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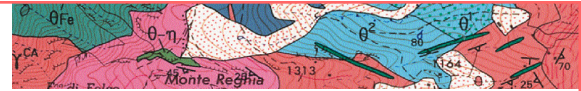
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Remediation of CO₂ Leakage from Deep Saline Aquifer Storage Based on Reservoir and Pollution Engineering Techniques

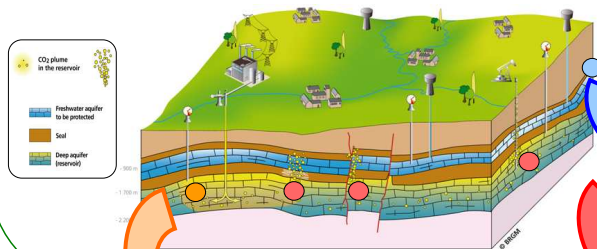
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CONTEXT

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

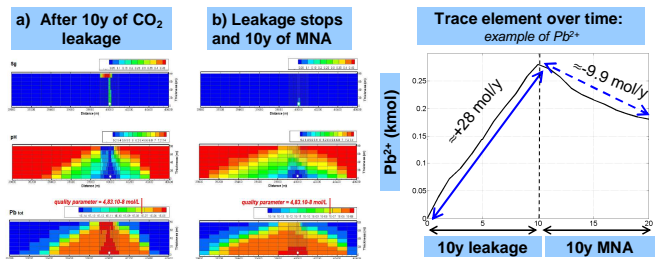
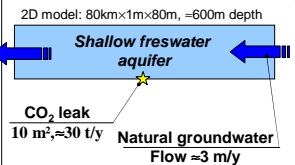
Article 16, **Measures in case of leakages or significant irregularities**
« Member States shall ensure that in the event of leakages or significant irregularities, the operator immediately notifies the competent authority, and takes the necessary corrective measures ».
« **significant irregularity** » 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

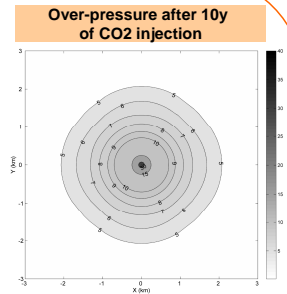
- **Objective:** remediate the **geochemical impact of a CO₂ intrusion** (release of Al, Ba, Cd, Cu, Fe, Mn, P, Pb and Zn);
- **Remediation technique:** **monitored natural attenuation MNA**;
- **2D Reactive transport simulation:** TOUGHREACT (Xu et al., 2004);
- **Properties based on the glauconitic sandstone Albian aquifer** (France) with mineral precipitation/dissolution reactions as being the main processes, (Vong et al., 2009).



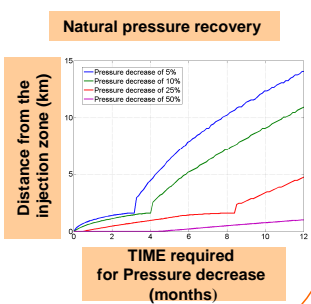
- Provided that the leakage is stopped, we show:
1. **Rapid decrease** of the free mobile accumulated gas in the aquifer;
 2. **Natural attenuation of trace element release may be a long process**; in this case, the re-precipitation of the released Pb²⁺ requires almost 30y;
 3. **More active intervention** 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).

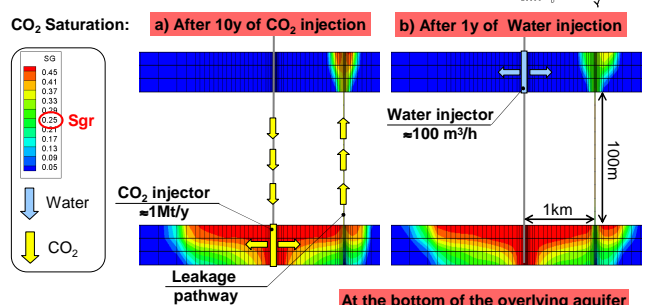
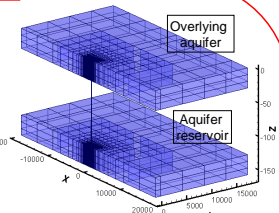


	Benefits = Pressure decrease		Cost
	in the injection zone	at 3km from the injection zone	
1.	65%	30%	1Mt CO ₂
2.	80%	45%	1.5Mt CO ₂
3.	70%	35%	1Mt CO ₂ +1 well+0.5 Mt brine

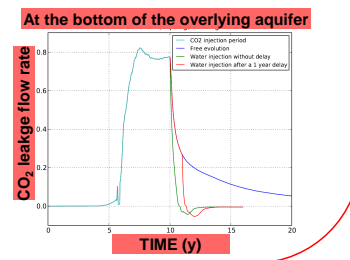


TRANSFER

- **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.



- 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**.



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