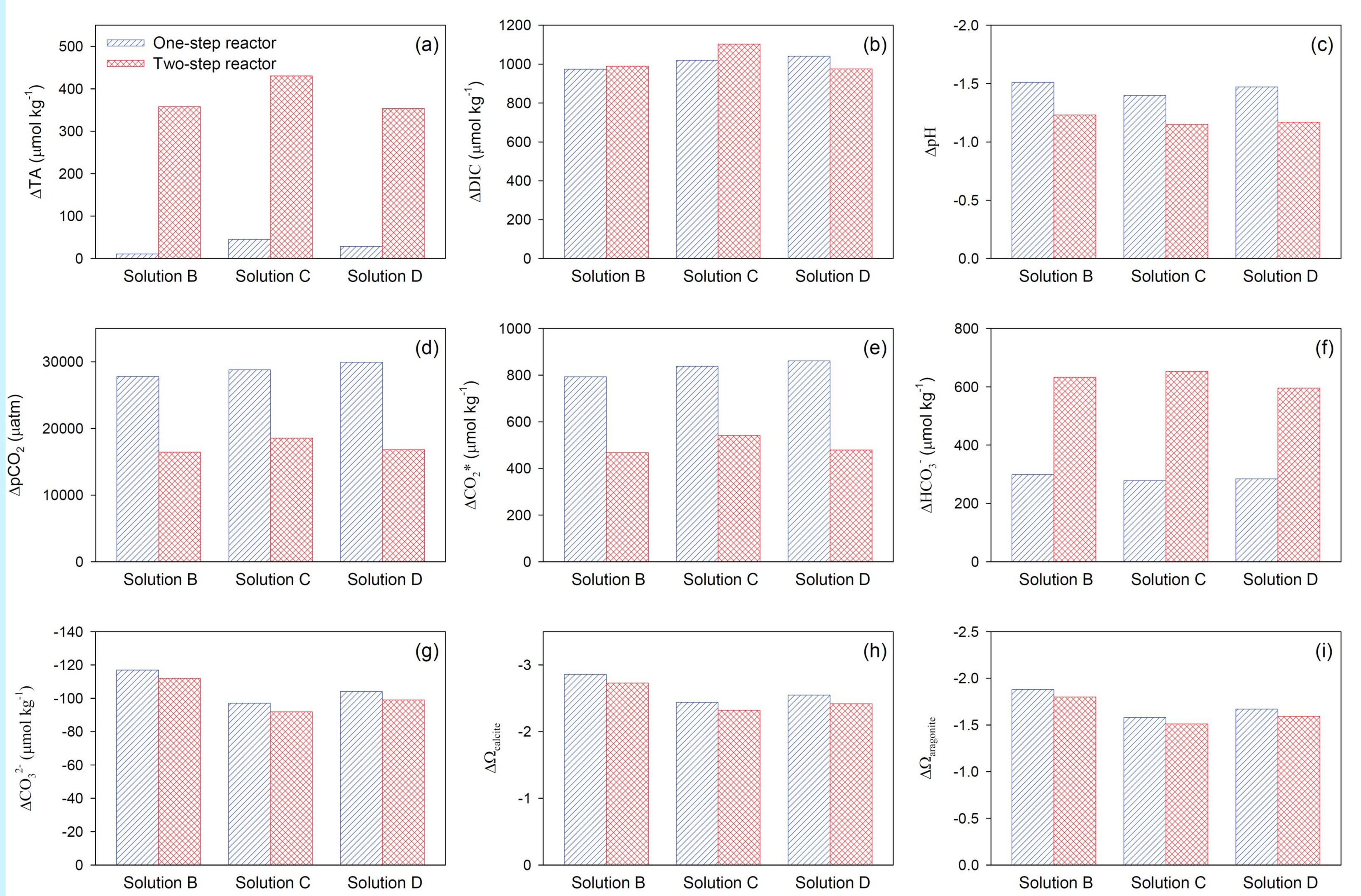


The concepts of the One-step and Two-step AWL reactions were used in this study:
For the **One-step system**, all of the reactions proceed in a gas-liquid-solid reactor. Flue gas and water are pumped into the reactor, which is full of limestone ($CaCO_3$) particles. Within this reactor, CO_2 and limestone dissolution progress simultaneously. The **Two-step system** is operated with two reactors: one is for the gas-liquid reaction and the other is for the liquid-solid reaction.

