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Accelerated Weathering of Limestone on Cargo Ships

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The shipping industry accounts for about 3% of global CO2 emissions. It is an industry that is not easily electrified but is under pressure from IMO 2050 to find a way to bring emissions back to 50% of their 2008 levels by 2050. Given that a ship's flue gas is 3-5% CO2, this stream can be combined with a limestone slurry, in the presence of seawater, to drive the neutralization reaction known as the accelerated weathering of limestone (AWL). The 1:1 stoichiometry of CO2 plus CaCO3 leads to a scaling of one twenty-foot equivalent (TEU) container full of limestone needing to be reacted every hour to neutralize the ship's emissions while underway. For a Pannamax sized vessel (>10,000 TEU) that takes ~2 weeks to cross the Pacific, this is <4% of the ship's volume. We have built fluidized bed reactors in the lab to study the kinetics of this reaction where the water fluxes are scaled to match the ~70m^3/sec of seawater intake needed to flush the reaction chamber.

There are two key mass transfer steps that limit the proposed reaction in sea water. Dissolution of the CaCO3 is a non-linear function of the saturation state of the seawater. First, our previous work on the physical chemistry of calcite and aragonite dissolution rates and mechanisms greatly informs this mass transfer. Second, solubilization of CO2 from the flue gas into seawater follows the standard gas flux bulk formula equation with seawater piston velocities for CO2. Models of these two 'dissolution' processes in a Panamax sized fluidized bed reactor indicate that the IMO 2050 goal can be met with calcite grain sizes of 100 µm and bubble radii of around 1 mm. A key issue for implementation of this process on cargo ships is the effect of Ca+HCO3 rich effluent being returned to seawater with negligible impact on the environment. Very efficient mixing with ambient seawater in the ship's wake takes the effluent pCO2 from 1,000s of ppm to about 550 ppm in a few minutes thereby reducing CO2 evasion to the atmosphere.