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Chemical Analyses of Soil Samples Collected from the Vicinity of the Thermal Test Complex at Sandia National Laboratories, New Mexico Environs, 2006

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Abstract

In the summer of 2006, the Environmental Programs and Assurance Department of Sandia National Laboratories in Albuquerque, New Mexico (SNL/NM), collected surface soil samples at 37 locations within one mile of the vicinity of the newly constructed Thermal Test Complex (TTC) for the purpose of determining baseline conditions against which potential future impacts to the environs from operations at the facility could be assessed. These samples were submitted to an offsite analytical laboratory for metal-in-soil analyses. This work provided the SNL Environmental Programs and Assurance Department with a sound baseline data reference set against which to assess potential future operational impacts at the TTC. In addition, it demonstrates the commitment that the Laboratories have to go beyond mere compliance to achieve excellence in its operations. This data are presented in graphical format with narrative commentaries on particular items of interest.

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Introduction

In order to establish a baseline for trace metals that exist in the soils in the vicinity of the Thermal Test Complex (TTC) in Technical Area III at Sandia National Laboratories, New Mexico (SNL/NM), the Environmental Programs and Assurance Department at SNL/NM collected soil samples at 37 locations within one mile of the TTC for the purpose of determining baseline conditions against which potential future impacts to the environs from operations at the facility could be evaluated. The sampling plan was designed to collect and analyze soils for this purpose and was assembled in consultation with subject matter experts within the Environmental Programs and Assurance Department to ensure that a true multi-media approach was taken in the process of determining the location of the various sampling points. The locations are shown in Figure 1, and tabulated in Table 1. Samples were submitted to an analytical laboratory for metal-in-soil analyses (target analyte list [TAL] metals) plus metallic uranium.

These soil results are presented in graphical format for quick reference. In some cases, the ratio between two or more elements can be used to determine if the observed concentrations are natural or anthropogenic (Hooper 2004). When more than one distribution is observed in these plots, the data are assumed to be heterogeneous (i.e., a separate source is associated with each distribution) (McLish 1994). This work provided the SNL Environmental Programs and Assurance Department with a sound baseline data reference against which to compare future operational impacts at the TTC or other nearby facilities.

First of all, it was desirable to collect a sufficient number of samples from the area of interest to enable statistical evaluation of the data (e.g., MIN, MAX, MEAN, RANGE, etc). Also, since the primary vector for the occurrence of non-natural concentrations of the metals in soils would be air deposition, consultations were made with the Environmental Programs and Assurance meteorologist to identify primary wind patterns so that samples would be collected in likely “downwind” (and “upwind”) directions from the facility effluent stack. (Depositional modeling results are actually available for this facility, which suggest deposition patterns extending further than indicated in Figure 1. However, as a practical consideration, the distances considered here were limited to a one-mile radius.)

Existing nearby monitoring stations that already exist for other reasons were also considered in the selection of sample locations. For example, there are PM-10 and PM-2.5 stations within the 0.5 mile radius where samples were collected for possible correlation with materials collected on the air filters. Soil samples were also collected near the existing groundwater monitoring wells in the selected sampling area, since contaminants in the surface soils are potential contaminants of the groundwater, if they are mobile in the vadose zone. Of course, in the desert environment at SNL with the groundwater table over 500 feet below the ground surface, the likelihood of this scenario is remote.

With that general background guiding the approach to selection of the sampling points, Figure 1 below depicts the general locations sampled.

Figure 1. Sampling Locations in the Vicinity of the TTC to Establish Baseline Metals-in Soils Concentrations

The precise GPS location of each sample point was logged at the time of sample collection to record the exact location from which each sample was collected. Table 1 below lists the locations, their sampling coordinates, and the rationale for sampling at that location.

Table 1. TTC Metals-in-Soil Sampling Locations (NM State Plane Coordinates)

