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# NATURAL BACKGROUND GEOCHEMISTRY OF SEDIMENTS, LOS ALAMOS NATIONAL LABORATORY

by

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## INTRODUCTION

Background elemental concentrations were determined for inorganic constituents of the sediments as part of Environmental Restoration (ER) investigations conducted at Los Alamos National Laboratory (LANL). These background investigations conform with guidelines set forth in Task IV of the Laboratory's Hazardous and Solid Waste and Amendments (HSWA) permit to "...describe the extent of contamination (qualitative/quantitative) in relation to the background levels indicative for the area". The background data supplements information from earlier regional background sediment investigations by Longmire et al. (1995, **this is the three chapter background report**).

Standard EPA analytical methods used to measure concentrations of inorganic chemicals and radionuclides for these sediment background samples. This ensures comparability of these background sample data to samples collected in RCRA and Canyons investigations.

This report summarizes the results of the sediment background chemistry investigations. Field, analytical, and statistical methods used to describe background element concentrations are described, and geologic factors that control elemental distributions are discussed. Potential differences in sediment background chemistry by canyon, by grain size, and geomorphic unit.

Background screening values are calculated based on upper tolerance limits or maximum reported concentrations. The data are summarized in tables and figures, and the underlying data will be available through the Facility for Information Management and Display (FIMAD).

## METHODS

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## GEOLOGIC SETTING

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## STATISTICAL APPROACH

### Statistical Analysis of Sediment Analytical Data

The background data are used to support the Canyons investigations and RCRA investigations. As a part of these investigations, data are compared to natural background

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concentrations of inorganic and radionuclide analytes. Statistical comparisons will include comparing post-closure data to geologically appropriate background screening values (or hot measurement comparison). The background screening value for inorganic and radionuclide analytes is the upper tolerance limit (UTL) calculated as the upper 95% confidence limit of the 95th percentile. In addition to the background screening comparison, other statistical tests may be used to determine if there are any residual elevated concentrations.

The statistical analysis of the background data consists of the following steps:

a) determine if old sediment data (from Indio and Ancho Canyons) can be combined with the new data (from Los Alamos, Pueblo and Guaje Canyons) to establish one set of new LANL sediment background data

b) compare data from channel and floodplain geomorphic units to determine if there significant differences, and sediment background should be subsetted by geomorphic unit

c) compare data from fine fractions and total grain size analyses to determine if there significant differences, and sediment background should be subsetted by grain size

d) estimate the type of data distribution for each inorganic and radionuclide analyte so that UTLs can be calculated.

e) calculate background screening values for each analyte by stratigraphic unit using either UTLs or the maximum reported values for infrequently detected analytes or sparsely sampled stratigraphic units.

**Initial Data Analysis Steps**

Some of the inorganic results in the combined background rock data set are reported as less than the detection level (<DL). To facilitate statistical analysis of the data, all values reported as <DL were replaced by one-half of the detection limit. This replacement approach is recommended in the EPA risk assessment guidance (EPA 1992, 1166). Concentrations below detection limits commonly occurred for antimony, boron, cadmium, mercury, selenium, silver, tantalum, and thallium. These analytes are excluded from further statistical analyses.

All radionuclide results are reported, whether or not the value is greater than the minimum detectable activity (MDA). For consistency with the analysis of the inorganic data, radionuclide results less than the MDA were replaced by one-half of the MDA. Evaluation of statistical distributions and differences between data groups is facilitated by using this uncensored data. However, radionuclides with no values reported above the MDA are eliminated from statistical analysis. These radionuclides included: barium-140, bismuth-211, bismuth-212, cadmium-109, cerium-139, cerium-144, cesium-134, cobalt-57, cobalt-60, europium-152, iodine-129, lanthanum-140, manganese-54, mercury-203, neptunium-237, protactinium-231, protactinium-233, protactinium-234m, lead-210, lead-211, radium-223, radium-224, radon-219, ruthenium-106, selenium-75, sodium-22, strontium-85, thorium-234, tin-113, yttrium-88, and zinc-65.

**Comparisons of Canyon Source, Geomorphic Unit and Grain Size**

The box plots of all inorganic chemicals are presented in Figure xx through yy. These box plots compare background elemental concentrations for Los Alamos, Pueblo, Guaje, Indio and Ancho Canyons sediment background data to LANL all soil horizon background data. Actual detected values (as filled circles) are shown for each data source. Values reported as less than the detection limit are shown as open circles. The ends of the box represent the "inter-quartile" range of the data distribution. The inter-quartile range is specified by the 25th percentile and 75th percentile of the data distribution. The line within the box plot is the median (50th percentile) of the data distribution. Thus the box indicates concentration values for the central half of the data, and concentration shifts can be readily assessed by comparing the boxes If the majority of the data is represented by a single concentration value (usually the detection limit), the box is reduced to a single line.

Background sediment data for Los Alamos, Pueblo, Guaje, Indio and Ancho Canyons were statistically compared by the Wilcoxon rank sum test. The Wilcoxon rank sum test is one of the "distribution shift" methods discussed in the LANL ER Project Policy Paper on background comparisons (Ryti et al. 1996, 1298). The Wilcoxon rank sum test was also used to determine if there are significant chemicals differences between floodplain and channel geomorphic unit background data.

