Monitoring, Verification, and Accounting Plans for Protection of Water Resources During the Geologic Storage of Carbon Dioxide

Introduction

Geologic storage (GS) is an evolving strategy being investigated for the long-term management of carbon dioxide (CO₂) emissions. A key component of CO₂ GS is the presence of cost-effective and efficient CO₂ monitoring, verification, and accounting (MVA) programs designed to demonstrate that each GS site is performing as anticipated, CO₂ is being sequestered, and water resources are being protected (Figure 1). The U.S. Department of Energy’s (DOE’s) Carbon Storage Program is researching, developing, and demonstrating a wide variety of the technologies for GS, including those needed for MVA. This fact sheet, developed by DOE’s Water Working Group, focuses on the monitoring aspects of the MVA framework and provides an overview of the monitoring technologies that are being investigated for the protection of water resources.

MVA Monitoring Framework for GS Projects

An MVA monitoring framework has evolved that captures both the physical and temporal aspects of a typical GS project. This monitoring framework focuses on three distinct vertical zones: atmospheric, near surface, and subsurface, during four distinct periods of operation: preoperation (or baseline), operation, closure, and postclosure (U.S. Department of Energy, 2009) (Figure 2). The framework comprises appropriate monitoring technologies needed to validate GS storage performance and to meet applicable EPA permit requirements. For the protection of water resources, i.e., underground sources of drinking water (USDW) and surface water bodies, these potential pathways include 1) natural leakage from the reservoir through cap rock seals, 2) leakage from the reservoir through cap rock faults and fractures, and 3) leakage from reservoirs through wellbores. Diligent site characterization activities are the first line of defense for addressing these migration pathways, with the goal of screening out those sites where they pose a measureable risk. However, the potential existence of these pathways should still be addressed on a site-by-site basis along with other potential pathways that may be unique to individual sites.

An MVA plan contains a mixture of monitoring techniques designed to detect the presence or absence of migration along each of these pathways and to provide assurance that storage site integrity is maintained. Should migration along a potential leakage pathway be detected, the MVA plan provides the basis for implementing mitigation strategies (e.g., halting CO₂ injection or implementing pump and treat scenarios), if required, to prevent and/or reduce the impacts of this migration to water resources.
Baseline data are critical in establishing variability of monitored parameters before injection begins. In some cases, a year or more of baseline data may be needed to adequately establish preinjection conditions. After baseline has been established, it may be qualitatively and quantitatively compared to data from other phases of the project to assess the potential leakage pathway and to verify that impacts have not occurred to the environment.

Candidate Monitoring Technologies

Table 1 presents a subset of the potential monitoring technologies that are available for use in MVA plans at GS projects (U.S. Department of Energy, 2009). These monitoring technologies have been grouped based on the three previously identified zones (atmospheric, near surface, and subsurface).

Midale enhanced oil recovery/GS project in Canada. This BMP provides detailed descriptions of MVA approaches for the protection of water resources (Petroleum Technology Research Centre, 2012; International Journal of Greenhouse Gas Control, 2013). In addition, DOE recently updated its earlier document regarding BMP for MVA of GS projects (U.S. Department of Energy, 2012). As part of this effort, insights gained from the use of monitoring technologies by the RSCPs, as well as other large-scale demonstration tests, are presented. In summary, the waters that were targeted for analysis at these demonstration test sites and the nature of the analyses that were performed are as follows:

- Surface water, shallow groundwater wells (140 to ~1000 feet, both public and private) and upper- and lowermost USDWs:
  - Major cations, anions, pH, and other water quality measurements
  - Common trace constituents of concern
  - Isotopic analysis
- Formation water and brines (at point of CO2 injection and monitoring wells at injection depth):
  - pH, iron, and manganese, among other water quality parameters
  - Geochemical and tracer analyses
  - Ion chromatography (e.g., mobilization of metals), isotopic analyses, salinity, major ions, and HCO3−, CO3−, and CO2−

Each field example presented in the DOE (2012) update contains an overview of the geologic setting and the objectives of the field test, the relationship between site-specific risk analysis and monitoring plans, monitoring requirements, site injection operations, and the lessons learned from deploying monitoring tools in each setting. Collectively, these projects are investigating the best practices for MVA of CO2 GS in various geologic settings.

MVA Plan Requirements

EPA’s rulemaking entitled Federal Requirements under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO2) Geologic Sequestration (GS) Wells [40 CFR 146.81 et seq.], referred to as the Class VI Rule, includes testing and monitoring requirements for GS projects. In addition, EPA released a guidance document to describe the technologies, tools, and methods available to owners and operators of Class VI wells to fulfill the Class VI Rule requirements related to developing and implementing site- and project-specific strategies for testing and monitoring (U.S. Environmental Protection Agency, 2013). These rules apply only to wells designed solely for GS operations, not to other injection activities such as EOR.

The goal of the various testing and monitoring activities required by the Class VI Rule is to identify any risks to, and endangerment of, USDWs during the various phases of a GS project. The owner

Table 1. Candidate MVA Monitoring Technologies

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<th>Atmospheric Monitoring</th>
<th>Near Surface Monitoring</th>
<th>Subsurface Monitoring</th>
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<tr>
<td>• Ambient CO2 Concentration</td>
<td>• Groundwater monitoring</td>
<td>• Groundwater monitoring*</td>
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<td>• CO2 Surface Flux</td>
<td>• Fluid chemistry</td>
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or operator is expected to work in consultation with the UIC Program Director to develop a risk-based approach for Class VI well testing and monitoring that uses appropriate technologies and techniques, based on site-specific information, to ensure protection of and to minimize risk to USDWs. For example, while it is required that groundwater quality and geochemical changes above the confining zone(s) be conducted at a site-specific frequency and spatial distribution, surface air and soil gas monitoring are only necessary if required by the UIC Program Director.

Owners or operators must submit, as part of the permit application, a testing and monitoring plan that describes how they will meet the requirements of the Class VI Rule and establishes a detailed site- and project-specific testing and monitoring strategy. Additional details on the testing and monitoring plan are provided in the testing and monitoring guidance document referenced above as well as in other guidance documents such as the UIC Program Class VI Well Project Plan Development Guidance available on EPA’s Web site (http://water.epa.gov/type/groundwater/uic/class6/gsguidedoc.cfm).

The existing monitoring framework allows an assessment of the potential leakage pathways and determinations of whether impacts to water resources have occurred. In addition, large-scale demonstration projects are assessing the technologies that may provide for early detection of CO2 and brine movement in the subsurface to prevent contact with USDWs and other water resources of interest.

### Additional Information

**Federal Register, 2010, Federal requirements under the underground injection control (UIC) program for carbon dioxide (CO2) geologic sequestration wells: Final Rule, v. 75, no. 237, p. 77230–77303.**

**Federal Register, 2009, Part 98 mandatory greenhouse gas reporting: v. 74, no. 209.**


**Petroleum Technology Research Centre, 2012, Best practices for validating CO2 geological storage—observations and guidance from the IEAGHG Weyburn–Midale CO2 monitoring and storage project: Geoscience Publishing.**


**U.S. Environmental Protection Agency, 2013, Geologic sequestration of carbon dioxide—underground injection control (UIC) program Class VI well testing and monitoring guidance: EPA 816-R-13-001, March.**