



July 9, 1998

Ms. Jennifer Kaduck  
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Dear Ms. Kaduck:

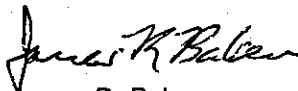
We are pleased to submit the attached Draft GIEC White Paper, *"Recommendations for the Evaluation of Background Concentrations for Soil"*, as proposed by GIEC during the meeting among several EPD, EPA and GIEC representatives held earlier this year.

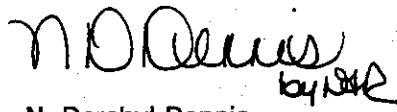
The purpose of this paper is to assist EPD by providing clarification of some of the key issues concerning the determination of concentration ranges representative of background, particularly for sites with small sample numbers. For instance, the paper includes discussion of the various types of background (e.g., ambient and site background), the number of background samples needed to characterize background, balancing data quality needs to the decisions, and some of the practical considerations in addressing this issue.

We are looking forward to receiving comments back from you before finalizing this paper and moving on to the next of the several issues associated with "background" identified in the same meeting referred to above.

If you have any questions regarding the paper attached, please feel free to contact either of us (J. Baker: tele: 912-238-7506 / e-mail: JIM\_BAKER@UCAMP.COM or D. Dennis: tele: 404-506-7064 / e-mail: N.D.DENNIS@GPC.COM) at your convenience.

Sincerely,

  
James R. Baker  
GIEC Chairman *by LAK*

  
N. Darahyl Dennis  
GIEC Steering Committee Member

Cc: EPD - D. Word, T. Cash, B. Mundy, M. Burgess, C. Opdyke  
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Georgia Industry Environmental Coalition

**DRAFT WHITE PAPER**

**RECOMMENDATIONS FOR THE EVALUATION  
OF BACKGROUND CONCENTRATIONS FOR SOIL**

**Submitted to: Georgia Environmental Protection Division**

**Submitted by: Georgia Industry Environmental Coalition**

*July 9, 1998*

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- 1 Example Background Determinations

## RECOMMENDATIONS FOR THE EVALUATION OF BACKGROUND CONCENTRATIONS FOR SOIL

Defining concentration ranges representative of background conditions for soil is a crucial step in any environmental investigation and remediation program. A background range for a particular constituent is used to determine if anthropogenic activities have affected soil conditions. Background concentrations are used in conjunction with risk assessment principles to determine the need and extent of remedial activities. Practically, the development of a background concentration ranges presents many challenges. These challenges arise from the fact that soil concentrations are naturally and inherently variable both vertically and horizontally, and may be influenced by anthropogenic activities. It is important to account for this natural variability so that remediation programs ensure that public health and the environment are protected (i.e., minimize false negative error rate for identification of impacts) while also realistically defining the need and endpoints for remediation (i.e., minimize false positive identification of impacts). This paper presents concepts and approaches for determining background concentrations. The process of defining background concentrations consists of determining the expected range and variability of background.

### Types of Background

The term background is used here to define the range of constituent concentrations in soils surrounding a site, but which have not been influenced by site activities or releases from the site. The term background can be used to represent different types of background conditions. Generally, for the purposes of environmental programs there are two issues of concern: ambient or regional background; and site background. It is important to identify potential contributors to the background concentrations in implementing a program of sampling and analysis. Ambient or regional background is defined when the constituents are naturally occurring and have not been influenced by human activity. Studies may exist that provide information on the composition of surficial soils over large regional, and sometimes state-wide areas. Under these conditions, background sampling may be used to verify that site conditions are the same as ambient or regional background conditions.

In more complex situations (industrial and commercial settings), ambient background for a site may be elevated due to activities not associated with site sources. In these cases, the site background concentrations may be higher than ambient background due to anthropogenic as well as natural contributions, but not due to site activities. (see USEPA, 1989a). Examples include elevated soil lead concentrations from urban highways, and the influence of other sources in the vicinity of the site. Under these conditions, a more detailed sampling and evaluation program may be required to determine site background concentrations, including defining the contributions to site background from other non-site sources.

### The Number of Background Samples

Soil sampling programs can be developed using formal experimental design procedures or experience (i.e., judgmental sampling). Both of these approaches can be considered statistical. The term statistics is defined here as methods for summarizing or describing available information. When formal experimental design procedures are used, this summary involves estimating parameters such as the mean and standard deviation from collected quantitative (concentration) information. These parameters are used to estimate the expected range of concentrations if additional background samples (or site samples not affected by operations) are collected and measured. When judgmental sampling is considered, the summary takes the form of drawing opinions from qualitative information regarding site operations and activities. The number of background samples required and the necessity to delineate the site from ambient background

requires an initial decision regarding the complexity of the site and the potential for contributions from sources other than ambient background levels.

