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Remediation of CO₂ Leakage from Deep Saline Aquifer Storage Based on Reservoir and Pollution Engineering Techniques

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CONTEXT

European Directive 2009/31/EC on the geological storage of CO₂ states:

Article 16, **Measures in case of leakages or significant irregularities**

« Member States shall ensure that in the event of leakages or significant irregularities, the operator immediately notifies the competent authority, and takes the necessary corrective measures ».

« **significant irregularity** » means any irregularity in the injection or storage operations or in the condition of the storage complex itself, which implies the risk of a leakage or risk to the environment or human health;

« **corrective measures** » means any measures taken to correct significant irregularities or to close leakages in order to prevent or stop the release of CO₂ from the storage complex.

➤ Available remediation measures mainly stem from the field of **reservoir and pollution engineering** (e.g. IEA GHG, 2007);

➤ But due to the **uniqueness of CO₂ geological storage activities** (time and spatial scale): the extent to which such measures can be used, if not **adapted**, for CO₂ storage in deep saline aquifers should be investigated;

➤ We adopt the global framework of the "source – transfer – target" approach in case of the monitoring plan has detected an accidental CO₂ leakage from the reservoir (either through faults or through abandoned wells).

TARGET

➤ **Objective:** remediate the **geochemical impact** of a CO₂ intrusion (release of Al, Ba, Cd, Cu, Fe, Mn, P, Pb and Zn);

➤ **Remediation technique:** monitored natural attenuation MNA;

➤ **2D Reactive transport simulation:** TOUGHREACT (Xu et al., 2004);

➤ **Properties based on the glauconitic sandstone Albain aquifer** (France) with mineral precipitation/dissolution reactions as being the main processes, (Vong et al., 2009).

a) After 10y of CO₂ leakage

b) Leakage stops and 10y of MNA

Trace element over time: example of Pb²⁺

Provided that the leakage is stopped, we show:

1. **Rapid decrease** of the free mobile accumulated gas in the aquifer;
2. **Natural attenuation of trace element release may be a long process**; in this case, the re-precipitation of the released Pb²⁺ requires almost 30y;
3. **More active intervention** procedures should be envisaged (e.g. pump and treats techniques).

SOURCE

➤ **Objective, in case of abnormal behaviour,** control the injection-induced overpressure within the reservoir;

➤ **Remediation technique:**

1. Pressure natural recovery;
2. Extract the injected CO₂;
3. Extract brine.

➤ **Multiphase flow transport simulation:** TOUGH2/ECO2n (Pruess et al., 2005);

➤ **Application case:** 2D model of the Dogger aquifer in the Paris basin (Le Guenan et al., 2009).

Over-pressure after 10y of CO₂ injection

Natural pressure recovery

TRANSFER

➤ **Objective:** control the upwards migration of the CO₂ leak;

➤ **Remediation technique:** hydraulic barrier through water injection in the overlying aquifer;

➤ **Multiphase flow transport simulation:** TOUGH2/ECO2n (Pruess, 2005) and Local grid refinement (e.g. Audigane et al., 2009);

➤ **Typical properties** of sedimentary aquifers.

CO₂ Saturation:

a) After 10y of CO₂ injection

b) After 1y of Water injection

Hydraulic barrier has a twofold effect:

1. The **CO₂ leakage flow rate** at the bottom of the overlying aquifer is **stopped**;
2. The **trapping** (dissolution and residual) of the accumulated CO₂ is **enhanced**.

At the bottom of the overlying aquifer

	Benefits = Pressure decrease		Cost
	in the injection zone	at 3km from the injection zone	
1.	65%	30%	1Mt CO ₂
2.	80%	45%	1.5Mt CO ₂
3.	70%	35%	1Mt CO ₂ +1 well+0.5 Mt brine

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