Considerations Related to Post-Closure Monitoring of Uranium In-Situ Leach/Recovery Sites

An Advisory

Presented by
U.S. Environmental Protection Agency
Office of Radiation and Indoor Air
Radiation Protection Division

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Presented to
EPA Science Advisory Board
Radiation Advisory Committee
Overview of Presentation

• Draft Technical Report

• Elements of the Charge (Statement)

• Regulatory Context and Framework

• ISL/ISR Operations

• Elements of the Charge (Detail)
Content of Draft Technical Report


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Elements of the Charge

1. Comment on the technical areas described in this report and their relative importance for designing and implementing a monitoring network. Identify any technical considerations that have been omitted or mischaracterized.

2. Comment on the proposed approaches for characterizing baseline groundwater chemical conditions in the pre-mining phase and proposed approaches for determining the duration of such monitoring to establish baseline conditions.

3. Comment on the approaches considered for monitoring in the post-mining/restoration phase and the approaches considered for determining when groundwater chemistry has reached a “stable” level.

4. Comment on statistical techniques about which you are aware that have been used in other applications (particularly for the areas in items 2 and 3 above).
Regulatory Context

• The goal of baseline definition/restoration stability is to ensure that future users of groundwater are protected
  – Within the ore zone (water quality is not degraded)
  – Outside of the ore zone (i.e., no migration)
• Your advice will help us develop technical options to address
  – Technical analyses that best demonstrate that these goals are achieved
  – How much analysis/data is necessary
Regulatory Framework

• UMTRCA requires EPA’s standards to be consistent with requirements for non-radiological hazardous constituents under the Resource Conservation and Recovery Act (RCRA)

• 40 CFR Part 192 incorporates RCRA groundwater protection requirements for units managing hazardous waste, e.g.,
  – Landfills
  – Surface impoundments
  – Waste piles

• Separate permit for injection well(s) by EPA
  – Aquifer exempted for injection, but there is no exemption under UMTRCA
RCRA Monitoring Requirements

- RCRA requirements in 40 CFR Part 264 address:
  - Groundwater protection standard
  - Hazardous constituents
  - Concentration limits
  - Point of compliance
  - Compliance period
  - General monitoring requirements
  - Detection and compliance monitoring
  - Corrective action

- Flexibility in use of statistical methods
  - Focus on applicability of existing methods
Applying RCRA to ISL/ISR Sites

• RCRA applies well to conventional mills
  – Engineered surface impoundments
  – Processed material placed into impoundments
  – Intent to avoid releases to uppermost aquifer

• Why specific provisions for ISL/ISR facilities?
  – “Unit” is a natural feature not defined by engineered boundaries, likely not homogeneous
    • More complex to determine “background” conditions
  – May extend for tens of square miles
  – ISL/ISR process creates intentional “releases” of “contaminants” to groundwater
    • Potential to affect multiple water-bearing units
ISL/ISR OPERATIONS
Lifecycle of an ISL/ISR Facility

• Exploration and site characterization
• Establish baseline conditions
• Recover uranium from ore body
• Restore groundwater to predetermined conditions
• Demonstrate that restored groundwater has reached steady state
• Post-restoration stability monitoring of groundwater
• Decommission mined area and surface facilities
Comprehensive Cross-Section

- Ground Surface
- Overlying Aquifers
- Water Levels
- Ore Locations
- Underlying Aquifers

Source: Nuclear Regulatory Commission
Injection/Production Well Patterns
Ore Body

• Variability possible in
  – Shape
  – Thickness
  – Depth
  – Proximity to recharge zones
  – Degree of confinement
  – Flow properties
Typical Wellfield
Some Wellfields Close to Public
ELEMENTS OF THE CHARGE
Comment on the technical areas described in this report and their relative importance for designing and implementing a monitoring network. Identify any technical considerations that have been omitted or mischaracterized.

- There are three main technical issues for consideration:
  - Defining pre-operational baseline levels of constituents and chemical conditions
  - Defining post-operational stability of constituents and chemical conditions
  - Comparing post-operational monitoring results to a pre-determined level
Groundwater Monitoring Phases

Phase 1: Measure baseline groundwater concentrations
Phase 2: Conduct in-situ operations
Phase 3: Conduct wellfield restoration
Phase 4: Establish wellfield steady state
Phase 5: Conduct long-term stability monitoring

Phase 1: Begin Extraction
Phase 2: End Extraction
Phase 3: End Treatment
Phase 4: Begin Stability Monitoring
Phase 5: End Monitoring

Measured Groundwater Concentration

Time

Restoration Goal
Purpose of Statistical Testing

• Statistical testing is applied for two purposes
  – Determining trends within monitoring data
  – Determining compliance with restoration goals

• Tests used for these purposes may have different characteristics and data needs, depending on how the test is applied
Issues Associated with Statistical Tests

• Parametric vs. non-parametric
  – Relative performance depends on data distribution
  – How to manage non-detects?

