Evaluation of Statistical Methods for CCS-Related Groundwater Monitoring Programs
Based on Illinois Basin - Decatur Project Monitoring

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Introduction
The Midwest Geological Sequestration Consortium is conducting the Illinois Basin – Decatur Project (IBDP), a large-scale carbon capture and storage (CCS) project in Decatur, Illinois, USA. The IBDP study area (Figure 1) covers approximately 185 square miles (480 km²). As part of an extensive Monitoring, Information, and Accounting (MIA) program, shallow groundwater monitoring is being conducted to verify that project activities are protective of human health and the environment (Figure 2).

Shallow regulatory compliance wells were installed in thin sands of the Pennsylvanian-aged Decatur Sandstone that was designated by the regulatory agency as the least important groundwater source of drinkable water (USDW). Carbon dioxide (CO₂) injection began at the IBDP site in November 2011 and terminated in November 2014 after 999,215 tonnes of CO₂ had been injected into the 3-Ms Sandstone.

Methodology

The goal of this study was to: 1) compare statistical methods that can be used for CCS-related groundwater monitoring, and 2) determine if statistically CO₂ injection at the IBDP site has impacted shallow groundwater quality (Figure 3).

• To evaluate if groundwater quality has been impacted:
  - Establish baseline (i.e., pre-injection) data
  - Model groundwater quality
  - Establish control charts
  - Establish non-parametric prediction limits

• To test if groundwater quality has been impacted:
  - Mann-Whitney test
  - Welch's t-test
  - Prediction limit
  - Tolerance limit
  - Control charts

The Illinois Basin – Decatur Project (IBDP) shallow groundwater network.

Test of Hypothesis
Mann-Whitney and Student’s t-test were used to determine if the mean measured parameter’s pre-injection and injection data are equal. Overall results produced by these methods show no significant difference in shallow groundwater quality between the pre-injection and injection periods (Table 1).

Acceptable ranges of concentrations (i.e., below thresholds of statistical methods: prediction limit, tolerance limit, and control charts) were established before injection began (Table 1). When a pre-injection data point is not within the acceptable range, the injection sample is flagged for further analysis. In the present study, the flagging was limited to the injection period and control charts respectively.

Table 1. Comparison of methods of statistical evaluation.

An evaluation was performed on 13 analytes that were present in all samples: pH, specific conductance, alkalinity, Ca, Mg, Na, K, Cl, SO₄, Br, Fe, Cu, Pb, and NO₃. Only a few data from well G104 fall outside of these ranges. Investigations suggest this ultra-saline related to periodic recharge from shallow strata.

Multivariate Statistical Evaluation of Groundwater Chemistry Data

Principal Component Analysis (PCA) was used for a more comprehensive evaluation of groundwater data collected from October 2010 to November 2014 (Figure 4). The goal of this assessment was to use a multivariate technique to understand the most extreme potentially affected groundwater quality and evaluate whether injection has impacted shallow groundwater quality.

Test Hypothesis for shallow groundwater quality data in IBDP, 2010–2014

Conclusions

Statistical Considerations Based on Groundwater Quality Date at 800M

- Distribution (i.e., normal distribution) of pre-injection data sets is a main factor to choose a statistical method.
- Acceptable range of concentrations (i.e., limits) vary based on statistical method used.
- Increasing the sample size generally improves a test’s power.
- Multivariate statistics are needed to perform integrated assessment of large datasets with many variables.

Project:
- Water-rock interactions were the primary mechanism that controlled water quality in the Permian basalt.
- Bivariate and multivariate statistical assessments showed CO₂ injection activities have not impacted shallow groundwater quality.

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References