**Calculation of Background Screening Values**

UTLs were calculated for all inorganic elements, except for antimony, boron, cadmium, mercury, selenium, silver, tantalum, and thallium, where enough values were detected to allow estimation of the statistical distribution. Chloride and sulfate have unusual distributions, which do not allow use of a simple statistical distribution model. Therefore, we propose use of the maximum detected value as a background screening value for chloride and sulfate as well as for the rarely detected elements (antimony, boron, cadmium, mercury, selenium, silver, tantalum, and thallium).

UTLs were calculated for detected radionuclides, except for americium-241, cesium-137, plutonium-238, plutonium-239/240, strontium-90 and uranium-235 where a statistical distribution was not fit to the data. The maximum detected value is proposed as the background screening value for americium-241, cesium-137, plutonium-238, plutonium-239/240, strontium-90 and uranium-235.

For the elements that are normally distributed without any data transformation (1), we calculated parametric tolerance limits by using the following equation:

UTL = mean + standard deviation * $k_{0.90, 0.95}$ (1)

The k-factor depends on the number of background samples; complete tables of k-factors are published in the RCRA ground water statistical analysis document (EPA 1989, 1141) and Gilbert (1987, 0312). Readers are referred to the LANL ER Project policy paper on background comparisons for example k-factors.

The raw calculated UTL results were screened to ensure that the estimated UTLs were not artificially inflated due to a small sample size or the presence of a single high concentration, or outlier, value.

## RESULTS AND DISCUSSION

Tables I and II summarize the detection limits, number of samples above and below detection limits, and the minimum, maximum, median, mean and standard deviation of samples for inorganic analytes in the < 2 mm and fine fractions. Tables III and IV summarize the detection limits, number of samples above and below detection limits, and the minimum, maximum, median, mean and standard deviation of samples for radionuclides in the < 2 mm and fine fractions.

The box plot summary by canyon of inorganics and radionuclides are presented in Figures xx through yy. These box plots show minimal differences between canyons in nearly all background analytes, and justify consolidation of sediment background data. An advantage in lumping all canyons into one data set is that this larger data set will provide more accurate estimates of statistics and can be used to detect smaller differences when used in statistical distribution shift tests.

The Wilcoxon rank sum test (see Tables V,VI) indicated that there were some significant differences between the channel and floodplain samples, and there were more significant differences between the <2 mm and fine fraction data. The standard size fraction analyzed in ER Project samples is the <2 mm fraction. The fine fraction will be useful in evaluating specific contaminant transport hypotheses. Because of the differences observed between the <2 mm and fine fraction samples, these data will be considered separately for background comparisons. The difference between geomorphic units is viewed as less significant, and the channel and floodplain geomorphic unit background samples will be pooled to form a single sediment background data set. This has the advantage of improving the estimates of statistics, and this larger sediment background data can be used to detect smaller differences when used in statistical distribution shift tests.

All of the concentration could be adequately modeled by a normal statistical distribution, with the exception of five radionuclides (americium-241, cesium-137, plutonium-239/240, strontium-90 and uranium-235). The frequency of non-detects for uranium-235 interfered with estimating a statistical distribution, and for the other four radionuclides, a single high value was measured. Because the samples were carefully located in areas upgradient of LANL impacts, this maximum reported value is proposed a background screening value for americium-241, cesium-137, plutonium-239/240, strontium-90 and uranium-235. For all other analytes subjected to statistical analysis, the background screening value was the calculated UTL based on an assumption of a normal statistical distribution. The background screening value for rarely detected inorganics and radionuclides is the maximum detected concentration. The maximum detection limit or MDA is proposed as the background screening value for inorganics and radionuclides that were not detected in the background samples. The proposed background inorganic background screening values are summarized in Table VII, and the proposed background radionuclide background screening values are summarized in Table VIII.

In summary, the sediment background samples collected for the Canyons investigations. The UTLs calculated from these samples will be useful in making screening level background comparisons. Other statistical tests may also be used, as needed, to support the Canyons investigations.

Table 1 - Summary of concentration range of detects and non-detects for inorganics in the <2 mm size fraction.

