Beyond Net Zero: A Data-Driven Mathematical and Experimental Investigation of Atmospheric Carbon Overshoot and Magnesium Hydroxide Mediated Ocean Alkalinity Enhancement

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The ocean absorbs 25-30% of anthropogenic CO_2, serving as a critical carbon sink. This sink property self-limits under increasing atmospheric CO_2 due to accumulation of hydrogen ions (acidification), causing a negative feedback loop whereby increasing atmospheric demand for oceanic carbon sink propagates a decreasing supply of the same. Ocean Alkalinity Enhancement (OAE) is a potential mitigation strategy, but experimental evidence is limited. Magnesium hydroxide, $Mg(OH)_2$, is a safe, food-grade, naturally occurring mineral, brucite, that restores oceanic carbon sink potential via pH control, but has never been systematically optimized for OAE in particle size or water agitation level. This experimental study applied $Mg(OH)_2$ to sparkling mineral water, where mineral presence, mineral particle size, and magnetically-stirred water agitation level varied independently across 54 trials. Per trial, six timed pH readings were taken and written to dataset per 10-minute trial by a C++ custom-programmed Arduino pH sensor to obtain 216 pH observations read to Serial Monitor and imported to a .csv file in real time for statistical and visual analysis in R. Multivariate regression showed significant and substantial increased alkalinity gains over control in presence of $Mg(OH)_2$ fineness of grain size, and water agitation level. Finer particles dissolve more readily to enhance alkalinity and restore CO_2 absorption capacity, and higher water agitation increases mineral-water contact. Mean pH change reached 1.35 at 200-mesh (fine grain) / high-agitation versus .437 at 50-mesh (coarse-grain) / low-agitation. Given industrial technology and geographic variation in water agitation levels, respectively, both findings can be scaled and implemented toward OAE field optimization.

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