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Experimental determination of noble gas, SF_6 and CO_2 flow profiles through a porous sandstone

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The noble gases (He, Ne, Ar, Kr and Xe) and SF_6 have recently been used as artificial and inherent tracers of CO_2 flow and migration from within[1,2] and from geological reservoirs[3]. However, outstanding questions remain, particularly regarding the flow behaviour of the noble gases compared to CO_2. Here we present results from specially constructed experimental equipment, which has been used to determine the factors affecting transport of noble gases relative to CO_2 in a porous sandstone.

The experimental setup consists of a sample loop that can be loaded with a desired gas mixture. This sample can be released as a pulse into a feeder gas stream through a flow cell. The flow cell consists of a 3.6 cm diameter core, which can be of any length. The sample is surrounded by aluminium foil and treated with epoxy resin inside stainless steel tubing. The flow cell is encased by two purpose designed dispersion end plates. Real-time analysis of the arrival peaks of the gases downstream is recorded using a Quadrupole Mass Spectrometer (QMS).

For the experiments, a 0.96 m core of Fell Sandstone was selected to represent a porous media. Noble gases and SF_6 pulses were flowed through a CO_2 carrier gas at five different pressure gradients (10 – 50 kPa) with arrival profiles measured using the QMS. Surprisingly, peak arrival times of He were slower than the other noble gases at each pressure gradient. The differences in peak arrival times between He and other noble gases increased as pressure decreased and the curve profiles for each noble gas differ significantly. The heavier noble gases (Kr and Xe) along with SF_6 show a steeper peak rise at initial appearance, but have a longer duration profile than the He curves. Interestingly, the breakthrough curve profiles for both Kr and Xe were similar to SF_6 indicating that Kr and Xe could be substituted for SF_6, which is a potent greenhouse gas, in tracing applications. In addition, CO_2 pulses were passed through a N2 carrier gas. The CO_2 pulses yield slower peak arrival times compared to those of both the noble gases and SF_6.

Modelling of these results show that they cannot be explained by simple one dimensional flow through a porous media. A combination of analytical and statistical modelling of the dataset has allowed constraint of dispersion values for each noble gas, SF_6 and CO_2 under the experimental conditions. A conceptual model that incorporates different preferential flow paths depending on flow velocities of individual gas streams has been proposed. This can explain the observed dataset and shows that the flow of noble gases and SF_6 tracers is influenced by the apparent heterogeneity of the sandstone core.

References

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[3]Gilfillan et al., (2011) IJGGC 5 (6) 1507-1516 DOI:10.1016/j.ijggc.2011.08.008