Number	Easting	Northing	Rationale
1	358557	3874028	N of PM-2.5
2	358627	3873976	E of PM-2.5
3	358551	3873920	S of PM-2.5
4	358486	3873973	W of PM-2.5
5	359824	3873545	Upwind Transect Day Wind Rose (N of A36 Met Tower)
6	359857	3873485	Upwind Transect Day Wind Rose (E of A36 Met Tower)
7	359782	3873472	Upwind Transect Day Wind Rose (S of A36 Met Tower)
8	359758	3873512	Upwind Transect Day Wind Rose (W of A36 Met Tower)
9	359050	3873302	Upwind Transect Night Wind Rose (N of MW1 Met Tower)
10	359108	3873241	Upwind Transect Night Wind Rose (E of MW1 Met Tower)
11	359042	3873186	Upwind Transect Night Wind Rose (S of MW1 Met Tower)
12	358993	3873256	Upwind Transect Night Wind Rose (W of MW1 Met Tower)
13	358208	3874837	Downwind Transect Night Wind Rose
14	358360	3874665	Downwind Transect Night Wind Rose
15	358472	3874539	Downwind Transect Night Wind Rose
16	358638	3874371	Downwind Transect Night Wind Rose
17	358746	3874255	Downwind Transect Night Wind Rose
18	358955	3874051	Downwind Transect Night Wind Rose
19	359163	3873847	Downwind Transect Night Wind Rose
20	359320	3873694	Downwind Transect Day Wind Rose
21	359422	3873786	Downwind Transect Day Wind Rose
22	359722	3874105	Downwind Transect Day Wind Rose
23	359883	3874276	Downwind Transect Day Wind Rose
24	360058	3874468	Downwind Transect Day Wind Rose
25	360230	3874642	Downwind Transect Day Wind Rose
26	360430	3874855	Downwind Transect Day Wind Rose
27	360772	3873008	Upwind Transect Night Wind Rose

28	360552	3873114	Upwind Transect Night Wind Rose
29	360375	3873189	Upwind Transect Night Wind Rose
30	360197	3873282	Upwind Transect Night Wind Rose
31	360038	3873355	Upwind Transect Night Wind Rose
32	359222	3873485	Upwind Transect Day Wind Rose
33	358979	3872967	Upwind Transect Day Wind Rose
34	358868	3872736	Upwind Transect Day Wind Rose
35	358778	3872537	Upwind Transect Day Wind Rose
36	358709	3872383	Upwind Transect Day Wind Rose
37	358639	3872236	Upwind Transect Day Wind Rose

The results from the laboratory were received, evaluated, tabulated, and summarized. This summary will constitute the baseline information against which any future potential environmental impact from TTC operations can be evaluated. By logging the precise locations from which these samples were collected, any future samples can be collected from essentially the same locations, reducing the potential error that may be attributable to sampling variability due to location.

Results of the soil samples were evaluated using probability plotting, which provided a visual representation of the entire data set for all locations. If the results were similar, or fit a linear distribution when plotted on logarithmic or log-probability scales, then the results were attributable to natural origin. Summary statistics for each element were imbedded in each plot. If any samples indicated concentrations greater than expected from the rest of the sample distribution, further evaluation was conducted to determine possible explanations responsible for the observed result. Table 2 provides various reference values for metals-in-soil. NMED Screening Levels (if available) (ftp://ftp.nmenv.state.nm.us/hwbdocs/HWB/guidance_docs/NMED_June_2006_SSG.pdf, NMED 2006) for Industrial and Residential use are indicated for reference purposes on some of the graphs.

Appendix A contains a detailed description of the mechanics of log-normal plotting. Appendix B contains the plots of the soil data, sorted alphabetically by analyte name as it appears on the Periodic Table of the Elements (common name is also included in parenthesis). Associated with each plot presented are the summary statistics for each analyte.

Table 2. Various Reference Values for Metals-in-Soil

	NM Soil Concentrations ¹		NMED Soil Screening Levels ²		US Soil Concentrations ³	
Analyte	Lower Limit	Upper Limit	Residential	Industrial	Lower Limit	Upper Limit
Aluminum	5000	100000	74000	100000	4500	100000
Antimony	0.2	1.3	30	92	0.25	0.6
Arsenic	2.5	19	4	17	1	93
Barium	230	1800	5200	15000	20	1500
Beryllium	1	2.3	150	440	0.04	2.54
Cadmium	ND	11	70	190	0.41	0.57
Calcium	600	320000	n/a	n/a	n/a	n/a
Chromium	7.6	42	230	660	7	1500
Cobalt	2.1	11	4500	13000	3	50
Copper	2.1	30	2800	8500	3	300
Iron	1000	100000	23000	69000	5000	50000
Lead	7.8	21	400	1000	10	70
Magnesium	300	100000	n/a	n/a	n/a	n/a
Manganese	30	5000	7800	14000	20	3000
Mercury	0.01	0.06	7	20	0.02	1.5
Molybdenum	1	6.5	380	1200	0.8	3.3
Nickel	2.8	19	1500	4400	5	150
Potassium	1900	63000	n/a	n/a	n/a	n/a
Selenium	0.2	0.8	380	1200	0.1	4
Silica (Silicon)	150000	440000	n/a	n/a	24000	368000
Silver	0.5	5	380	1200	0.2	3.2
Sodium	500	100000	n/a	n/a	n/a	n/a
Strontium	88	440	37000	89000	7	1000
Thallium	n/a	n/a	6	18	0.02	2.8
Titanium	910	4000	n/a	n/a	20	1000
Vanadium	15	94	530	1600	0.7	98
Zinc	18	84	23000	69000	13	300

