The use of polymer-gel solutions for remediation of potential CO_2 leakage from storage reservoirs

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Abstract

In recent years, significant research has been carried out across disciplines on the behaviour of CO_2 in the subsurface geological formations, however, the mitigation of potential leakages from the storage reservoir through a fractured caprock, abandoned and unaccounted wells or any other form of non conformal CO_2 flow has not been fully investigated yet. The current work fills this crucial knowledge gap and illustrates a methodology for the mitigation of non-conformal flow of CO_2 (including leakage from host reservoir into surrounding aquifers) in subsurface reservoirs. This paper presents a detailed laboratory investigation and numerical simulation studies of leakage remediation scenarios for the use of a polymer-gel system to control non conformal flow of CO_2 in the subsurface.

A polymer-gel based on Polyacrylamide (PAAm) and triggered by the addition of a Chromium (III) Acetate cross-linker was investigated for its use in CO_2 leakage remediation. First the rheology of the aqueous polymer-gel at various concentrations (2.1%, 4.1% and 6% by volume) of PAAm was characterised under different temperatures representative to CO_2 storage reservoirs. Key parameters known as the gelation and working times, which define the duration during which the polymer-gel solution retains its flow characteristics after the addition of a crosslinker were measured at different temperatures for various concentrations of polymer in the solution. It was observed that the gelation and working times decrease with increase in both concentration and temperature. For the polyacrylamide based polymer-gel considered in the study, the impact of temperature was noted to be more significant than the increase in polymer concentration. Core flood experiments were then carried out on cylindrical clastic reservoir rock and synthetic fractured core samples in the laboratory to test the suitability of polymer-gel solution for flow through and containment of CO_2 in porous media. The core samples were initially saturated with brine of representative reservoir salinities and CO_2 was injected to simulate CO_2 injection and brine drainage. The core was then saturated with CO_2 at residual brine saturation and permeability was measured. The prepared polymer-gel solution was then injected into the core sample and the core was saturated with

polymer-gel solution at residual brine and CO_2 saturation. The core was left undisturbed for the period of gelation time to enable the formation of solid gel. CO_2 was then injected and core sample permeability for CO_2 was measured. For the experiments carried out it was observed that the polymer-gel solution reduces the CO_2 permeability of the core sample by almost 99%. Similar reduction in permeability of a synthetically fractured rock sample, which was used as an analogue for fractured caprock, was observed. In all cases, the change in CO_2 permeability of rock sample before and after the polymer-gel injection was noted.

Reservoir simulations for different scenarios of leakage remediation were carried out on a realistic reservoir model representative of the deep North Sea type CO_2 storage reservoirs. Results from reservoir simulations supported the feasibility of polymer-gel remediation at reservoir scale and identified the spatial extent of the leakage that can be remediated for various concentrations of polymer-gel solutions. The laboratory experiments and reservoir simulations have shown that the penetration of the polymer-gel solution into the reservoir to remediate a potential leakage or non conformal flow of CO_2 would depend on the concentration of polymer and the reservoir temperature. It was further noted that remediation of leakage or non conformal flow by polymer-gel solution is more suited to shallow depth and low temperature reservoirs such as Sleipner.