For small sites in areas not influenced by other sources, an initial sampling may be used to evaluate whether ambient background conditions exist. It is recommended that four to eight samples be collected in order to estimate the expected background concentrations and the variability for the site. Fewer samples could underestimate the variability of background concentrations, increasing the uncertainty of decisions made from the comparison with published ambient background concentrations. Guidelines for evaluating background concentration ranges are provided in a later section of this paper. In the event the site background sampling results are not similar to ambient background data, further characterization of site background (including defining the anthropogenic contributions to site background) is recommended.

Specific sites may require a more detailed determination of ambient background concentrations. These cases may include sites located adjacent to other potential contributors and sites where ambient background is not well defined because of geology or lack of published representative results. Background concentration information may also be available from sampling programs from environmental investigation and remediation programs conducted at nearby properties. Compilation of these data by the Georgia EPD or other groups could be used to supplement small background datasets. When historical or other regional literature data are not available, or are considered to be unreliable, one solution is to take a phased approach in the sampling design. A number of guidance documents are available to provide assistance in the design of statistically-based sampling programs to address this situation (e.g., USEPA 1995). The initial phase of sampling would be used to provide preliminary data on the average or expected value and the variability of concentrations. These parameters may then be used to estimate the number of samples needed to fully characterize variability to some specified degree of certainty (e.g., USEPA, 1986). When using a phased-approach to the sampling design, one goal might be to make the "best informed guess" right from the start so that the number of samples collected in subsequent phases is minimized, and also the need to conduct multiple sampling phases is reduced.

### **Balancing Data Quality Needs to the Decisions**

Once the type of background and a reasonable number of samples have been selected, it is necessary to also define the quality of the analytical data needed so that the maximum benefit can be drawn from the data. The most basic data quality decision is specification of detection limits for the chemical analyses. Detection limits need to be low enough so that information to support risk assessment calculations can be made. The detection limits need to be less than risk reduction standards provided in Rules of Georgia EPD, Chapter 391-3.19.

The analytical data generated from background sampling programs will be reported as a combination of actual concentrations, and concentrations below a specified analytical limit. These analytical limits may represent the method detection limit (MDL) or the practical quantitation limit (PQL). Concentrations of compounds reported above the PQL would reflect conditions with more confidence than compounds reported as below the PQL but greater than the MDL (i.e., estimated concentrations). Compounds below the MDL represent measurements not distinguishable from zero. The presence of greater than 15 percent of less than (LT) or non-detect (ND) values present specific difficulties that are typically addressed using non-parametric statistical methods. Other methods for handling LT and ND values are discussed in "Engineering Forum Issue: Determination of Background Concentrations of Inorganics in Soils and Sediments at Hazardous Waste Sites," (USEPA, 1995), and in various other USEPA guidance documents (including USEPA 1989b, 1989c, 1992 and 1994).

## **Practical Background Sampling Design and Interpretation**

The previous discussions have identified a number of considerations in defining background. These considerations are combined to design a background sampling program and then define the background concentration range. The goal is to determine whether anthropogenic activities have affected soil quality. These types of decisions are made for small sites as well as for larger sites. As expected, small sites generally will require fewer samples to assess on-site and background concentrations in relatively simple settings. Generally, as the sites get larger and the adjacent land use becomes more diverse, more data are required to assess both on-site and background conditions. A larger dataset generally provides a more complete and reliable determination of background concentrations. However, this does not imply that sampling programs that include few points are considered inadequate and provide unreliable results. Rather, it emphasizes that the sampling program needs to be consistent with the site requirements and the decisions to be made.

The data collected provide estimates of the mean and standard deviation of background concentrations. It is then possible to use tabulated constants to assert with specified confidence that a designated proportion (i.e., 95%) of the background population is below an estimated upper background limit. The background data may also be evaluated against ambient background concentrations based on results obtained over a larger area to determine whether results are consistent. The following matrix provides a summary of recommendations for defining the concentration range for varying sample sizes, and also provides for additional comments to obtain the maximum information from a limited background sampling program.

