Groundwater Detection Monitoring

Technical Memorandum 16.04 October 2016

Alaska Department of Environmental Conservation
Division of Environmental Health
Solid Waste Program

Groundwater monitoring and corrective action are required at all solid waste disposal facilities unless otherwise specified in accordance with 18 AAC 820. **Detection monitoring** is required at Class I and several Class II landfills in Alaska in accordance with Alaska Department of Environmental Conservation (ADEC) Solid Waste regulation 18 AAC 60.850. Monitoring is conducted throughout the facility's active life and post-closure care period. Landfills are routinely monitored for the commonly-encountered landfill constituents listed in Appendix I of Title 40, Part 258 of the Code of Federal Regulations (40 CFR 258) to determine if there is evidence of a contaminant release from the facility. In accordance with 18 AAC 60.840, alternative or additional constituents or parameters may be required for monitoring by ADEC. A possible contaminant release is indicated by a change in groundwater quality, and is demonstrated by comparing the concentration of contaminants in upgradient (background) and downgradient (compliance) groundwater samples (i.e. interwell comparisons) or by evaluating past and present concentrations in samples from a given monitoring location (i.e. intrawell comparisons). Statistical analysis of the results substantiates whether a downgradient or current concentration is significantly different from the background or baseline concentration.

Groundwater Monitoring System

An effective detection monitoring program requires assessing many factors to ensure that monitoring will detect any contaminant release, but not falsely imply a landfill impact has occurred. A thorough understanding of the site's hydrogeology and a monitoring system that reflects those site-specific conditions is necessary to allow accurate assessment of a landfill's impact on local groundwater quality. See our Hydrogeological Studies Fact Sheet for more information on how to characterize groundwater in preparation for a detection monitoring program as well as the ongoing assessment of groundwater conditions.

Once groundwater flow has been *determined*, at least one well (more may be necessary) must be installed upgradient of the landfill to establish background water quality for comparison. Additional upgradient background wells are recommended for greater statistical power. Several compliance wells must be installed downgradient of the landfill in locations likely to intercept any contaminant releases. The size of the facility, the groundwater flow direction, and the complexity of the hydrogeology determine the number and placement of these wells [18 AAC 60.825(e)].

Properly installed and maintained wells are essential for a monitoring system to operate effectively. Monitoring wells must be designed and installed according to the ADEC Contaminated Sites Program September 2013 Monitoring Well Guidance. Direct push wells may be used for short-term purposes, such as the hydrogeological study, but are not approved for long-term landfill monitoring. Permanent monitoring wells must be drilled. Maintenance of the monitoring wells is also essential to an effective monitoring system. Well structures must be visually monitored for damage and field and analytical results must be reviewed to determine if wells may be fouled and require redevelopment or replacement. See the Maintaining Monitoring Wells Technical Memorandum for details.

Monitoring Schedule

Once the wells are completed for a new landfill, at least four independent samples from each well must be collected prior to waste being placed in the landfill to establish initial background concentrations. At least four additional samples must be collected from each well during the first year of operations. Initial sampling should occur quarterly to best represent the four seasons and allow evaluation for potential temporal variability. Additional wells installed at an existing facility must be sampled quarterly over the first year and thereafter in accordance with the approved monitoring schedule. Future monitoring will occur during the active life and post-closure care of the landfill at a schedule as determined by the ADEC.

Quality Assurance Project Plan

In accordance with 18 AAC 60.830, a landfill owner/operator must establish monitoring procedures that result in a consistent and accurate representation of the groundwater quality at the upgradient and downgradient wells. The elements of a Quality Assurance Project Plan (QAPP) (a.k.a. Monitoring Plan) must provide the appropriate detail to properly collect the groundwater samples, ensure program specific analytical sensitivity requirements are met, analyze the samples for the appropriate parameters, evaluate the data usability, and perform statistical analyses of the results. Implementation of the QAPP, regardless of the individual performing the task(s), provides the necessary consistency to maintain an effective detection monitoring program. For additional assistance, ADEC has developed a QAPP Checklist for landfill groundwater monitoring.

Note: Detection monitoring requires analytical detection limits be as low as technologically achievable to support the project specific data quality objective of detecting changes in groundwater quality as opposed to comparison to a regulatory standard.

Statistical Analyses for Detection Monitoring

Once the site hydrogeology is clearly understood, the basic assumption in detection monitoring is that the facility is not impacting groundwater unless statistically demonstrated otherwise (i.e. innocent until proven guilty). Statistical comparisons are made between background and downgradient compliance wells (i.e. interwell comparisons), or over time in a single well (i.e. intrawell comparisons), to identify significant changes in groundwater quality that may be caused by the landfill. Intrawell comparisons might be required if no upgradient background can be determined; as an interim measure when there is not enough data to statistically calculate background; when there is a change in groundwater flow; or if the upgradient background becomes contaminated from an outside source. The regulation in 40 CFR 258.53 explicitly identifies five statistical procedures that can be used for detection monitoring, but not every test will be appropriate at a given site or for each constituent. The appropriate statistic requires consideration of the accumulated data for normality, independence, outliers, non-detects, spatial and temporal variability, etc. See Chapters 6 in EPA's *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities - Unified Guidance* for recommendations on choosing the proper statistical methods for detection monitoring. The Interstate Technology and Regulatory Council's (ITRC's) *Groundwater Statistics for Monitoring and Compliance* (ITRC 2013) provides guidance on the practical application of groundwater statistics to groundwater detection monitoring as well as other stages within the environmental project life cycle.

Note: Statistical testing methods should be reevaluated as necessary as additional data are collected and/or as site conditions change.