| Analyte | Non-detects count | Non-detects min | Non-detects max | Detects count | Detects min | Detects max | median | mean | Standard deviation |
|---|---|---|---|---|---|---|---|---|---|
| AG | 16 | 0.1 | 0.1 | 2 | 0.11 | 0.28 | 0.050 | 0.066 | 0.055 |
| AL | 0 | | | 25 | 740 | 13300 | 5510 | 5840 | 3240 |
| AS | 2 | 0.5 | 0.5 | 29 | 0.3 | 3.6 | 1.80 | 1.84 | 0.967 |
| B | 10 | 1.2 | 1.2 | 10 | 1.2 | 4.1 | 0.900 | 1.40 | 0.994 |
| BA | 0 | | | 31 | 8 | 127 | 64.6 | 60.4 | 30.1 |
| BE | 2 | 0.08 | 0.08 | 29 | 0.17 | 1.3 | 0.545 | 0.590 | 0.324 |
| CA | 0 | | | 31 | 180 | 4240 | 1640 | 1680 | 980 |
| CD | 18 | 0.1 | 0.2 | 6 | 0.1 | 0.18 | 0.100 | 0.093 | 0.037 |
| CN | 4 | 0.15 | 0.15 | 20 | 0.16 | 0.63 | 0.250 | 0.295 | 0.186 |
| CO | 0 | | | 31 | 0.6 | 4.2 | 2.20 | 2.35 | 1.08 |
| CR | 0 | | | 31 | 0.8 | 9.2 | 5.40 | 5.62 | 2.21 |
| BA | 0 | | | 31 | 1400 | 13000 | 8400 | 8000 | 2600 |
| HG | 21 | 0.02 | 0.02 | 3 | 0.02 | 0.03 | 0.010 | 0.012 | 0.005 |
| K | 0 | | | 31 | 180 | 2600 | 1120 | 1300 | 630 |
| MG | 0 | | | 31 | 170 | 2370 | 826 | 977 | 520 |
| MN | 0 | | | 31 | 46 | 517 | 302 | 289 | 115 |
| NA | 0 | | | 31 | 34 | 1970 | 458 | 551 | 414 |
| NI | 2 | 2 | 2 | 29 | 2.5 | 8.9 | 4.60 | 4.98 | 1.99 |
| PB | 1 | 4 | 4 | 30 | 3.5 | 25.6 | 8.90 | 9.26 | 4.72 |
| SB | 30 | 4.9 | 5 | 1 | 5 | 5 | 2.45 | 2.54 | 0.457 |
| BE | 2 | 0.08 | 0.08 | 29 | 0.17 | 1.3 | 0.545 | 0.590 | 0.324 |
| TA | 7 | 0.3 | 0.3 | 0 | | | | | |
| TH | 0 | | | 7 | 0.9 | 7 | 5.50 | 4.20 | 2.60 |
| TH-total | 0 | | | 7 | 3.3 | 18 | 13.0 | 11.1 | 5.73 |
| TI | 0 | | | 24 | 102 | 400 | 226 | 242 | 85.3 |
| TL | 7 | 0.3 | 0.4 | 24 | 0.56 | 3.2 | 1.20 | 1.24 | 0.862 |
| U | 3 | 0.3 | 0.3 | 28 | 0.14 | 2 | 0.660 | 0.685 | 0.423 |
| U-total | 0 | | | 31 | 1 | 6.3 | 4.00 | 3.76 | 1.47 |
| V | 0 | | | 31 | 1 | 20 | 10.0 | 10.4 | 4.19 |
| ZN | 0 | | | 31 | 180 | 5240 | 1640 | 1680 | 980 |
| CL | 5 | 2.5 | 2.5 | 2 | 8.4 | 10.3 | 1.25 | 3.56 | 3.99 |
| SO4 | 5 | 5 | 5 | 2 | 26.5 | 35 | 2.50 | 10.6 | 14.0 |
| CD | 18 | 0.1 | 0.2 | 6 | 0.1 | 0.18 | 0.100 | 0.093 | 0.037 |

Table II - Summary of concentration range of detects and non-detects for inorganics in the fine size fraction.

| Analyte | Non-detects | | | Detects | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | count | min | max | count | min | max | median | mean | Standard deviation |
| AG | 4 | 0.1 | 0.1 | 0 | | | | | |
| AL | 0 | | | 10 | 3200 | 13200 | 7450 | 7910 | 3140 |
| AS | 0 | | | 11 | 1 | 4.2 | 2.40 | 2.26 | 0.989 |
| B | 1 | 1.2 | 1.2 | 4 | 1.4 | 3.9 | 2.70 | 2.360 | 1.343 |
| BA | 0 | | | 11 | 37 | 123 | 99.0 | 94.273 | 29.367 |
| BE | 0 | | | 11 | 0.3 | 1.6 | 0.890 | 0.898 | 0.350 |
| CA | 0 | | | 11 | 960 | 5860 | 2200 | 2480 | 1350 |
| CD | 3 | 0.1 | 0.2 | 2 | 0.2 | 0.22 | 0.100 | 0.134 | 0.073 |
| CN | 5 | 0.15 | 0.15 | 0 | | | | | |
| CO | 0 | | | 11 | 1.5 | 4.8 | 3.30 | 3.22 | 0.976 |
| CR | 0 | | | 11 | 2.2 | 12.6 | 5.90 | 6.76 | 3.17 |
| CU | 0 | | | 11 | 2.7 | 10.1 | 7.20 | 6.55 | 2.21 |
| FE | 0 | | | 11 | 4800 | 12000 | 9400 | 8870 | 2190 |
| HG | 2 | 0.02 | 0.02 | 3 | 0.03 | 0.04 | 0.030 | 0.024 | 0.013 |
| K | 0 | | | 11 | 650 | 2200 | 1500 | 1580 | 475 |
| MG | 0 | | | 11 | 590 | 2070 | 1500 | 1410 | 441 |
| MN | 0 | | | 11 | 180 | 784 | 330 | 366 | 180 |
| NA | 0 | | | 11 | 75 | 845 | 120 | 297 | 276 |
| NI | 0 | | | 11 | 4 | 11.9 | 7.00 | 6.76 | 2.30 |
| PB | 0 | | | 11 | 5 | 20.4 | 10.0 | 11.6 | 5.33 |
| SB | 11 | 4.9 | 5 | 0 | | | | | |
| SE | 5 | 0.2 | 0.2 | 0 | | | | | |
| TA | 6 | 0.3 | 0.3 | 0 | | | | | |
| TH | 0 | | | 6 | 3.6 | 7.7 | 7.00 | 6.12 | 1.71 |
| TH-total | 0 | | | 6 | 8.8 | 18 | 15.5 | 14.1 | 3.82 |
| TI | 0 | | | 5 | 61.5 | 329 | 203 | 186 | 115 |
| TL | 6 | 0.3 | 0.3 | 5 | 1 | 2.6 | 0.150 | 0.845 | 0.893 |
| U | 0 | | | 11 | 0.4 | 1.9 | 0.900 | 0.996 | 0.481 |
| U-total | 0 | | | 11 | 0.4 | 7.7 | 4.90 | 4.91 | 1.47 |
| V | 0 | | | 11 | 5 | 19.1 | 12.0 | 11.5 | 3.95 |
| ZN | 0 | | | 11 | 24 | 74.2 | 37.0 | 39.5 | 15.0 |
| CL | 6 | 2.5 | 2.5 | 0 | | | | | |
| SO4 | 4 | 5 | 5 | 2 | 5.9 | 10 | 2.50 | 4.32 | 3.10 |