ND = not detectable

n/a = not available

(1) Dragun, James, A. Chiasson, *Elements in North American Soils*, 1991, Hazardous Materials Control Resources Institute, (Used San Juan Basin, A Horizon to determine values).

(2) NMED Soil Screening Levels (SSL), New Mexico Environmental Department Hazardous Waste Bureau and Ground Water Quality Bureau Voluntary Remediation Program, *Technical Background Document for Development of Soil Screening Levels*, NMED 2000

(3) US Soil Surface Concentrations

Kabata-Pendias, A., Pendias, H., CRC, *Trace Elements in Soils and Plants*, 3rd Edition, 2002

Summary

In the summer of 2006, the Environmental Programs and Assurance Department of Sandia National Laboratories in Albuquerque, New Mexico (SNL/NM) collected soil samples at 37 locations within one mile of the vicinity of the newly constructed TTC in Technical Area III. These samples were submitted to an analytical laboratory for metal-in-soil analyses and the results presented herein. These data will provide SNL with a sound baseline data reference set against which to assess potential future operational impacts of the facility. Table 3 below presents summary statistics for the analytes reported.

Table 3. Analyte Summary Statistics for TTC Metals-in-Soil

Analyte	Mean	StDev	Minimum	Median	Maximum
Aluminum	10053	2335	7390	9610	20100
Antimony	0.69	0.15	0.40	0.73	0.99
Arsenic	2.37	0.51	1.48	2.35	3.78
Barium	77.75	16.32	54.20	74.90	123.00
Beryllium	0.48	0.10	0.35	0.45	0.86
Cadmium	0.19	0.05	0.10	0.19	0.30
Calcium	7375	10277	1180	2820	39100
Chromium	10.66	2.21	7.41	9.85	16.90
Cobalt	3.48	0.75	2.40	3.34	5.32
Copper	7.36	1.65	4.68	6.99	12.30
Iron	11556	1972	8120	11300	17400
Lead	8.47	2.01	5.56	8.24	15.20
Magnesium	2630	722	1710	2450	4600
Manganese	189.62	44.35	134.00	174.00	284.00
Mercury	0.0087	0.0027	0.0036	0.0088	0.0147
Nickel	7.47	1.77	5.00	6.73	12.50
Potassium	2218	574	1360	2060	4590
Silver	0.13	0.21	0.10	0.10	1.40
Sodium	54.14	17.63	34.40	48.30	111.00
Thallium	0.49	0.01	0.48	0.49	0.50
Uranium	0.50	0.13	0.34	0.46	0.92
Vanadium	21.61	3.85	15.00	21.00	31.30
Zinc	29.93	6.24	20.80	28.80	45.20

Appendix A - Data Analysis

The data in this report are presented in the form of log-normal probability plots. Such plots are useful tools for conveniently cataloguing and evaluating large amounts of data, as well as providing a first approximation of the similarity (or differences) of the data. The basis for using log-normal plotting is experience which has shown that large quantities of environmental data (many similar analyte/media combinations) yield a straight line when plotted on a log-probability or logarithmic scale (Miller 1977). The presumption of log-normal distribution is never a bad presumption and is never worse than the presumption of arithmetic-normal (Michels 1971). Because the data are represented graphically, the mean, standard deviation, expected upper limits, and any abnormalities can be readily determined visually (Waite 1975).

