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Mechanical dispersion in UHS: Insights from laboratory experiments on hydrogen-methane interactions

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In the context of sustainable energy systems, underground hydrogen storage plays an important role. With the growing emphasis on renewable energy sources, the intermittent nature of their output requires effective and scalable storage solutions for the future. Underground hydrogen storage is emerging as a key player in meeting this need, providing a safe and geologically stable environment for storing excess energy during periods of surplus electricity generation. One of the aspects influencing the effectiveness of underground hydrogen storage is the mixing processes between injected hydrogen-gas mixtures and residual natural gas in the subsurface reservoir. Besides molecular diffusion, mechanical dispersion is a major process leading to the mixing of fluids due to their movement and flow in porous media. Dispersion is driven by variations in flow velocity caused by pore size distribution, tortuosity and heterogeneity of the porous rock.
To understand the dynamics of mechanical dispersion and its implications for underground hydrogen storage, laboratory experiments with hydrogen, methane, hydrogen-carbon dioxide-methane gas mixtures and methane-nitrogen gas mixtures were conducted. For the experiments a slim tube coil with a length of 25 m filled with glass beads, which represent the porous medium, was initially filled with methane or a methane-nitrogen gas mixture. During the experiment, the methane was displaced by constantly injecting hydrogen or hydrogen bearing gas mixtures. The composition of the outflowing gas was analysed using a gas chromatograph. The experiments were conducted with different flow rates, temperatures and pressures to investigate how these parameters affect the dispersion.
Longitudinal dispersivities were calculated from the measurements. The determined dispersivities range between 0.0042 and 0.060 m. This shows that large variations occur when changing the parameters of the experiment It was observed that dispersivity is dependent on pressure, temperature, flow velocity and gas composition. The knowledge gained from this study contributes to the ongoing development of underground hydrogen storage technologies and provides a basis for the development of efficient energy storage solutions.