Background Sample Size (N)	Methods to Calculate Upper Background Limit <sup>1</sup>	Additional Comments and Suggestions
N= 2 to 3	Maximum concentration or regional background from literature studies	<ul style="list-style-type: none"> <li>• Non-parametric methods not appropriate for estimating upper 95 % confidence limit.</li> <li>• Compare results to expected background from a larger regional data set (e.g. Boerngen and Shacklette, 1981).</li> <li>• If results are all NDs or LTs, need to consider defaulting to regional background concentrations or to the highest detection limit.</li> </ul>
N= 4 to 6	<p>Non-parametric methods</p> <ul style="list-style-type: none"> <li>• Order statistics</li> </ul> <p>Parametric methods</p> <ul style="list-style-type: none"> <li>• t-test for comparison with regional data or</li> <li>• mean plus 2 standard deviations<sup>1</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Expect to use maximum concentration as upper background concentration limit for non-parametric method.</li> <li>• If results are all NDs or LTs, need to consider defaulting to regional background concentrations or to the highest detection limit.</li> <li>• Due to small number of samples, the confidence associated with determined background concentration is low.</li> </ul>
N= 7 to 8	<p>Use parametric or non-parametric methods</p> <p>Non-parametric methods</p> <ul style="list-style-type: none"> <li>• Order statistics</li> </ul> <p>Parametric methods</p> <ul style="list-style-type: none"> <li>• t-test for comparison with regional data or</li> <li>• mean plus 2 standard deviations<sup>1</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Non-parametric methods will likely be used.</li> <li>• Maximum concentration detected will likely be upper background concentration limit.</li> <li>• Although less likely due to increasing sample size, if results are all NDs or LTs, need to consider defaulting to regional background concentrations or to the highest detection limit.</li> <li>• Confidence associated with background determination increases with increasing sample size; confidence level expected to range from 55 to 65 percent. Expect to use maximum concentration as upper background concentration limit.</li> <li>• If results are all NDs or LTs, need to consider defaulting to regional background concentrations or to the highest detection limit.</li> <li>• Due to small number of samples, the confidence associated with determined background concentration is low.</li> </ul>

Background Sample Size (N)	Methods to Calculate Upper Background Limit <sup>1</sup>	Additional Comments and Suggestions
N= 9 to 10	<p>Use parametric or non-parametric methods</p> <p>Non-parametric methods</p> <ul style="list-style-type: none"> <li>• Order statistics</li> </ul> <p>Parametric methods</p> <ul style="list-style-type: none"> <li>• t-test for comparison with regional data or</li> <li>• mean plus 2 standard deviations<sup>1</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Equal likelihood that parametric or non-parametric methods be used.</li> <li>• Confidence level of determined background expected to range from 65 to 85 percent.</li> <li>• Although less likely due to increasing sample size, if results are all NDs or LTs, need to consider defaulting to regional background concentrations or to the highest detection limit.</li> </ul>
N= 10 +	<p>Use parametric or non-parametric methods</p> <p>Non-parametric methods</p> <ul style="list-style-type: none"> <li>• Order Statistics</li> </ul> <p>Parametric methods</p> <ul style="list-style-type: none"> <li>• t-test for comparison with regional data or</li> <li>• mean plus 2 standard deviations<sup>1</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Sufficient data should be available to formally determine if parametric or non-parametric methods should be applied.</li> <li>• Likely will be able to use parametric methods to calculate the background upper limit.</li> <li>• Development of a 85- to 95-percent confidence level estimate for background is possible.</li> <li>• Although less likely due to larger sample size, if results are all NDs or LTs, need to consider defaulting to regional background concentrations or to the highest detection limit.</li> </ul>

<sup>1</sup> The parametric method presented in this table is specified by the Georgia EPD. However, for some situations, other methods (i.e., the upper prediction limit, or the upper tolerance limit) may be more appropriate for background definitions and comparisons. A number of statistical method guidance documents are listed in the Engineering Forum Issue (USEPA, 1995). These documents describe the methodology as well as the assumptions of a number of statistical procedures, including those described in this paper.

LT = less than values  
 ND = non-detect values

## Summary Comments and Recommendations

Background determinations are key in all decision-making for site investigations. It is recommended that a regional data set of background concentrations be established for evaluating results from sites based on a small numbers of samples. Ideally, this data should be based on a statistical design that adequately samples ambient background concentrations, including differences among physiographic regions.

