Mitigation and Remediation of Leakage from Geological Storage: Polymer-Gel Injection as Flow Diversion Option

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Abstract

This paper presents the results of numerical modelling carried out to investigate the application of polymer-gel barriers for remediation of CO_2 leakage as flow diversion option. The main objectives of this work were: i) to perform reservoir simulations of polymer-gel injections with different remediation layouts after CO_2 leakage has been detected, and ii) to estimate the area of influence and volume of polymer-gel solution required for each remediation case.

Using Schlumberger's Eclipse 300 (E300) software, the injection of polymer-gel solution was simulated and the area of influence and volume of polymer-gel needed were estimated for a number of scenarios. The effect of delaying agent on gelation process was considered by using a range of polymer-gel viscosities for the different scenarios. CO_2 injection was then resumed and the efficiency of the polymer-gel treatment in diverting the CO_2 plume from a leaky fault was assessed for each scenario.

Structural and geological model

The structural model represents a saline aquifer with a fluvial-channel system (Fig. 1). Simulations were carried out for 30 years, typically including three stages: 1) CO_2 injection at a rate of 1Mt/year; 2) remediation after leakage detection; 3) post-remediation CO_2 injection . A sub-seismic fault was introduced in the model at a distance of 1km away from the injection well (Fig. 2).

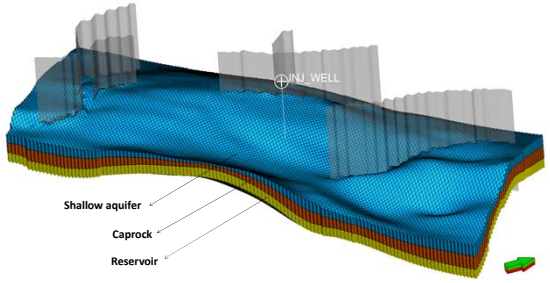

Fig. 1. The structural model of the numerical saline aquifer (36km×10km) containing five major faults and three stratigraphic layers: reservoir layer, caprock (seal) layer and shallow aquifer layer.

A number of scenarios were considered for the remediation of CO_2 leakage through the subseismic fault into the shallow aquifer, using polymer-gel injection. The scenarios were defined based on two factors:

- ❑ The effect of reducing polymer-gel viscosity (in practice, by introducing delaying agents) on its radius of influence in the reservoir.
- ❑ The proximity of polymer injection to the leaky fault.

The relationship between the polymer concentration and a water viscosity multiplier was varied in Eclipse as a proxy for the inclusion of delaying agents in the polymer-gel solution. CO_2 leakage remediation was assessed during a total simulation period of 5 years.

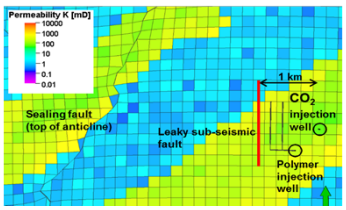

Fig. 2. Location of polymer injection well, sub-seismic fault and CO_2 injection well.

Effect of polymer viscosity on area of influence

The relationship between the polymer concentration and water viscosity multiplier was varied in the Eclipse simulator as a proxy for the inclusion of delaying agents in the polymer solution. Three cases were simulated for a fixed period of 20 days and their radiuses of influence were noted (Fig. 3).

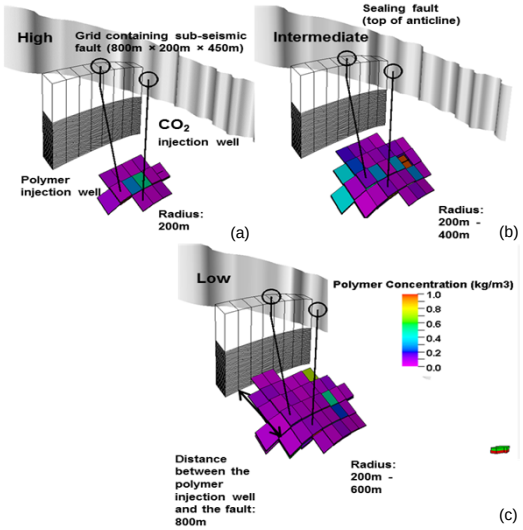

Fig. 3. Area of influence after 20 days of polymer-gel injections for a) high, b) intermediate, and c) low viscosity cases.

