Guidance for
Comparing Background and Site Chemical Concentrations in Groundwater

Florida Department of Environmental Protection
Division of Waste Management
Office of District & Business Support
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Overview

The purpose of this guidance is to describe procedures acceptable to the Florida Department of Environmental Protection (FDEP) for the comparison of site contaminant levels to background concentrations in groundwater. An evaluation of local background concentrations is appropriate at a cleanup site whenever it is suspected that certain contaminants detected above applicable cleanup criteria may be equal to, or less than, natural background concentrations. Some chemicals, such as inorganics and radionuclides, are present naturally in groundwater or may be introduced as contaminants. If they are present from a chemical release and exceed risk-based criteria, cleanup or other risk management measures are typically required. If the chemical is present due to natural conditions, cleanup is not needed under current rules, even if the concentrations exceed risk-based criteria. Consequently, it is important in the management of a number of sites to determine whether or not the presence of a chemical represents natural background conditions.

Some chemicals, both man-made and natural, can be enriched in area groundwater due to human activities not associated with a specific release of contaminants. An example of this would be pesticides and nitrate associated with agricultural activity. Low levels that exist in the environment due to an area wide application of these chemicals are termed anthropogenic background. Current statutes and rules in Florida do not recognize comparisons with anthropogenic background concentrations as a basis to eliminate a chemical as being of concern for a site. However, when delineating the boundaries of contamination attributable to a release, anthropogenic background concentrations become important. They are used to help establish the area where liability for cleanup exists. The procedures described in this guidance are also useful in this context (i.e., for comparing site with anthropogenic background), despite the somewhat different objective from comparisons with natural background.

Note that this guidance presents some alternatives for demonstrating background conditions when it is believed that some of the chemicals found on-site are not site related but rather are due to either natural or anthropogenic background. If background is only being obtained to satisfy the rule requirements for site assessment (e.g., rule 62-780.600(3)(d) Florida Administrative Code (F.A.C.) then it generally will not be necessary to present the level of information described in this guidance. A much reduced data set, potentially a single sample from a single well, can be used to satisfy this rule requirement. This single background well and sample could also be adequate to establish whether or not site groundwater qualifies as Poor Quality as defined by 62-780.200(35), F.A.C.

Decision to Perform Background Sampling

Background analysis should be conducted in the early stage of the site investigation process. Typically, an environmental site investigation is conducted in response to a known or suspected release of contaminants. The media sampled, and the analytical tests performed, are based on the history of site utilization or knowledge of specific contaminants released. This initial screening for contaminants may identify one or more naturally occurring constituents in site groundwater that show concentrations above applicable cleanup target levels. In shallow groundwater in Florida, metals such as aluminum, iron and manganese are frequently present in dissolved form

at concentrations above groundwater cleanup criteria. If such naturally occurring constituents are detected above screening criteria, but suspected to be representative of local background concentrations, then an analysis can be performed to support that claim and avoid further site assessment or cleanup.

Location and Number of Samples

Typically, background sampling well locations should be as geographically close to the corrective action site as possible, but not in the area(s) suspected to have been impacted by the site or other non-site related activities. Wells installed for use in determining background water quality should be located outside impacted aquifer zones of known or suspected contaminant source areas. Background samples may be collected from unimpacted areas of the study site, or from areas adjacent to the site, if appropriate. When collecting background samples from on-site locations, plume concentration gradients may be useful in determining appropriate sampling locations. Samples collected during the contamination assessment phase may be used in the background study if it is confirmed by plume concentration gradients, and additional background sampling results, that the samples were collected from unimpaired areas and are, therefore, indicative of natural background concentrations. Background data from similar and nearby sites may also be used if those data were collected using standard sampling protocols comparable to that of the site characterization sampling.

Wells used to establish background conditions should be located up-gradient or side-gradient to the investigation site. The well screen interval(s) need to be comparable with those that establish onsite groundwater quality. In Florida this usually assures that groundwater samples are being taken from the same aquifer zones. The actual number of groundwater samples needed to establish site specific background can vary considerably depending on the selected basis upon which background concentrations are derived. A minimum of three groundwater wells sampled quarterly for one year per impacted aquifer zone is a good rule-of-thumb for background sampling. This accounts for both spatial and seasonal variation, and provides at least 12 values for data analysis. The Department may require additional samples above this suggested minimum number on a case-by-case basis.

Concentrations from background studies published in the literature cannot be used as the basis of comparison with site concentrations. However, published background studies may be of value in determining whether or not a site-specific background data set lies within the range of observations by others. If it does not, the validity of the site-specific background data set may need to be evaluated. Also, in measuring chemical concentrations in background samples, the same analytical methods used for the investigation source area samples should be employed.