The initial evaluation for sites using a small number of background samples will consist of comparing results to accepted ranges in background concentrations. This comparison may be done using non-parametric, parametric or graphical procedures. In specific cases, this evaluation may indicate that background concentrations are elevated above expected ambient concentrations. In those instances, the background concentration range should be determined from more detailed site-specific sampling. Where results from small sample sets are consistent with the ambient background data, it is recommended that the established upper limit on ambient background concentrations be used since this value will be based on a large sample size.

GIEC would welcome the opportunity to work with EPD on a statistical design that adequately samples ambient background concentrations, including differences among physiographic regions. We recognize that this approach may require significant effort, time and funding, but we believe this approach is the best from a scientific standpoint.

Further we recognize that there are some smaller scale things that could be done on a more timely and economical basis. These things include:

1. Compiling existing background data already accepted by EPD;
2. Initially focusing on region(s) where much data is available and compiling this data (e.g., the Brunswick area);
3. Compiling background data available in technical literature;
4. Coordinating with GIEC member companies on consistent background determinations for on-going or planned investigations at sites across the state.

GIEC strongly supports a "sound science" approach to determining background concentrations for soils and we are available to assist EPD in this effort in whatever way is needed.

## References

- Boerngen, J. G. and H. T. Shacklette. 1981. Chemical Analysis of Soils and Other Surficial Materials of the Conterminous United States. USGS Open-File Report 81-197.
- USEPA, 1989a. Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A).
- USEPA, 1989b. Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance.
- USEPA, 1989c. Methods for Evaluating the Attainment of Cleanup Standards, Volume 1: Soils and Solid Media.
- USEPA, 1992. Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance.
- USEPA, 1994. Statistical Methods for Evaluating the Attainment of Cleanup Standards, Volume 3: Reference-Based Standards for Soils and Solid Media.
- USEPA, 1995. EPA 540/1-96/500 Engineering Forum Issue: Determination of Background Concentrations of Inorganics in Soils and Sediments at Hazardous Waste Sites.
- USEPA, 1986. Test Methods for Evaluating Solid Waste, SW-846, Chapter 9. Third Edition and subsequent updates.

## Attachment 1 - Example Background determinations.

Example 1. A background sampling program is conducted. A total of five samples for the background determination are collected. All samples were collected outside the facility boundary. The constituent of interest is arsenic. The following sample results are reported: < 3 ppm; < 3 ppm; < 3 ppm; 5 ppm and 9 ppm.

60% of the values are non-detects, so values are compared with ambient background values published in Boerngen and Shacklette (1981). The published values indicate a mean concentration of 2.6 ppm, with 95% of soil concentrations below 13 ppm. The background data appear consistent with ambient background concentrations, and the upper limit of 13 ppm is used.

Example 2. A background determination is conducted for lead. The site is adjacent to a well-traveled highway. A total of eight samples are collected from outside the property boundary. The results are 74, 84, 38, 57, 66, 23, 58 and 69 mg Pb per Kg soil.

The data are assumed to be normally distributed and an upper confidence limit is calculated.  
Average = 59 ppm

Standard Deviation = 20 ppm

Upper Confidence Limit = Average + 2 • Standard Deviations

$$= 59 + 2 \cdot 20 = 99 \text{ ppm}$$

The data published in Boerngen and Shacklette (1981) indicate a mean lead concentration of 12 ppm, with a mean plus 2 standard deviations of 44 ppm. The results suggest that lead concentrations are elevated above expected ambient values and the site background is 99 ppm for lead.

This data could also be evaluated using Student's t-test.

Example 3. A background sampling program is conducted for chromium. A total of eight samples for the background determination are collected. All samples were collected outside the facility boundary. The following sample results are reported: < 5 ppm; < 5 ppm; < 5 ppm; 10 ppm; 12 ppm; 20 ppm; 70 ppm and 100 ppm.

Three of the eight values are non-detect (38%), so a non parametric test (rank order) is used. The critical value of the order statistic is calculated from the binomial distribution with  $p=0.5$  and  $n = 8$ , such that 95 per cent of the ordered results will be less than  $i$ 'th value. In this case, 96.5 per cent of the results would be expected to be less than the seventh value ( 70 ppm ), while 86 per cent would be expected below the sixth value. The non-parametric estimate for the background concentration is 70 ppm chromium.

The data published in Boerngen and Shacklette (1981) indicate a mean chromium concentration of 37 ppm with a standard deviation of 29. An upper confidence limit based on these data (mean plus two standard deviations) is 96 ppm. Since the parametric limit is based on a larger sample number, the upper background limit recommended is 96 ppm. Note that the largest value collected in the set of eight background samples ( 100 ppm) is equivalent to this limit.