The proximity of polymer injection well to the leaky fault

The time period and amount of polymer required to seal the leaky fault at the base of the caprock was assessed. Four cases were considered in which the injection of polymer-gel at distances of 200m and 400m from the fault were compared using a horizontal well injection. For all cases, the injection was performed at the top of the reservoir (depth of 1,800m). The effect of varying polymer viscosity was also considered for low and intermediate viscosity ranges (Table 1). The results of simulations are presented in Fig. 4.

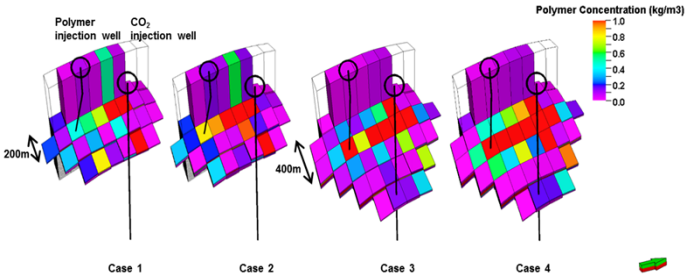

Fig. 4. The results of numerical simulations for polymer-gel injections at different distances to the leaky fault and with various viscosities.

Table 1. Polymer-gel injection cases considered to assess the effect of proximity of the injection well to the leaky fault.

Distance of polymer injection from the fault (m)	Polymer Viscosity	Case #	Amount of polymer injected (Mt)	Time period of injection (days)
200	Low	1	0.29	30
	Intermediate	2	0.34	95
400	Low	3	0.59	60
	Intermediate	4	0.63	185

Efficiency of polymer-gel remediation

To assess leakage remediation, it was assumed that gelation occurs almost immediately after the polymer injection was stopped. After polymer-gel treatment (Case 1 of Table 1), CO_2 injection was resumed for the remaining simulation period. Fig. 5 shows the results of CO_2 plume distribution after 1.7years when the CO_2 leakage was detected (Fig. 5a), and after 5 years of post-remediation CO_2 injections (Fig. 5b). Fig. 6 shows the results of the amount of CO_2 leakage into shallower formations for the unremediated case as well as the remediated cases of low and high polymer viscosity ranges.

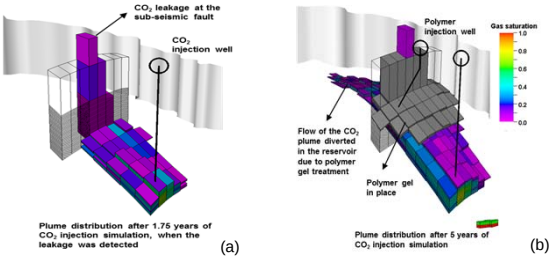

Fig. 5. The results of numerical simulations of CO_2 plume distribution: (a) at the time of leakage detection, and (b) after 5 years of post-remediation CO_2 injections.

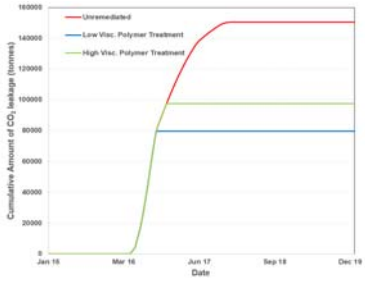

Fig. 6. The results of CO_2 leakage remediation for cases of un-remediated leakage, low and high viscosity polymer-gel treatments.

Conclusions

- ❑ The results of polymer-gel injection using Eclipse (E300) showed that polymer-gel injection (with delaying agents) from a horizontal well close to the leaky fault and near the caprock can seal the caprock and effectively remediate the CO_2 leakage.
- ❑ The simulation results also showed that increasing the period of injection, potentially clogs the CO_2 injection well when the polymer is injected at the bottom of the reservoir. Therefore, polymer injection just below the caprock using the horizontal well configuration was found to be more suitable.
- ❑ For the scenarios considered, an appreciable reduction in CO_2 leakage was achieved depending on the viscosity of the polymer gel used and no significant CO_2 leakage was observed after the implementation of polymer-gel treatments.

Acknowledgements

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