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Development of stable geological storage technique by CO2 nano-sizing

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Introduction

Geological storage is considered as an important key technology to mitigate CO_2 emissions into the atmosphere. However, the risk of CO_2 leakage from storage reservoirs remains a crucial problem. The injected CO_2 migrates upward because of the buoyancy effect, and caprock structures are therefore necessary to prevent CO_2 leakage.

Injected CO_2 generally forms a continuous plume in aquifers, and larger buoyancy effects are caused by the larger continuous phase of CO_2. To develop a stable geological storage technique, this study proposes a novel method that uses nanosized CO_2 droplets in a porous structure to allow stable geological storage. The buoyancy effect can be reduced by changing the CO_2 from a continuous phase to nanosized droplets before injection. In this study, experimental and study was performed to examine the stability of nanosized CO_2 droplets in the aquifer.

Experimental apparatus

The experimental study focused on the nanosizing process, the size distribution of the CO_2 droplets, and their behaviour in porous media. Figure 2 shows the experimental apparatus. The CO_2 nanosizing process was observed using a closed circulation channel that consisted of a static mixer, a circulation pump, and an observation section. The circuit pressure was controlled to give 6 to 9 MPa. The temperature was set approximately 20 to 40 degree Celsius. The volume ratio of CO_2 to water was set to 1:2, and a surfactant was added to assist with the micronization of the CO_2. The concentration of surfactant was kept as low as possible to reduce the storage costs.

The size distribution and time evolution of the nanosized CO_2 droplets were observed through windows made of sapphire glass. The droplet size distribution of the CO_2, and its time evolution, were measured using dynamic light scattering (DLS).

The nanosized CO_2 droplets and water were slowly aspirated using a syringe pump, and were injected into water-saturated porous media. The porous media was a packed silica sand bed (with grain diameters of 125 to 250 micrometer) in a stainless steel tube. The behaviour of the nanosized CO_2 in the porous media was investigated using X-ray computed tomography (CT).

Results and discussion

As the result, nanosized CO_2 droplets were successfully generated and observed through observation windows made of sapphire glass placed in the channel. The average diameter of the CO_2 droplets was initially 40 to 70 nm. The average diameter increased with time. It is considered that the change in the diameter distribution was caused by the coalescence and Ostwald ripening of the CO_2 droplets.

The nanosized CO_2 was injected into the porous media and it was observed by using X-ray CT. Reconstructed three-dimensional CT images were obtained with spatial resolution 20 micrometre (i.e. pore-scale structure can be observed). The CT images cannot resolve the shape of nanosized CO_2 droplets itself right after injection. After a day, micro-scale CO_2 droplets emerged in the pores because of coalescence of nanosized CO_2 droplets; however, the number of pore-scale CO_2 droplets and their positions remained unchanged during an observation period of a few days. It is considered that any increase in the CO_2 droplet diameter was prevented in the porous media by capillary force, and the droplets were finally trapped in the pore-throat structure. The experimental results suggested the high potential of the nanosized CO_2 droplets for stable geological storage.

Keywords: CO2 geological sequestration, Micronization, Nano-sizing, X-ray CT