Simple Approach for Comparing Site and Background Data

For most sites, a determination of whether site concentrations represent background conditions can be made without using statistical tests. The basic approach is to define the upper end of the range of background concentrations as the lower of:

1) the maximum background concentration, or
2) twice the mean background concentration.

The maximum concentration in the site impacted groundwater zone is compared with this upper limit on background. If the maximum concentration is less than or equal to this upper background limit, the chemical can be considered to be background and removed from further consideration in any risk assessment or site remediation decisions. If site concentrations are above background, and background concentrations are above risk-based criteria, cleanup to background levels only may be warranted. In this situation, the site-specific upper limit on background (i.e., the lower of the maximum or twice the mean background concentration) can be used as a not-to-exceed cleanup criterion. That is, removal or management of all concentrations above this value will be considered to have restored the site to background conditions with respect to a given contaminant.

Statistical Approach for Comparing Site and Background Data

As an alternative, and if sufficient data are available, statistical methods offer a stronger, more robust method of comparing site and background data. Unless a compelling case can be made for a parametric test, non-parametric approaches should be used. The WRS test is recommended for use in site-to-background comparisons when the site and background data sets contain no more than 40% non-detect values in the sampling results (EPA, 2002). The WRS test compares two data sets of size n and m (n>m), and tests the null hypothesis that the samples were drawn from populations with distributions having the same medians, and is not performed on data sets having less than four detected concentrations. The USEPA guidance (EPA, 2002) listed below provides instruction on how to compare sampling data sets using the background "Test Form 2" which begins with a null hypothesis (H_o) that states "The site distribution exceeds the background distribution by more than a substantial difference". The following points must be considered in applying this guidance:

- FDEP requires at a minimum the use of Test Form 2 of the statistical test described in USEPA guidance cited above. This form tests the null hypothesis that the mean chemical concentration of site samples exceeds background by more than a specified concentration level. Test Form 1 of the null hypothesis may also be included as additional information. Test Form 1 employs the null hypothesis that the mean chemical concentration of site samples does not exceed background.

- In general, a *minimum* of 15 samples from separate wells for both the background and contaminated site data sets is required. Greater numbers of samples may be needed, depending in part upon the confidence and power desired in the analysis. Default confidence and power specifications can be found in the USEPA guidance cited above.

- Form 2 of the test requires specification of a "substantial difference" (S). The substantial difference is the value above which a sample is no longer considered a result of variation in background concentrations and is deemed contaminated. There are several ways to derive S, as summarized in Appendix A of the USEPA guidance. At present, S derived using any of the methods described in Appendix A will be accepted.

- Tests should be conducted as "one-tailed". Critical values for a one-tailed WRS test (Test Form 2) are calculated using the following equation:

$$W_{crit} = \frac{n_B(N+1)}{2} + z_\alpha \left[\frac{n_S n_B (N+1)}{12} \right]^{1/2}$$

where W_{crit} is the critical value for the WRS test, n_S is the number of measurements in the site sample, n_B is the number of measurements in the background sample, $N = n_S + n_B$, and z_α is the $100(1 - \alpha)^{th}$ percentile of the standard normal distribution. A table of common z_α values is included below:

Confidence Level (α)	z_α value
0.20	0.842
0.15	1.039
0.10	1.282
0.05	1.645
0.01	2.326

- For "non-detect" background samples, one-half the detection limit should be used as a surrogate value.[1]

- As with non-statistical approaches, comparisons should be made between site and background groundwater from the same aquifer zone.

- The background data set should be examined carefully for the presence of outliers, i.e., data that may not in fact represent background conditions. Formal outlier tests as well as professional judgment can be used in evaluating the background data set.

Under extraordinary circumstances, there are alternative approaches that may be of value. Before using any alternative approaches in comparing site and background data sets, it is advisable to consult the Department and gain approval in advance.

References:

Department of the Navy (DON), 2004, *Guidance for Environmental Background Analysis, Volume III: Groundwater*. NFESC User's Guide UG-2059-ENV. Naval Facilities Engineering Command. April.

[1] The US EPA recommends using zero as a surrogate for "non-detect" values. This guidance suggests the use of one-half the detection limit to be consistent with FDEP convention. Substitution of non-detects with surrogate values instead of interpolating the values may raise some statistical issues. However, substitution is suggested here for simplicity.

U.S. Environmental Protection Agency (EPA), 2000, *Guidance for Data Quality Assessment: Practical Methods for Data Analysis*, EPA QA/G-9, QA00 Update, Office of Environmental Information, EPA/600/R-96/-84, July.

U.S. Environmental Protection Agency (EPA), 2002, *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites*, Office of Emergency and Remedial Response, EPA 540-R-01-003, September.