Determining Whether a Facility Degrades Ground Water (Newsletter)*

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Ground water pollution is a nationwide concern associated with landfills, hazardous waste disposal sites, mine mills, tailing ponds, power plants, and similar industrial facilities. While regulators might state explicit instructions for ground water sampling and chemical analyses, not all the statistical models are appropriate or capable of separating natural variability from anthropogenic influence.

Analysis of Variance (ANOVA) models are commonly used to compare mean values of two or more populations (of upgradient and downgradient ground water monitoring wells in this case). Both univariate ANOVA and multivariate MANOVA can yield false positive, and other incorrect, results when used to determine whether a facility degrades downgradient water quality.

Ground water quality usually includes consideration of multiple chemical constituents rather than a single one. A univariate ANOVA model does not allow multiple comparisons and will produce false positive or other incorrect results. Multivariate ANOVA (MANOVA) is also not appropriate because it requires equal variance of all constituent concentration values, a condition which almost never occurs with environmental data.

Another reason to not apply ANOVA/MANOVA to ground water analyses is that they are more sensitive to spatial variability than to concentration variability. Spatial variability affects mean values but rarely affects variance values. Therefore, small differences in mean values can produce false significant results. When a facility degrades ground water both mean concentrations and variances differ so only larger differences produce significant results. Pre-construction baseline data can display upgradient and downgradient differences because the ANOVA/MANOVA F-statistic tests for any significant difference, and such differences might be among only upgradient wells or only downgradient wells. Also, intra-well constituent concentrations vary over time so small differences will be attributed to the facility rather than inherent natural variability. In the common situation where there are more downgradient monitoring wells than upgradient monitoring wells there is an increased likelihood that natural variability in means and variances of the more numer-

ous downgradient wells will be misinterpreted as proof of water quality degradation by the facility.

Parametric ANOVA requires all data to fit a normal distribution and to have the same variance; environmental chemical data almost never meets these constraints. Regulators sometimes recommend use of nonparametric ANOVA to avoid these problems. Nonparametric ANOVA does not require data to fit a probability distribution but does require all samples to have the same variance. This, too, almost never occurs with environmental chemical data. ANOVA results can indicate downgradient water quality degradation when that conclusion comes from violating the model's assumptions or the models inability to detect a narrow contaminant plume that affects only one of several downgradient wells.

Use of ANOVA requires pooling data over the reporting period. If there is a brief contaminant release by the facility during that time the analysis will not detect it because the increased concentration values will occur in only one or two of the pooled samples.

Rather than ANOVA/MANOVA models to determine whether a facility degrades ground water use a nonparametric spatial statistical model. These models accommodate spatial and temporal variability inherent in environmental chemical data and support better informed decisions whether a facility degrades ground water.

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