Table III - Summary of concentration range of detects and non-detects for radionuclides in the <2 mm size fraction.

| Analyte | Non-detects count | min | max | Detects count | min | max | median | mean | Standard deviation |
|---|---|---|---|---|---|---|---|---|---|
| ALPHA | 0 | | | 24 | 8.47 | 49.28 | 30.7 | 30.8 | 12.1 |
| BETA | 0 | | | 24 | 22.7 | 41.12 | 34.8 | 34.6 | 4.98 |
| AC-228 | 3 | 0.31 | 0.55 | 21 | 1.14 | 3.07 | 1.72 | 1.66 | 0.710 |
| AM-241 | 0 | | | 24 | 0.009 | 0.139 | 0.019 | 0.026 | 0.025 |
| BA-140 | 24 | 0.11 | 0.44 | 0 | | | | | |
| BI-211 | 24 | 0.84 | 1.38 | 0 | | | | | |
| BI-212 | 24 | 1.11 | 4.61 | 0 | | | | | |
| BI-214 | 8 | 0.25 | 0.46 | 16 | 0.49 | 1.4 | 0.740 | 0.669 | 0.408 |
| CD-109 | 24 | 2.6 | 4.65 | 0 | | | 1.67 | 1.73 | 0.244 |
| CE-139 | 24 | 0.03 | 0.12 | 0 | | | | | |
| CE-144 | 24 | 0.47 | 1.31 | 0 | | | | | |
| CO-57 | 24 | 0.03 | 0.1 | 0 | | | | | |
| CO-60 | 24 | 0.05 | 0.14 | 0 | | | | | |
| CS-134 | 24 | 0.07 | 0.17 | 0 | | | | | |
| CS-137 | 17 | 0.06 | 0.13 | 7 | 0.21 | 1.28 | 0.060 | 0.211 | 0.307 |
| EU-152 | 24 | 0.09 | 0.6 | 0 | | | | | |
| H-3 | 0 | | | 23 | 0.003 | 0.0856 | 0.018 | 0.024 | 0.019 |
| HG-203 | 24 | 0.06 | 0.15 | 0 | | | | | |
| I-129 | 24 | 0.13 | 0.36 | 0 | | | | | |
| K-40 | 0 | | | 24 | 24.21 | 35.1 | 30.1 | 29.8 | 3.03 |
| LA-140 | 24 | 0.02 | 0.08 | 0 | | | | | |
| MN-54 | 24 | 0.04 | 0.12 | 0 | | | | | |
| NA-22 | 24 | 0.02 | 0.1 | 0 | | | | | |
| NP-237 | 24 | 0.78 | 1.4 | 0 | | | | | |
| PA-231 | 24 | 2.34 | 4.46 | 0 | | | | | |
| PA-233 | 24 | 0.08 | 0.25 | 0 | | | | | |
| PA-234M | 24 | 7.93 | 21.2 | 0 | | | | | |
| PB-210 | 24 | 1.41 | 2.66 | 0 | | | | | |
| PB-211 | 24 | 2.12 | 4.69 | 0 | | | | | |
| PB-212 | 0 | | | 24 | 0.66 | 2.22 | 1.54 | 1.47 | 0.386 |
| PB-214 | 0 | | | 24 | 0.58 | 2.13 | 1.19 | 1.16 | 0.350 |
| PU-238 | 4 | 0.001 | 0.01 | 20 | 0 | 0.006 | 0.002 | 0.002 | 0.002 |
| PU-239/240 | 0 | | | 24 | 0.002 | 0.197 | 0.012 | 0.025 | 0.040 |
| RA-223 | 24 | 0.7 | 1.7 | 0 | | | | | |
| RA-224 | 24 | 1.85 | 3.4 | 0 | | | | | |
| RA-226 | 23 | 1.91 | 3.55 | 1 | 2.24 | 2.24 | 1.39 | 1.42 | 0.268 |
| RN-219 | 24 | 0.96 | 2.45 | 0 | | | | | |
| RU-106 | 24 | 0.35 | 1.31 | 0 | | | | | |
| SE-75 | 24 | 0.05 | 0.23 | 0 | | | | | |
| SN-113 | 24 | 0.04 | 0.35 | 0 | | | | | |
| SR-85 | 24 | 0.09 | 0.15 | 0 | | | | | |
| SR-90 | 13 | 0.1 | 1.9 | 11 | 0.1 | 1 | 0.450 | 0.481 | 0.355 |
| TH-227 | 24 | 1.04 | 1.93 | 0 | | | | | |
| TH-228 | 0 | | | 24 | 0.7 | 2.12 | 1.40 | 1.44 | 0.365 |
| TH-230 | 0 | | | 24 | 0.69 | 2.12 | 1.33 | 1.38 | 0.396 |
| TH-232 | 0 | | | 24 | 0.66 | 2.03 | 1.40 | 1.43 | 0.390 |
| TH-234 | 24 | 2.64 | 4.46 | 0 | | | | | |
| TL-208 | 0 | | | 24 | 0.28 | 0.81 | 0.560 | 0.562 | 0.149 |
| U-234 | 0 | | | 24 | 0.59 | 2.5 | 1.30 | 1.40 | 0.429 |
| U-235 | 9 | 0.06 | 0.61 | 15 | 0.06 | 0.16 | 0.115 | 0.098 | 0.066 |
| U-238 | 2 | 0.06 | 1.5 | 22 | 0.51 | 2.1 | 1.30 | 1.22 | 0.461 |
| Y-88 | 24 | 0.02 | 0.06 | 0 | | | | | |
| ZN-65 | 23 | 0.1 | 0.35 | 0 | | | | | |