Characteristics of special importance in the use of log-normal plots are linearity (denoting data from a common population), standard geometric deviation (σ_g , an indicator of variability or range), and geometric mean (X_g). The unit of slope in a log-normal plot involves a logarithmic increment. Thus, the standard deviation is a multiplier of the geometric mean (Michels 1971). The values for σ_g and X_g can be obtained from the graphs by the ratio of the 84%/50% intercepts and the 50% intercepts, respectively (Miller 1977). Linearity of the graph implies that any potential SNL/NM contribution to the observed concentration is indistinguishable from regional levels of the element. Anomalous results (i.e., potentially attributable to SNL/NM operations) must necessarily occur at a higher concentration than would be expected from regional distributions. For convenience, summary statistics for each element are imbedded in each plot of the 2006 TTC soils data and the 1993-2005 SNL/NM soils data. Included in this list is the Upper Tolerance Limit (UTL), which is defined as:

$$95^{\text{th}} \text{ UTL} = \bar{X} + K * S$$

Where $\bar{X}$ = Sample Arithmetic Mean
S = Sample Standard Deviation
K = One-sided normal tolerance factor

Values for K are commonly determined from tables such as those provided by Lieberman (Lieberman 1958). This UTL can be used to estimate a level above which a sample result may not be attributable to naturally occurring “background” levels of the element.

Whenever a particular results appears elevated (on the log-normal plot) compared to the expected concentration based on the population comprised of all the other locations, further investigation to determine a plausible explanation responsible for the observed phenomenon may include (but should not be limited to) the following:

- What is the geographical location of the sample? Is there a detectable pattern to the anomalous observation or is the sample from an area in close proximity to a facility which has the potential for release of the analyte or contaminant?

- Does the location of the sample(s) show elevated levels for other analytes?
- If several locations appear to be elevated, what might be a plausible explanation? How did these compare to other “site results”?

As can be observed in many of the graphs, data at the lower end of the range frequently “fall off” in a manner that suggests that these results do not belong in the distribution being plotted, or are otherwise anomalous. However, in almost all instances, these results represent reported values that were at the extreme lower limit of the analytical method employed at the time of analysis. This is not atypical, since the plotted values do not include the analytical uncertainty or method detection level (MDL) for a given result. Also, the MDL changes (frequently becomes better) over time as the state-of-the-art for analytical science improves, and the aggregated data may include data that actually have a range of MDLs, which only becomes noteworthy if the given analyte’s concentration is near the MDL. In several of the plots, many of the same reported values appear as a “flat line”. These values are typically the “less than” values (sometimes coded as “U” or not detected) reported by the laboratory when the analyte was not otherwise detected.

Appendix B contains the plots of the soil data, sorted alphabetically by analyte name as they appear in the Periodic Table of the Elements. Any noteworthy anomalies in the plots are discussed by notes within the given plot. Associated with each plot presented in Appendix B are the summary statistics and (for reference) NMED Screening Levels for each analyte.

Useful tips for interpreting the graphs

- Consider the data in each graph as the entire “population” under consideration. Outliers or anomalies are the primary items that may require further investigation.
- The X-axis (Percent) is the indicator of the “spread” of the data. For example, the 80th percent value in the Aluminum graph is 11,300 mg/kg. This means that 80 percent of the data “population” have values below 11,300 and 20 percent of the data “population” have values greater than 11,300.
- The NMED Screening Values indicated on the graphs are for reference only. They have no direct regulatory significance.
- Notice the “stair step” appearance in the Cadmium and Mercury (and some other) graphs of SNL/NM Soils from 1993-2005. This is typical of data that is collected over a period of many years. The explanation is typically that the “plateau values” are from earlier times when the laboratory’s analytical capabilities (their MDLs) were higher than more recent, better analytical capabilities. The lab typically reported these as “less than” values, and they were logged as such.
- The Lognormal – 95% CI blue lines are the statistical 95% confidence intervals for the data population in the graphs.

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Appendix B – TAL Metals in Soil in the Thermal Test Complex and the General SNL/NM Environs

(As) Arsenic in TTC-Vicinity Soils, 2006

Lognormal - 95% CI

As (Arsenic) in SNL/NM Soils 1993-2005

Lognormal - 95% CI

Ba (Barium) TTC-Vicinity Soils, 2006

Lognormal - 95% CI

Ba (Barium) in SNL/NM Soils 1993-2005

Lognormal - 95% CI

Co (Cobalt) in TTC-Vicinity Soils, 2006

Lognormal - 95% CI

Co (Cobalt) in SNL/NM Soils 1993-2005

Lognormal - 95% CI

Cu (Copper) in TTC-Vicinity Soils, 2006

Lognormal - 95% CI

Cu (Copper) in SNL/NM Soils 1993-2005

Lognormal - 95% CI

U (Uranium) in TTC-Vicinity Soils, 2006

Lognormal - 95% CI

Zn (Zinc) in TTC-Vicinity Soils, 2006

Lognormal - 95% CI

Zn (Zinc) in SNL/NM Soils 1993-2005

Lognormal - 95% CI

Distribution

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