OVERVIEW OF MITIGATION AND REMEDIATION OPTIONS FOR GEOLOGICAL STORAGE OF CO2

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DISCUSSION OUTLINE

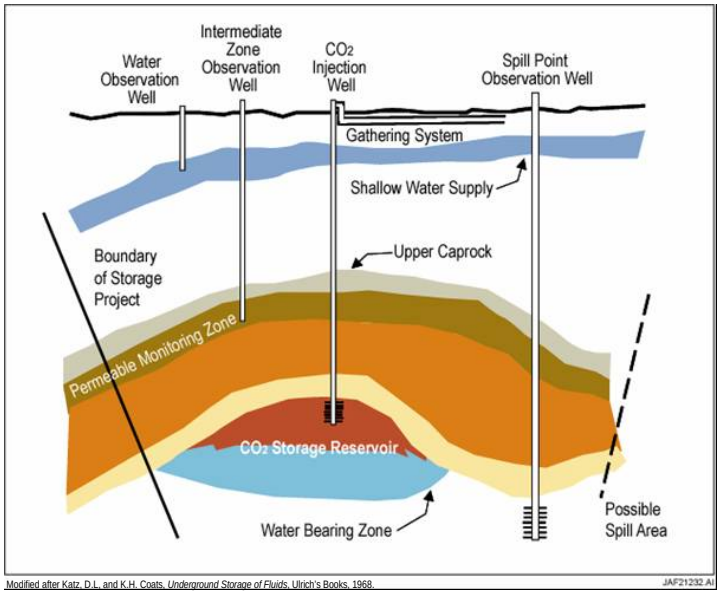
1. **Leak Prevention and Remediating Strategy**
2. **Mitigating CO2 Leakage**
   - Initial Steps
   - Detailed Response
3. **Remediating Impacts of CO2 Leakage**
4. **Costs of Mitigation and Remediation**
5. **Improving CO2 Storage Remediation Technology**

OVERVIEW OF THE LEAK PREVENTION AND REMEDIATION STRATEGY

A comprehensive strategy for leak prevention and remediation for CO2 storage contains five main elements.

1. **Selecting Favorable Storage Sites With Low Risks of CO2 Leakage.**
2. **Placing Emphasis on Well Integrity.**
3. **Installing and Maintaining a Comprehensive Monitoring System for the CO2 Storage Site.**
4. **Conducting a Phased Series of Reservoir Simulation-Based Modeling to Track and Project the Location of the CO2 Plume.**
5. **Establishing a "Ready-to-Use" Contingency Plan/Strategy for Remediation.**

Monitoring in Natural Gas Storage Fields



Modified after Katz, D.L. and K.H. Coats, *Underground Storage of Fluids*, Ulrich's Books, 1968. JAF21232.AI

INITIAL STEPS FOR MITIGATING CO2 LEAKAGE

Other than plugging the source of the leak (such as in a wellbore or a fracture), where possible, three basic steps would be used to mitigate or stop CO2 leakage from a reservoir:

- Reduce the pressure in the storage reservoir from which the leak is occurring;
- Increase the pressure in the geologic interval (generally a shallower reservoir) into which the leak is occurring; and
- Intercept the CO2 plume and extract the CO2 from the reservoir before it leaks, and, if possible, reinject CO2 into another formation.

DETAILED RESPONSE TECHNOLOGIES AND ACTIONS

Nine essential CO2 remediation and mitigation steps form the core of any strategy and response to CO2 leakage:

1. **Stop CO2 Injection.**
2. **Notification.**
3. **Identify Source of Leak.**
4. **Remediate Wellbore Leak.**
5. **Remediate Caprock or Spill-Point Leak.**
6. **Conduct Integrated Leakage and CO2 Accumulation Study.**
7. **Create Pressure Boundaries.**
8. **Drill Shallow CO2 Recovery Well(s).**
9. **Remediate or Reconfigure Storage Site.**

REMEDIATING THE ASSOCIATED IMPACTS OF CO2 LEAKAGE

Once the source of the CO2 leak has been identified and mitigated, the next step is to examine how to remediate, when required, the associated impacts of CO2 leakage.

1. **Remediating Accumulation of CO2 in Groundwater.**
2. **Remediating the CO2 Leakage into Vadose Zone.**
3. **Extracting CO2 from Near-Surface Accumulations.**
4. **Remediating Surface Accumulations of CO2.**

COSTS OF MITIGATION AND REMEDIATION: EXAMPLE STORAGE CASE

To illustrate the costs of remediation, we use a sample saline formation CO2 storage site.

- The storage site serves one new 1,000 MW coal-fired IGCC power plant, with 6 million metric tons of annual CO2 emissions. The site will operate for 50 years, with 30 years for CO2 injection and 20 years for post-closure monitoring.
- The CO2 storage site has 20 new CO2 injection wells, each capable of injecting 1,000 tonnes of CO2 per day (with a 90% operating factor), including 2 spare CO2 injection wells.
- The CO2 plume extends radially and underlies an area of about 50 square miles (216 km2) at the end of 50 years.

Representative Costs for Leak Mitigation and Remediation

Remediation Activity	Costs ($ Million)	Assumptions
1. Locating Sources of CO_2 Leaks		
Locating Old, Abandoned Wells	$1.0 to $2.0	Assumes 5 to 10 leak location surveys
New CO_2 Injection Wells	$3.0 to $6.0	Assumes 10 to 20 sets of diagnostic logs
2. Well Plugging		
Plugging Old, Abandoned Wells	$1.0 to $2.0	Includes plugging of 10 to 20 old wells
3. Well Problems		
Remediation	$2.00	Includes remediating 20 CO_2 injection wells
New Wells	$7.0 to $14.0	Includes drilling 2 to 4 new CO_2 injection wells
4. Geologic/Caprock Leakage		
Diagnostic Survey	$3.0 to $6.0	Includes 1 to 2 20 mi^2 seismic surveys
Horizontal Leak Detection Wells	$8.0 to $16.0	Includes 2 to 4 horizontal wells
Pressure Boundary	$10.0 to $18.0	Includes 2 to 4 horizontal wells plus one water plant
Other Problems	Large	May need to abandon original storage site and build a new site
Sub-Total	$35 to $66	

Assuming the injection of 180 million metric tones of CO2, the cost per ton for these efforts would be about $0.20 to $0.36 per metric ton of CO2.

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RECOMMENDATIONS FOR IMPROVING CO2 STORAGE REMEDIATING TECHNOLOGY

- Develop a “Best Practices Remediation Manual”.
- Study Remediation in the Natural Gas Storage Industry.
- Invest in Research and Technology Development for Remediation of CO2 Storage.
- Develop New Procedures and Technology for Locating and Assessing the Integrity of Abandoned Wells.
- Launch a Series of “Best Practice”, Large-Scale Field Tests of CO2 Storage.

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