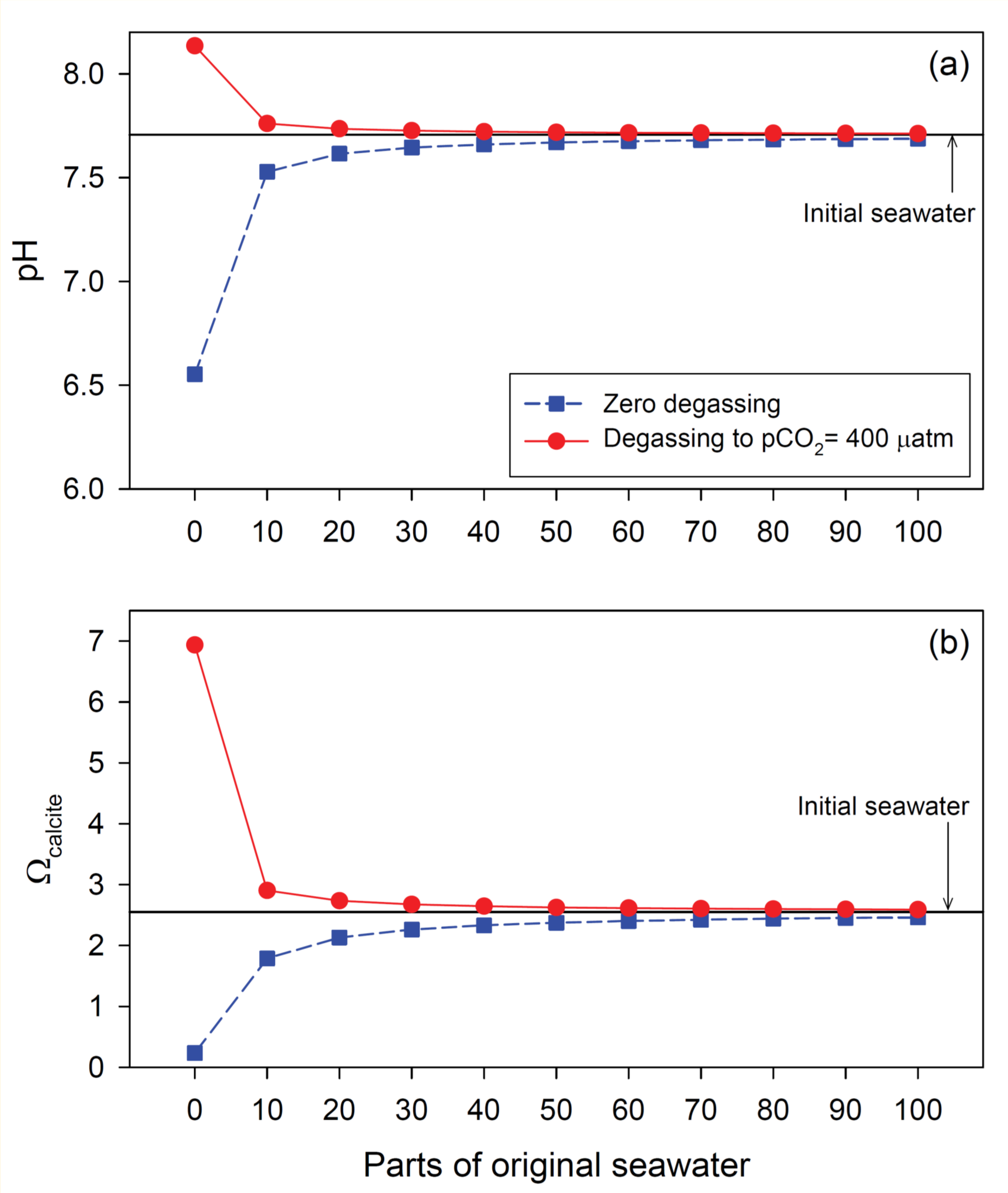
Results



In this study, we found that minimal $CaCO_{3(s)}$ dissolution had hardly occurred in the One-step reactor. The absorbed CO_2 remained mainly as CO_2^* in the effluent solution; this form of CO_2^* would hasten ocean acidification and is unable to be stored for the long-term. This suggests that the One-step reactor may not be a suitable design for the AWL technique. Conversely, **the Two-step reactor demonstrated the ability to partially convert the captured CO_2 into HCO_3^-, which is thought to be environmentally benign and can be stored for the long-term in the ocean, and thus may represent a better design.** However, under current experimental conditions, neither $CO_{2(g)}$ nor $CaCO_{3(s)}$ dissolution reached optimal levels, even in the Two-step reactor. Consequently, further research and experimentation are still needed to optimize reaction conditions and reactor designs for the greatest effectiveness.



Impacts on seawater carbon chemistry



Here, we evaluate the effects on pH and $\Omega_{calcite}$ (two biologically important parameters) from adding TA and DIC into the ocean by mixing the outflow solution with various parts of the initial seawater. The simulated result shows that the impacts of the AWL effluent on the carbon chemistry of the receiving seawater could be restricted within a safe range by properly diluting the effluent solution with the surrounding seawater. For instance, a 10-fold dilution would be sufficient to maintain the pH change within a range of 0.2 for the effluent from the Two-step reactor in this study. It is worthy to note that **if the effluent solution degassed back to the ambient air pCO_2, pH and Ω would become higher in the receiving seawater, suggesting that the degassed effluent solution to the ocean may eventually mitigate, at least locally, the effect of ocean acidification due to anthropogenic CO_2 uptake.**

Concluding remarks:

- Two-step reactor demonstrated the ability to partially convert the captured CO_2 into HCO_3^-, which is thought to be environmentally benign and can be stored for the long-term in the ocean, and thus may represent a better design.
- The mixing simulation indicated that the impacts of the AWL effluent on the carbon chemistry of the receiving seawater could be restricted within a safe range by properly diluting the effluent solution with the surrounding seawater.