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Visualisation of [11C]CO₂ storage in coal with positron emission tomography imaging

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CO₂ geo-sequestration is a practical approach to achieve net-zero carbon target. Coal has become an optimal geological storage option due to its large adsorptive capability for CO₂. However, one of the main challenges for successful CO₂ geo-sequestration is the reduced injectivity that are caused by adsorption-induced swelling of coal matrix. In addition, its complex and heterogenous internal pore and fracture structure make the processes of gases adsorbing, desorbing, and transporting more complicated compared with conventional rocks. This work aims to gain insights about the gas transport behaviours in coal by developing a novel experimental framework with Positron Emission Tomography (PET) imaging technology to directly visualise gas flow multiphysics in coal.

PET imaging has demonstrated its capability in providing real-time visualisation of fluids flow in geological materials. However, it has not been used for the study of CO₂ injection and storage in coal for the application of CO₂ geo-sequestration. To observe the processes directly, [11C] CO₂ is the most optimal radiotracer, which is rarely used due to its short half-life (20.4 min) and handling safety issues as a gaseous tracer. In this work, a novel laboratory protocol is developed to use gaseous [11C] CO₂ as the radiolabelled tracer to visualise and quantify dynamic processes of gas spreading, adsorption, diffusion, and advection flow in coal under in-situ conditions. The experimental setup integrates core flooding setup with PET scanning. Coal samples are pre-treated to mimic different injection conditions, including coal seam gas reservoirs in early production stage, gas depleted stage and CO₂ storage stage. Due to high temporal resolution of PET imaging, time-lapse CO₂ gas concentration map of each test is acquired by converting the PET intensity values to gas concentrations. Impacting factors on storage capacity and efficiency are also studied, including permeability, gas adsorption, gas exchange, and initial storage conditions.

This work introduces a new laboratory protocol and analysing framework to quantify sub-core scale multiphysics CO₂ flow in coal, which provides a foundation for future across-scale theoretical and experimental study of multiphase and multicomponent flow behaviours in coal for the application of CO₂ geo-sequestration.

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References

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