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# Inorganic and Radionuclide Background Data for Soils, Canyon Sediments, and Bandelier Tuff at Los Alamos National Laboratory

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## Abstract

This report summarizes the background data collected for soils, canyon sediments, and Bandelier Tuff in the area of Los Alamos National Laboratory (LANL). These data are used in the Resource Conservation and Recovery Act (RCRA) corrective action process to distinguish between contaminated and uncontaminated media and to establish cleanup levels for sites scheduled for remediation. The complete background data are presented in graphs in Appendix A. Summary statistics, including the upper tolerance limit (UTL) for each analyte, are provided in the body of this report. UTLs, which represent the upper range of the background concentrations, can be used as background values. Descriptions of how background comparisons are made for inorganic chemicals and radionuclides in the RCRA corrective action process are available in *Application of LANL Background Data to ER Project Decision-Making, Part 1: Inorganics in Soils, Sediments, and Tuff* (Ryti et al. 1996, ER ID 53953) and *Part II: Radionuclides in Soils, Sediments, and Tuff* (Environmental Restoration Project Decision Support Council and Earth Science Council 1997, ER ID 56186).

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## 1.0 INTRODUCTION

Los Alamos National Laboratory (LANL or "the Laboratory") has been in operation for over 55 years. To determine the impact of Laboratory operations on surface water, groundwater, soil, sediment, and bedrock, it is necessary to understand the background chemistry of the area's geological and hydrological media. The Resource Conservation and Recovery Act (RCRA) corrective action process developed by the U. S. Environmental Protection Agency (EPA) requires that accurate natural background levels be developed (reference). These background levels are the basis for the statistical analysis used to support risk management decisions in the Laboratory's Environmental Restoration (ER) Project. Accurate natural background levels are necessary to (1) distinguish between contaminated and uncontaminated media, (2) establish cleanup levels for sites scheduled for remediation, (3) develop sampling and remediation strategies, and (4) understand the processes controlling contaminant transport.

During the past five years, the Laboratory has conducted extensive analyses of soils, sediments, and Bandelier Tuff to determine the natural background levels of a variety of inorganic chemicals and radionuclides. These background data are summarized in this report. Details on the background comparison process for inorganic chemicals and radionuclides are provided in *Application of LANL Background Data to ER Project Decision-Making, Part I: Inorganics in Soils, Sediments, and Tuff* (Ryti et al. 1996, ER ID 53953) and *Part II: Radionuclides in Soils, Sediments, and Tuff* (ER Project Decision Support Council and Earth Science Council 1997, ER ID 56186).

This report summarizes the results from several studies that address the nature and variability of background levels for a variety of soil profiles, sediment types, and identified geological subdivisions of the Bandelier Tuff. Background levels for soils are addressed in *Natural Background Geochemistry and Statistical Analysis of Selected Soil Profiles* (Longmire et al. 1995, ER ID 52227), *Natural Background Geochemistry, Geomorphology, and Pedogenesis of Selected Soil Profiles and Bandelier Tuff* (Longmire et al. 1996, ER ID 55115), and *Baseline Data for Fallout Radionuclides at LANL* (Campbell 1998, ER ID 57858). This report summarizes these studies, including (1) sample locations and descriptions; (2) the analytical methods used to determine background analyte distributions; (3) the relationship among trace-element background levels, soil chemistry, and the degree of soil development (pedogenesis); and (4) statistical summaries of the background data. The background geochemistry of canyon sediments is presented in *Geochemistry of Background Sediment Samples at Technical Area 39* (Reneau et al. 1995, ER ID 52227) and *Natural Background Geochemistry of Sediments* (McDonald et al.

1997, ER ID 55532). This report summarizes these studies, including (1) sampling locations, (2) analytical methods, (3) differences in background levels among various canyons, and (4) differences in background levels among various geomorphic units and sample grain sizes. Lastly, the background analyte chemistry for the Bandelier Tuff is presented in *Natural Background Geochemistry of the Bandelier Tuff and Other Rock Units* (Broxton et al. 1995, ER ID 52227) and *Natural Background Geochemistry of the Bandelier Tuff at MDA P* (Broxton et al. 1996, ER ID 54948). This report summarizes these studies, including (1) sample locations, (2) sample collection and analytical methods, and (3) statistical data summaries.

To facilitate review of this document, Table 1.0-1 summarizes how the background studies described above established the background values for inorganic chemicals and naturally-occurring radionuclides that are described in this report. Table 1.0-1 also shows how fallout concentrations of radionuclides were established.

**TABLE 1.0-1**
**SUMMARY OF SOURCES USED**
**TO ESTABLISH BACKGROUND AND FALLOUT VALUES**

| Chemical Group | Soil | Sediment | Tuff |
|---|---|---|---|
| Inorganic chemicals | Directly measured in samples collected from several soil profiles in uncontaminated locations in Los Alamos County (except silver, for which the detection limit is used as background) | Directly measured in samples collected from five canyons in Los Alamos County (except antimony and thallium, for which soil data are used as surrogate background) | Directly measured in samples collected from several tuff profiles in uncontaminated locations in Los Alamos County (except mercury, for which the detection limit is used as background) |
| Naturally-occurring radionuclides | Not measured; sediment data are used as surrogate background | Directly measured in samples collected from three canyons in Los Alamos County | Used total elemental abundance (mass) of thorium and uranium to estimate the activity of isotopes |
| Fallout radionuclides | Used Laboratory Environmental Surveillance data for 1992 through 1995 | Directly measured in samples collected from three canyons in Los Alamos County | Not measured; fallout radionuclides are not expected in subsurface samples and detection limits are used as background |

## 2.0 Statistical Data Treatment

Several data preparation steps are needed before statistical calculations can be performed. First, the data must be inspected for suspect values that are exceptionally high or low relative to the rest of the data. Second, the data must be evaluated to determine whether the background data for each medium, or medium subunit, are derived from a single population. This can be demonstrated by fitting the background data to a standard statistical distribution (e.g., normal, square-root normal, or lognormal). Appendix A shows the fit of the background data to a normal statistical distribution. For further information on data transformations used for statistical distribution analysis, refer to *An Analysis of Transformations* (Box and Cox 1964, ER ID 57572) or Appendix C of *Introduction to Variance Estimation* (Wolter 1985, ER ID 57573).