Table IV - Summary of concentration range of detects and non-detects for inorganics in the fine size fraction.

| Analyte | Non-detects count | min | max | Detects count | min | max | median | mean | Standard deviation |
|---|---|---|---|---|---|---|---|---|---|
| ALPHA | 0 | | | 4 | 45.94 | 60.31 | 49.7 | 51.4 | 6.72 |
| BETA | 0 | | | 4 | 27.61 | 45.32 | 38.2 | 37.3 | 8.82 |
| AC-228 | 2 | 0.7 | 0.7 | 3 | 1.65 | 3.08 | 1.65 | 1.65 | 1.30 |
| AM-241 | 0 | | | 5 | 0.014 | 0.046 | 0.022 | 0.029 | 0.015 |
| BA-140 | 5 | 0.42 | 0.59 | 0 | | | | | |
| BI-211 | 1 | 1.4 | 1.4 | 4 | 2.33 | 3.68 | 3.34 | 2.69 | 1.23 |
| BI-212 | 5 | 2.8 | 5.02 | 0 | | | | | |
| BI-214 | 4 | 0.57 | 1.82 | 1 | 2.97 | 2.97 | 0.810 | 1.06 | 1.11 |
| CD-109 | 5 | 4.15 | 5.48 | 0 | | | | | |
| CE-139 | 5 | 0.09 | 0.2 | 0 | | | | | |
| CE-144 | 5 | 0.57 | 1.43 | 0 | | | | | |
| CO-57 | 5 | 0.09 | 0.14 | 0 | | | | | |
| CO-60 | 5 | 0.2 | 0.25 | 0 | | | | | |
| CS-134 | 5 | 0.12 | 0.33 | 0 | | | | | |
| CS-137 | 2 | 0.19 | 0.23 | 3 | 0.38 | 1.09 | 0.380 | 0.504 | 0.444 |
| EU-152 | 5 | 0.75 | 1.27 | 0 | | | | | |
| H-3 | 0 | | | 0 | | | | | |
| HG-203 | 5 | 0.13 | 0.27 | 0 | | | | | |
| I-129 | 5 | 0.02 | 0.04 | 0 | | | | | |
| K-40 | 1 | 5.49 | 5.49 | 4 | 31.06 | 38.13 | 34.0 | 28.7 | 14.8 |
| LA-140 | 4 | 0.06 | 0.18 | 1 | 0.12 | 0.12 | 0.045 | 0.065 | 0.038 |
| MN-54 | 4 | 0.14 | 0.26 | 1 | 0.15 | 0.15 | 0.120 | 0.110 | 0.034 |
| NA-22 | 5 | 0.05 | 0.15 | 0 | | | | | |
| NP-237 | 5 | 1.25 | 1.66 | 0 | | | | | |
| PA-231 | 5 | 4.92 | 10.6 | 0 | | | | | |
| PA-233 | 5 | 0.24 | 0.38 | 0 | | | | | |
| PA-234M | 5 | 14.1 | 20.3 | 0 | | | | | |
| PB-210 | 4 | 2.82 | 4.11 | 1 | 3.22 | 3.22 | 1.95 | 2.04 | 0.711 |
| PB-211 | 5 | 4.1 | 6.89 | 0 | | | | | |
| PB-212 | 0 | | | 5 | 1.18 | 2.27 | 1.68 | 1.74 | 0.431 |
| PB-214 | 3 | 0.45 | 0.62 | 2 | 0.4 | 0.87 | 0.310 | 0.413 | 0.264 |
| PU-238 | 0 | | | 4 | 0.002 | 0.005 | 0.004 | 0.004 | 0.001 |
| PU-239/240 | 0 | | | 4 | 0.026 | 0.277 | 0.064 | 0.108 | 0.116 |
| RA-223 | 5 | 1.83 | 2.3 | 0 | | | | | |
| RA-224 | 4 | 3.9 | 4.93 | 1 | 3.36 | 3.36 | 2.39 | 2.49 | 0.524 |
| RA-226 | 4 | 3.74 | 4.91 | 1 | 4.75 | 4.75 | 2.34 | 2.70 | 1.17 |
| RN-219 | 5 | 2.01 | 3.43 | 0 | | | | | |
| RU-106 | 5 | 1.4 | 2.91 | 0 | | | | | |
| SE-75 | 5 | 0.15 | 0.25 | 0 | | | | | |
| SN-113 | 5 | 0.09 | 0.28 | 0 | | | | | |
| SR-85 | 5 | 0.18 | 0.24 | 0 | | | | | |
| SR-90 | 0 | | | 4 | 0.1 | 0.2 | 0.200 | 0.175 | 0.050 |
| TH-227 | 5 | 1.88 | 2.44 | 0 | | | | | |
| TH-228 | 0 | | | 4 | 1.59 | 2.76 | 2.05 | 2.11 | 0.556 |
| TH-230 | 0 | | | 4 | 1.77 | 2.53 | 1.93 | 2.04 | 0.347 |
| TH-232 | 0 | | | 4 | 1.58 | 2.63 | 2.00 | 2.05 | 0.484 |
| TH-234 | 5 | 4.51 | 5.95 | 0 | | | | | |
| TL-208 | 0 | | | 5 | 0.82 | 1.2 | 0.850 | 0.934 | 0.163 |
| U-234 | 0 | | | 4 | 1.5 | 2.6 | 2.20 | 2.13 | 0.486 |
| U-235 | 3 | 0.06 | 1.11 | 2 | 0.18 | 0.18 | 0.180 | 0.266 | 0.205 |
| U-238 | 0 | | | 4 | 1.5 | 2.5 | 1.90 | 1.95 | 0.480 |
| Y-88 | 5 | 0.19 | 0.24 | 0 | | | | | |
| ZN-65 | 5 | 0.18 | 0.45 | 0 | | | | | |