Establishing Background Concentrations

The initial step in developing a detection monitoring program is establishing background concentrations for the required constituents. Background conditions are represented by groundwater that has not been affected

by the landfill and is assessed by sampling groundwater before it flows under the landfill. This requires an assessment of groundwater data that has not had the potential to be impacted by the landfill. Otherwise, challenges exist in differentiating between variability due to natural conditions or from landfill impacts. Background concentrations are used as the baseline or the reference level for statistical comparisons. Selection of background either from an upgradient location or at a given location over time is dependent upon whether or not groundwater samples across the site are comparable and represent the same aquifer. In some instances a suitable background location may not be available upgradient of the landfill. In such cases, an alternative location can be approved for use as a background well. However, enough data must be collected to statistically make this determination. EPA's Unified Guidance recommends a minimum of 8 to 10 independent background samples before performing most statistical tests, but as many background data points as possible are preferable to provide adequate statistical power to control false positive and negative errors. ADEC requires at least four independent samples from each well prior to waste being placed in the landfill to establish initial background concentrations and at least four additional samples collected from each well during the first year of operation. The selection of statistical test for detection monitoring may dictate how much background data is necessary. Although prediction limits, control charts or tolerance limit tests may be used requiring very small future sample sizes per compliance well, they require larger background sample sizes to have sufficient power.

Assessment of temporal (over time) and spatial (across site) variability is fundamental to determining the appropriate statistical approach. Assessment of both requires collection of data from multiple monitoring events over several seasons. Temporal effects can be assessed by evaluating time series plots from multiple wells and by performing a one-way ANOVA. Seasonal trends are readily identifiable as a regular pattern of changing concentrations noted at multiple wells (similar in direction and magnitude) and should not be confused with temporal variability. Temporal variability may result from precipitation or recharge events whereby there is no identifiable pattern. Spatial variability may be due to natural heterogeneity in the aquifer or to anthropogenic factors. EPA's Unified Guidance Chapter 13 recommends use of box plots and ANOVA testing to evaluate for spatial variability. Side-by-side comparison of box plots from multiple wells provides a picture of variability between wells. ANOVA testing on the other hand compares pooled data from one well to that of another well and spatial variability is noted by differing mean concentrations in the two data sets.

Statistical Comparisons for Detection Monitoring

Once the type of background (upgradient or baseline) has been determined, the appropriate statistical test should be used to detect a statistically significant landfill impact. Prediction limits, tolerance limits, and control charts allow individual samples to be compared to pooled background samples. T-tests and ANOVA-type testing are only appropriate for comparing pooled compliance samples to pooled background samples. EPA's Unified Guidance recommends prediction limits over tolerance limits for detection monitoring for their proven use of retesting strategies and ability to define an exact false positive error rate. Control charts are an alternative recommendation to prediction limits with the added benefit of evaluating data graphically over time. Whereas prediction limits only capture a snapshot-in-time comparison between the most recent compliance and background concentrations, data are plotted on the control chart as they are collected providing a visual overview of concentration patterns over time as compared to background. However, control charts lack the prediction limit testing statistical power and ability to set false positive rates. Selection of any statistical test method should therefore take into consideration the strengths and limitations of each test.

Statistical Methods Identified Under 40 CFR 258.53(g)

1. Parametric analysis of variance (ANOVA)
2. ANOVA based on ranks
3. Tolerance interval or prediction interval
4. Control chart
5. Alternative approved method

If no there are no detections in background to which compliance monitoring data can be statistically compared, Chapter 6 of the Unified Guidance recommends use of the Double Quantification Rule. However, whereas the Unified Guidance recommends comparing compliance results to the highest non-detect background analytical reporting limit, ADEC requires comparison to the highest non-detect background analytical detection limit or limit of detection and a weight of evidence approach. Any confirmed compliance well detection (i.e. repeated detection) above the highest non-detect background detection limit or limit of quantification should be considered indicative of a possible landfill impact, but the weight of evidence should be carefully considered prior to advancement to assessment monitoring (e.g. sufficient sample size to make comparisons, detection of multiple landfill constituents, possible offsite source, sampling or lab issue).

Note: ADEC-specific policies on data handling outlined in the *Guidelines for Data Reporting, Data Averaging, and Treatment of Non-Detect Values Technical Memorandum* (ADEC 2012) supersede those made in the Unified Guidance on these data handling issues.

If during detection monitoring the concentration of any constituent statistically exceeds the background (or baseline) concentrations, then the landfill operator must:

- within 14 days from receiving sample results indicating a statistical exceedance:
  - place a notice in the operating record, and
  - notify ADEC in writing; and
- within 90 days from receiving sample results indicating a statistical exceedance:
  - establish an assessment monitoring program in accordance with 18 AAC 60.860, or
  - under separate cover, demonstrate that the exceedance is not a landfill impact (i.e. an offsite source is to blame), or that an error in sampling, analysis, statistical evaluation, or natural variation occurred.

Detection Monitoring Report

A detection monitoring report should include the minimum required content for a landfill groundwater monitoring report as outlined in our Landfill Groundwater Monitoring Checklist (ADEC 2016).

References

EPA. 40 CFR Part 258, Subpart E- Groundwater Monitoring and Corrective Action

ADEC. 18 AAC 60.820 - 850. Groundwater Monitoring

EPA. 2009. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities - Unified Guidance*

ITRC (Interstate Technology & Regulatory Council). 2013. *Groundwater Statistics and Monitoring Compliance, Statistical Tools for the Project Life Cycle*. GSMC-1. Washington, D.C.: Interstate Technology & Regulatory Council, Groundwater Statistics and Monitoring Compliance Team. http://www.itrcweb.org/gsmc-1/.