For inorganic chemicals and some radionuclides, some data were reported as nondetected values. Nondetected values were typically reported as less than ("<") the method detection limit for that chemical. Values that were reported as nondetected by the laboratory were replaced by one-half of the detection limit value to calculate summary statistics. This replacement method is recommended by EPA when the frequency of nondetected values is relatively low (EPA 1992, ER ID 54947).

The upper tolerance limit (UTL) is a simple measure of the upper end of the background distribution. UTL values for the background data are calculated in one of four ways based on the statistical distribution of the data. These four calculations are described below.

For analytes that are normally distributed without any data transformation, UTL values are calculated using Eq. 2.0-1. The k-factor is dependent on the number of background samples with k-factor values increasing as sample size decreases (Gilbert 1987, ER ID 56179; EPA 1989, ER ID 54946).

$$\mathrm{UTL}_{0.95,0.95} = \text{mean} + \text{standard deviation} \times k_{0.95,0.95} \qquad \textbf{(Eq. 2.0-1)}$$

For analytes that are normally distributed after a square root transformation, the mean and standard deviation of the square-root transformed data are used in Eq. 2.0-2:

$$\mathrm{UTL}_{0.95,0.95} = \left(\text{mean} + \text{standard deviation} \times k_{0.95,0.95}\right)^2 \qquad \textbf{(Eq. 2.0-2)}$$

The UTL values for lognormally distributed elements are estimated by a first-order Monte Carlo simulation process (Longmire et al. 1995, ER ID 52227; Longmire et al. 1996, ER ID 55115). This simulation process uses the lognormal distribution function in the S-plus statistical programming

language. Inputs to this function are the lognormal mean (E) and the lognormal standard deviation (V). Definitions of E and V, as well as methods for calculating these statistics, can be found on page 164 of *Statistical Methods for Environmental Pollution Monitoring* (Gilbert 1987, ER ID 56179).

For analytes where a statistical distribution could not be estimated, a nonparametric approach was used to calculate UTL values (see Eq. 11.12 on page 141 of Gilbert 1987, ER ID 56179). The nonparametric UTL calculation is based on an order statistic of the analyte. The order statistic of the UTL is calculated from Eq. 2.0-3. Typically, the result of Eq. 2.0-3 is a noninteger order statistic value, which means that the estimated UTL value will be linearly interpolated between the appropriate nearest-integer order statistics.

$$\text{Rank(UTL)} = 0.95 \times (n+1) + 0.427 \times n^{0.5} \qquad \textbf{(Eq. 2.0-3)}$$

The UTL can be used as a background value, and analytes for which all potential release site (PRS) sample values are less than the UTL can be eliminated from further assessment. In cases where a UTL cannot be calculated, either the detection limit or maximum reported value is used as a background value.

## 3.0 SOIL BACKGROUND

In this report, the term "soil" refers to material overlying intact bedrock that has been subject to soil-forming processes such as the addition of organic matter, the vertical translocation of clay-sized particles, or the development of ferric oxyhydroxides. Thus, soils are the typical surficial material on mesa tops and hillslopes, and are widespread in canyon bottoms. At sites where potentially contaminated surface material represents imported fill or a combination of soil and fill, soil is considered to be the most appropriate background comparison material.

### 3.1 Inorganic chemicals

Information on the concentrations of 26 inorganic chemicals relevant to the Laboratory's ER Project are presented for a variety of soils and geomorphic settings across the Pajarito Plateau in two studies: *Natural Background Geochemistry and Statistical Analysis of Selected Soil Profiles* (Longmire et al. 1995, ER ID 52227) and *Natural Background Geochemistry, Geomorphology, and Pedogenesis of Selected Soil Profiles and Bandelier Tuff* (Longmire et al. 1996, ER ID 55115). These studies include analysis of 175 soil samples for background-elemental concentrations using two types of sample digestion techniques as described in Section 3.1.2.

### 3.1.1 Sample Locations

Twenty-one soil profiles distributed across the Pajarito Plateau were described in the field and were sampled for chemical analyses (see Fig. 3.1-1 and Table 3.1-1). These samples provide information about the varied soils and geomorphic settings that occur on the Pajarito Plateau, allowing for an evaluation of the variability in soil characteristics and chemistry within several of the soil series previously described by Nyhan et al. (1978, ER ID 5702). Most sampled soils were collected from mesa tops. Other geomorphic settings sampled include hillslopes and canyon bottoms (Table 3.1-1).

Soils were described using standard terminology and techniques (see Soil Conservation Survey 1981, ER ID XXXXX). The depths of the individual soil horizons sampled varied among soils, but all soils were continuously sampled from the surface to the base of the profile (depths varied from 25 to 394 cm).