Table V. Summary of the Wilcoxon Rank Sum test significance results for inorganics. Values less than 0.05 represent statistically significant differences.

| Analyte | Data source Canyon | Geomorphic Unit Channel vs Floodplain | Grain size <2 mm vs Fine fraction |
|---|---|---|---|
| AL | 0.365 | 0.108 | 0.100 |
| AS | **0.004** | 0.100 | 0.323 |
| BA | 0.925 | **0.029** | **0.004** |
| BE | 0.840 | **0.023** | **0.014** |
| CA | 0.528 | **0.007** | 0.053 |
| CN | 0.995 | 0.877 | **0.003** |
| CO | 0.063 | 0.273 | **0.041** |
| CR | 0.075 | 0.301 | 0.213 |
| CU | 0.949 | 0.057 | **0.010** |
| FE | 0.215 | 0.556 | 0.224 |
| K | 0.545 | **0.039** | 0.126 |
| MG | 0.455 | **0.047** | **0.021** |
| MN | **0.026** | 0.078 | 0.360 |
| NA | **<.001** | 0.174 | 0.054 |
| NI | 0.421 | 0.161 | **0.039** |
| PB | **0.026** | 0.065 | 0.165 |
| TH | 0.998 | 0.157 | 0.086 |
| TH-total | 0.972 | 0.285 | 0.281 |
| TI | 0.601 | **0.037** | 0.299 |
| U | **0.018** | 0.216 | 0.059 |
| U-total | 0.353 | **0.030** | **0.029** |
| V | 0.113 | 0.839 | 0.423 |
| ZN | **0.002** | 0.808 | 0.448 |

Table VI. Summary of the Wilcoxon Rank Sum test significance results for radionuclides. Values less than 0.05 represent statistically significant differences

| Analyte | Data source Canyon | Geomorphic Unit Channel vs Floodplain | Grain size <2 mm vs Fine fraction |
|---|---|---|---|
| ALPHA | 0.574 | 0.198 | **0.007** |
| BETA | 0.308 | **0.047** | 0.555 |
| AC-228 | 0.161 | 0.270 | 0.908 |
| AM-241 | 0.125 | 0.198 | 0.370 |
| BI-214 | 0.304 | **0.022** | 0.729 |
| CS-137 | 0.239 | 0.439 | **0.024** |
| H-3 | 0.579 | 0.093 | 1 |
| K-40 | 0.289 | 0.854 | 0.119 |
| PB-212 | 0.283 | **0.043** | 0.260 |
| PB-214 | 0.558 | **0.014** | **0.002** |
| PU-238 | 0.423 | 0.400 | 0.096 |
| PU-239/240 | 0.124 | 0.690 | **0.015** |
| RA-226 | 0.316 | 0.783 | **0.001** |
| SR-90 | **0.003** | 0.423 | 0.259 |
| TH-228 | 0.741 | 0.058 | **0.030** |
| TH-230 | 0.644 | **0.027** | **0.011** |
| TH-232 | 0.607 | 0.105 | **0.030** |
| TL-208 | 0.820 | 0.081 | **0.001** |
| U-234 | 0.321 | 0.166 | **0.018** |
| U-235 | 0.059 | 0.150 | **0.026** |
| U-238 | 0.255 | 0.097 | **0.016** |

