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Quantification for density-driven convection of CO2 in water

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Given the growing concerns about climate change, reducing anthropogenic carbon accumulation in the atmosphere has become a critical focus. Carbon capture and storage (CCUS) has gained increasing attention as an effective midterm measure that could accommodate massive amounts of CO2 underground (32 gigatons per year)[1,2]. As one of the important mechanisms of CCUS, solubility trapping greatly determines the efficiency of CO2 sequestration. The carbon dissolution rate largely depends on the density-driven convection (DDC) of CO2 in water. Various factors are deciding the CO2 convection behavior in the porous media[3], making it challenging to interpret. Although there are multiple relevant simulation works, experimental studies are still lacking in quantifying the phenomena. The opaqueness and uncertainty of most porous media complicate the reproduction of experimental results and the quantification of DDC. In our experimental study, we primarily employed optical 3D-printed porous media with defined pore structures and properties to conduct carbon convection experiments. To visualize the CO2 convection patterns under different experimental conditions, we utilized a novel universal pH indicator that covers a broader measurable pH range (4.4 to 9.6) and detects subtle pH variation (below 0.1 pH unit)[4]. By mapping the colors of indicators to the pH, we can determine the spatiotemporal pH and total dissolved carbon, which quantitatively indicates the CO2 convection. Our error analysis indicates that our experimental techniques have a smaller margin of error in carbon measurement compared to previous studies[2,5]. Furthermore, we quantified the convection behavior by determining the mixing length, carbon flux across the interface, and the wavenumber, etc[6,7]. This experimental work can be of great interest to CCUS projects.

Keywords: Carbon capture and storage, density-driven convection, experimental techniques, quantification

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