• Outliers in data set
  – Discard outliers or include all data (as in WRS test)
  – Identifying outliers should be done with caution

• Level of confidence
  – Number of samples determined by desired level
  – Greater confidence calls for greater sampling
## Example Statistical Tests

<table>
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<tr>
<th>Mann-Kendall Trend Test</th>
<th>Wilcoxon Rank Sum (WRS) Test</th>
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<tr>
<td>• Used to show whether data are stable or trending upwards/downwards</td>
<td>• Used for comparing post-restoration data with baseline conditions to determine when pre-ISL/ISR conditions are achieved</td>
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<td>• Applied to test the post-restoration data from each well for trends</td>
<td>• Applied to determine if post-restoration values have achieved targeted remediation goals</td>
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<td>• Samples are analyzed for trends well by well</td>
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<td>• Applied after seasonal adjustment of the data and before post-restoration conditions are compared with baseline conditions</td>
<td>• Applied once conditions are stable</td>
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Statistical Analyses
Examples in the Draft Report

• Parametric and non-parametric statistical tests can be used
• Data demands differ between approaches
• Parametric tests generally more data demanding
  – Need to prove data distributions first
• We used non-parametric tests because of limited data
  – No preference at this point
• See Attachment D of draft technical report
Comparing Before and After

• The goal of baseline definition/restoration stability is to ensure that future users of groundwater are protected
  – Within the ore zone (water quality is not degraded)
  – Outside of the ore zone (i.e., no migration)

• Technical approaches can be bounded by:
  – Comparison of individual wells
  – Comparison of the wellfield as a whole (average)
Well Comparison – Before and After

• Comparing individual wells prior to operation and after restoration provides the most detail
  – Identification of anomalies and “hot spots”
  – Identification of problematic zones within the field
  – May allow definition of “regions” for trending

• There may also be drawbacks
  – Likely to be much more data-intensive
  – Need to account for each well’s zone of influence
  – Many wells may be required
  – Groundwater chemistry has deliberately been altered
Wellfield Average

• It may be simpler to average over the entire wellfield as a baseline/restoration measure
  – Comparable to natural conditions as the goal
  – Requires less intensive data analysis

• This approach also has drawbacks
  – No accounting for residual “hot spots”
    • May be “hotter” than “natural hot spots”
  – No accounting for trending within the field
Technical Challenges

• In considering the technical application of these approaches
  – What are the strengths and weaknesses of each?
  – What are the impediments or demands of each?
  – How can the best of each be kept ("hybridized")?
  – What would be lost by sampling only a subset of wells?
  – What would be defensible approaches to dividing up the wellfield into different zones? (e.g., geology)
  – What technical analyses do you recommend?
Potential Hybrid Approach?

• Keeping the protection goals in mind, a simple conceptual approach might involve:
  – Comparing the wellfield average to pre-determined restoration goals
  – Using individual wells to identify anomalies or “hot spots” that may need further attention
  – Conducting trend analysis to ensure that there is no unacceptable migration of constituents downgradient within the field
Case Study

Irigaray Site, Wyoming

- Restoration goal is baseline water quality, by constituent, on production-unit average
- 27 of 29 constituents met restoration goal
  - 13 measured constituents exceeded baseline min-max range and baseline mean
  - 6 others exceeded baseline mean without exceeding baseline min-max range
  - Modeling to demonstrate no further degradation
Comment on the approaches considered for establishing baseline groundwater chemical conditions in the pre-mining phase and the proposed approaches for determining the duration of such monitoring to establish baseline conditions.