Table VII. Summary of background screening values for inorganics.

| Inorganic | UTL:95.95 | Maximum value | Maximum detection limit | Background screening value |
|---|---|---|---|---|
| AL | 13260 | 13300 | NA | 13260 |
| AS | 3.98 | 3.6 | <0.5 | 3.98 |
| BA | 127 | 127 | NA | 127 |
| BE | 1.31 | 1.3 | <0.08 | 1.31 |
| CA | 3850 | 4240 | NA | 3850 |
| CN | 0.723 | 0.63 | <0.15 | 0.723 |
| CO | 4.73 | 4.2 | NA | 4.73 |
| CR | 10.5 | 9.2 | NA | 10.5 |
| CU | 9.97 | 12 | NA | 9.97 |
| FE | 13790 | 13000 | NA | 13800 |
| K | 2690 | 2600 | NA | 2690 |
| MG | 2130 | 2370 | NA | 2130 |
| MN | 543 | 517 | NA | 543 |
| NA | 1470 | 1970 | NA | 1470 |
| NI | 9.38 | 8.9 | <2 | 9.38 |
| PB | 19.7 | 25.6 | <4 | 19.7 |
| TH | 13.0 | 7 | NA | 13.0 |
| TH-total | 30.6 | 18 | NA | 30.6 |
| TI | 439 | 400 | NA | 439 |
| U | 1.62 | 2 | <0.3 | 1.62 |
| U-total | 6.99 | 7.2 | NA | 6.99 |
| V | 19.7 | 20 | NA | 19.7 |
| ZN | 60.2 | 56.2 | NA | 60.2 |
| AG | | 0.28 | <0.1 | 0.28 |
| B | | 4.1 | <1.2 | 4.1 |
| CD | | 0.18 | <0.2 | 0.18 |
| HG | | 0.03 | <0.02 | 0.03 |
| SB | | 5 | <5 | 5 |
| SE | | NA | <0.2 | <0.2 |
| TA | | NA | <0.3 | <0.3 |
| TL | | 3.2 | <0.4 | 3.2 |
| CL | | 10.3 | <2.5 | 10.3 |
| SO4 | | 35 | <5 | 35 |

Table VII. Summary of background screening values for radionuclides.

| Radionuclide | UTL | Maximum value | Maximum MDA | Background screening value |
|---|---|---|---|---|
| ALPHA | 58.8 | 49.28 | NA | 58.8 |
| BETA | 46.1 | 41.12 | NA | 46.1 |
| AC-228 | 3.30 | 3.07 | <0.55 | 3.30 |
| AM-241 | | 0.139 | NA | 0.139 |
| BI-214 | 1.61 | 1.4 | <0.46 | 1.61 |
| CS-137 | | 1.28 | <0.13 | 1.28 |
| H-3 | 0.068 | 0.0856 | NA | 0.068 |
| K-40 | 36.8 | 35.1 | NA | 36.8 |
| PB-212 | 2.36 | 2.22 | NA | 2.36 |
| PB-214 | 1.97 | 2.13 | NA | 1.97 |
| PU-238 | 0.006 | 0.006 | <0.01 | 0.006 |
| PU-239/240 | | 0.197 | NA | 0.197 |
| RA-226 | 2.03 | 2.24 | <3.55 | 2.03 |
| SR-90 | | 1 | <1.9 | 1 |
| TH-228 | 2.28 | 2.12 | NA | 2.28 |
| TH-230 | 2.29 | 2.12 | NA | 2.29 |
| TH-232 | 2.33 | 2.03 | NA | 2.33 |
| TL-208 | 0.906 | 0.81 | NA | 0.906 |
| U-234 | 2.39 | 2.5 | NA | 2.39 |
| U-235 | | 0.16 | <0.61 | 0.16 |
| U-238 | 2.29 | 2.1 | <1.5 | 2.29 |
| BA-140 | | NA | <0.44 | <0.44 |
| BI-211 | | NA | <1.38 | <1.38 |
| BI-212 | | NA | <4.61 | <4.61 |
| CD-109 | | NA | <4.65 | <4.65 |
| CE-139 | | NA | <0.12 | <0.12 |
| CE-144 | | NA | <1.31 | <1.31 |
| CO-57 | | NA | <0.1 | <0.1 |
| CO-60 | | NA | <0.14 | <0.14 |
| CS-134 | | NA | <0.17 | <0.17 |
| EU-152 | | NA | <0.6 | <0.6 |
| HG-203 | | NA | <0.15 | <0.15 |
| I-129 | | NA | <0.36 | <0.36 |
| LA-140 | | NA | <0.08 | <0.08 |
| MN-54 | | NA | <0.12 | <0.12 |
| NA-22 | | NA | <0.1 | <0.1 |
| NP-237 | | NA | <1.4 | <1.4 |
| PA-231 | | NA | <4.46 | <4.46 |
| PA-233 | | NA | <0.25 | <0.25 |
| PA-234M | | NA | <21.2 | <21.2 |
| PB-210 | | NA | <2.66 | <2.66 |
| PB-211 | | NA | <4.69 | <4.69 |
| RA-223 | | NA | <1.7 | <1.7 |
| RA-224 | | NA | <3.4 | <3.4 |
| RN-219 | | NA | <2.45 | <2.45 |
| RU-106 | | NA | <1.31 | <1.31 |
| SE-75 | | NA | <0.23 | <0.23 |
| SN-113 | | NA | <0.35 | <0.35 |
| SR-85 | | NA | <0.15 | <0.15 |
| TH-227 | | NA | <1.93 | <1.93 |
| TH-234 | | NA | <4.46 | <4.46 |
| Y-88 | | NA | <0.06 | <0.06 |
| ZN-65 | | NA | <0.35 | <0.35 |