- **Characterizing the baseline groundwater conditions prior to operations is important since baseline levels may be the level to which an ISL/ISR wellfield is to be restored**
- **Issues such as seasonality of the measurements can be important influences that need to be considered**
Characterizing Baseline

• The key to baseline monitoring is to adequately characterize groundwater *temporal* and *spatial* variability before ISL/ISR operations begin
  – What technical information is necessary to determine that variability has been *adequately* captured, i.e., to say that baseline conditions have been established with some level of confidence?
Establishing Baseline Conditions

• Need to consider the following components and parameters:
  – Hydrogeologic setting
  – Hydrogeochemical conditions
  – Concentrations of constituents listed in 40 CFR Part 192 (e.g., arsenic, barium, cadmium, ...)
  – Uranium ore deposit types and oxidation states
    • How might characterization activities affect conditions?
Baseline Development Issues

• Basic decisions on the number and spacing of wells, frequency and duration of sampling will depend on the size of the wellfield and
  – Aquifer properties
  – Connectivity with overlying and underlying aquifers
  – Sampling effects
  – Seasonal variation
Seasonal Adjustment

How important is it to seasonally-adjust data set?
Case Study

Dewey-Burdock Site, South Dakota

- Proposed action area of 10,520 acres
  - ~16.4 square miles
- Operator proposed to characterize baseline
  - 19 wells (14 existing, 5 newly drilled)
  - Multiple water-bearing units
  - Quarterly sampling over one year (July – June)
  - State required 12 additional wells be sampled
    - Monthly sampling for one year
    - Upgradient, downgradient, and within production zone
Statistical Approach for Baseline Sampling

- Estimate required number of wells
- Estimate required number of samples
- Adjust measured data for seasonality
- Use Mann-Kendall test, or other similar statistical test, to check for unexpected trends
Comment on the approaches considered for monitoring in the post-operational (post-mining) / restoration phase and the approaches considered for determining when groundwater chemistry has reached a “stable” level.

- One technical option the Agency is considering (for addressing the post-operational phase issue of whether the chemistry has reached a stable level):
  - Establish a performance standard with a requirement that the constituent levels attain a specified confidence level in wells within the wellfield.
Post-Operational Monitoring

• Demonstrate when the groundwater chemistry has reached “stable” levels
  – Distinction between “steady state” and “stability” is largely a regulatory decision – greater level of demonstration for stability

• Determine if post-operation restoration levels for groundwater constituents have been met
Statistical Approach for Steady State and Stability Monitoring

- Adjust measured data for each well for seasonality
- Use Mann-Kendall test for trends of each well
- If trend is detected, assess trend magnitude
  - Use linear regression or Theil-Sen test
  - If trend is not detected, compare baseline to stability monitoring results for a single well
    - Use WRS
    - Repeat for each well
- If the before/after comparison is made between multiple wells, first test all wells for homogeneity
  - Use chi-squared approach
- Test to confirm compliance of all wells with restoration goals
- If post-restoration data are from different wells than baseline data and trends are not detected, compare baseline to stability monitoring results for the pooled data of all wells combined
  - Use Wilcoxon Rank Sum (WRS) test
- Summary of approach from Section 8.5 of draft technical report
ISL/ISR Restoration: Short-Term Stability Monitoring Trend Analysis

Total PVs treated=13 (122 mgal)

Max=1054 mg/l
Min=308 mg/l
No SSI

Source: Nuclear Regulatory Commission
ISL/ISR Restoration: Stability and Long-Term Monitoring Trend Analysis

Total PVs treated = 9.95 (171 mgal)

Trends: 3 SSI and 3 NS

Source: Nuclear Regulatory Commission
Comment on the statistical techniques about which you are aware that have been used in other applications (particularly for the areas in elements 2 and 3 above).

• The Agency has examined different statistical techniques for use in different environmental programs
  – Reviewed statistics used in the RCRA and CERCLA programs for applicability to ISL/ISR issues
  – Conducted some analyses to provide a basis for discussion (see Attachment D in draft technical report)
Hypothesis Testing

- Hypothesis testing can be a useful means of framing the purpose of a given test
  - In considering restoration, the *null hypothesis* can be framed as an assumption that compliance with restoration goals has not been achieved and must be proven
  - In considering stability, the *null hypothesis* can be framed as an assumption that no trends are present, i.e., stability has been achieved
  - The *null hypothesis* also defines Type I and Type II errors for the situation (false positive/false negative)
Summary of Monitoring/Statistical Issues

• We are seeking SAB advice on two key issues related to the application of statistical methods for ISL/ISR groundwater monitoring:
  – Appropriate use of statistical approaches/methods to assess baseline and post-restoration stability questions
  – Data demands and requirements for statistical tests and their field implementation implications
Purpose of Advisory

• EPA requests SAB advice on technical issues related to groundwater monitoring at ISL/ISR facilities
  – Establishing representative baseline site conditions
  – Post-operational stability issues
  – Application of statistical methods to compare pre- and post-operational conditions
  – Identification of additional technical analyses and information that would be useful in developing site-specific, performance-based standards

• We also request comments on the draft technical report providing background information on these groundwater monitoring issues for uranium ISL/ISR operations