## References

EPA (US Environmental Protection Agency), April 1989. "Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities. Interim Final Guidance," Office of Solid Waste, Waste Management Division, US Environmental Protection Agency. Washington DC. (EPA 1989, 1141)

Gilbert, R.O., 1987. Statistical Methods for Environmental Pollution Monitoring. Von Nostrand Reinhold Company Inc. New York. 320 pp. (Gilbert 1987, 0312)

Ryti, R., P. Longmire, and E. McDonald, March 1996. "Application of LANL Background Data to ER Project Decision-Making Part I: Inorganics," Los Alamos National Laboratory Report LA-UR-96-1534, Los Alamos. New Mexico. **(Ryti et al. 1996, 1298)**

## Appendix I

S-Plus Code Used to Calculate Lognormal UTLs

**File: lnorm_utl1.s**

```
function(q,p,n,ave,sd,nt)
{
# lnorm_utl1.s is used as function LUTL1 in Splus
# This function is used to estimate the upper p% CI of the qth percentile
# percentile for a lognormal distribution.  Uses Gilbert's MBE (minimum unbiased estimator) of LN.
#    q = the quantile to estimate
#    p = the confidence limit of q
#    n = number of values sampled
#  ave = mean of logtranformed data
#   sd = st. dev. of logtranformed data
#   nt = number of simulation trials
#.....................................................

# Calculate the qth quantile of the normal distribution
q1_qnorm(q)

# Initialize arrays
t1_rep(-1,n)
t2_rep(-1,nt)

i_0

repeat

 { i_i+1

# Get the "n" lognormal samples
   t1_rlnorm(n,ave,sd)

# Calculate the mean and sd the hard way
   dummy_lnormUMV.s(t1)
   ave1_dummy$mu
   sd1_sqrt(dummy$s2)

# Calculate an estimate of the qth percentile
   t2[i]_exp(ave1+q1*sd1)
   if(i>=nt) break
 }

# Find the upper p*100% of the qth percentile
quantile(t2,p)
}
```

**File: lnormUMV.s**

```
function(x)
{
# lnormUMV.s (Splus function)
# Calls: psi.s
# Min Variance Unbiased ests of parameters of lognormal(mu,var=s2) distn
# for X~lognorm(mu,s2), Y=log(X)~normal(mu,s2)
# returns:E=mean(X), V=var(X)
#       mu=mean(Y),s2=var(Y)
# ref:Gilbert('87),Stat Methods for Env Pollution Mon, pp165-166
        n <- length(x)
        y <- log(x)
        ymu <- mean(y)
        vy <- var(y)
        psi1 <- psi.s(vy/2, n)
        psi2 <- psi.s(2 * vy, n)
        psi3 <- psi.s((vy * (n - 2))/(n - 1), n)
        E <- exp(ymu) * psi1
        V <- exp(2 * ymu) * (psi2 - psi3)
        mu <- log(E^2/(V + E^2)^0.5)
        s2 <- log(V/E^2 + 1)
        return(E, V, mu, s2)
}
```

**File: psi.s**

```
function(t, n)
{
# psi.s (Splus function)
# called by lnormUMV.s
# psi function in Gilbert('87) Stat. Meth. Env. Pollution. Mon, pp 165
# for Min Variance Unbiased ests of parameters of lognormal(mu,var=s2) distn
        psi <- 0
        psi[1] <- ((n - 1) * t)/n
        for(i in 1:25) {
                psi[i + 1] <- (psi[i] * (n - 1)^2 * t)/((i + 1) * n * (n + (2 *
                        i - 1)))
                if(abs((psi[i + 1] - psi[i])/psi[i]) < 1e-09)
                        break
        }
        psi <- 1 + sum(psi)
        psi
}
```

**Figure 1. Al, Sb, As, Ba, Be, B by canyons source and geomorphic unit.**

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File Name : bxplota.ps
Title : (S-PLUS Graphics)
Creator : S-PLUS
CreationDate : Wed Sep 25 13:28:16 1996
Pages : 1