

6 Using Geochemical Evaluations in Risk Assessment

The results of geochemical evaluations provide insight into metals concentrations in soil in two main ways:

- using a background dataset to identify which detected concentrations are likely attributable to background (see [Section 5](#), [Section 14.4](#), and [Section 14.5](#))
- evaluating a site dataset to determine which of the detected concentrations, if any, are consistent with background conditions

These results can be used at two key points where background is considered in the risk assessment process:

- COPC selection
- risk characterization

The above depend on when the applicable risk assessment guidance allows consideration of background.

6.1 Using Geochemical Evaluations During COPC Selection

Typically, a geochemical evaluation is performed after an initial screening for COPC has occurred because concentrations below screening levels would not typically warrant a geochemical evaluation. Depending on the applicable guidance, soil chemical concentrations are compared to risk-based screening values alone or to the higher of two screening values: the risk-based screening value or background (default or site-specific). Any chemicals with site concentrations that exceed their associated screening values are then included in the site-specific geochemical evaluation. The geochemical evaluation is typically used to determine whether the site concentrations are consistent with background conditions (“background-related”), and thus that the element need not be evaluated further in the risk assessment even if concentrations exceed risk-based screening values.

As discussed in [Section 5.2](#), moderate or low-level contamination may be present in the site dataset that is not representative of background. Such concentrations may be lower than some of the higher naturally occurring background concentrations. Geochemical evaluation can assist in distinguishing low-level contamination from naturally occurring background, allowing the risk assessor or risk management team to decide whether a chemical should be retained as a COPC for risk evaluation.

Some *advantages* of geochemical evaluations at the screening (COPC selection) stage in the process are:

- Apparent statistical outliers (“false outliers”; [Section 11.5](#)) that are determined to be representative of background conditions (based on geochemical evaluation) can be recognized and retained in the background dataset to refine the estimation of a background concentration (for example, BTV) ([Section 5.2](#)) and provide a more representative background dataset.
- Multiple populations of background data, if present, can be identified geochemically ([Section 5.2](#)), and the knowledge of such populations can be used to guide additional sampling (if appropriate) and support the interpretation of results of the site assessment/risk assessment.
- Consideration of the relevant geochemical processes controlling element concentrations in soil can enhance the project team’s understanding of uncertainties inherent in quantifying soil background concentrations and natural mechanisms that affect soil background concentrations, as they apply to the site.
- COPC may be screened out of the risk assessment process at an earlier stage as attributable to background, thus allowing for focus on COPC not attributable to background and a more streamlined risk assessment.

Some *challenges* when considering geochemical evaluations at the screening (COPC selection) stage are:

- Although a geochemical evaluation at this early stage of risk assessment process is a best practice, the importance of background and the complexity of the site may not be sufficiently understood by all stakeholders at that point such that geochemical evaluations are not considered or used effectively.
- Geochemistry expertise is needed, along with additional cost, to perform the geochemical evaluation, and, in some cases, there can be a lack of expertise at regulatory agencies and thus lack of understanding and acceptance of these methods.

6.1.1 Example #1: Evaluate anomalous concentrations further

This simplified, hypothetical example demonstrates that if anomalous samples are identified in a site dataset, then those

samples should be scrutinized further to determine whether they represent potential contamination. As shown in [Figure 6-1](#) and [Figure 6-2](#), most samples exhibit covariance between Trace Element A and Major Element B, including the samples with the highest trace element concentrations (up to approximately 1,000 mg/kg). The trace element concentrations are most likely naturally occurring in most samples and are deemed representative of background. Three samples have anomalously high A/B ratios relative to the others ([Figure 6-2](#)). If these samples were a site dataset, then it might be concluded that most site samples are consistent with background conditions, with the exception of the three samples that lie above the general trend in the scatter plot and to the right of the other samples in the ratio plot (see arrows). However, additional lines of evidence regarding potential geochemical and physical processes should be evaluated to determine whether there is another explanation for the anomalously high ratios ([Section 5.5](#)). For example, are the trace element concentrations controlled primarily by adsorption on another soil-forming mineral that is not represented by the major element depicted here? The additional lines of evidence may support a more defensible conclusion as to whether these samples represent a component of site-related contamination, or their concentrations are consistent with background.

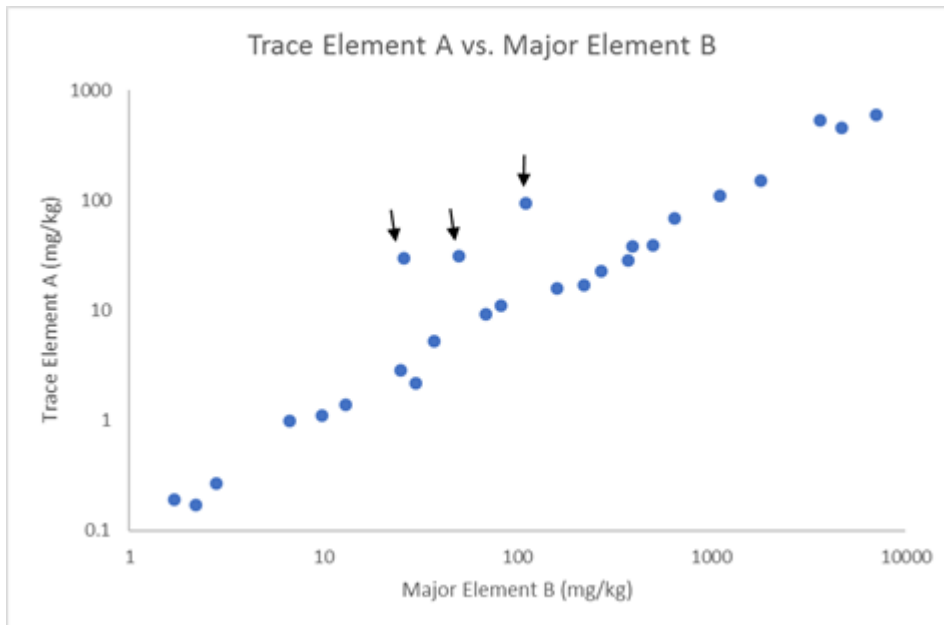


Figure 6-1. Scatter plot of Trace Element A vs. Major Element B shows anomalously high concentrations of Trace Element A in specific samples.

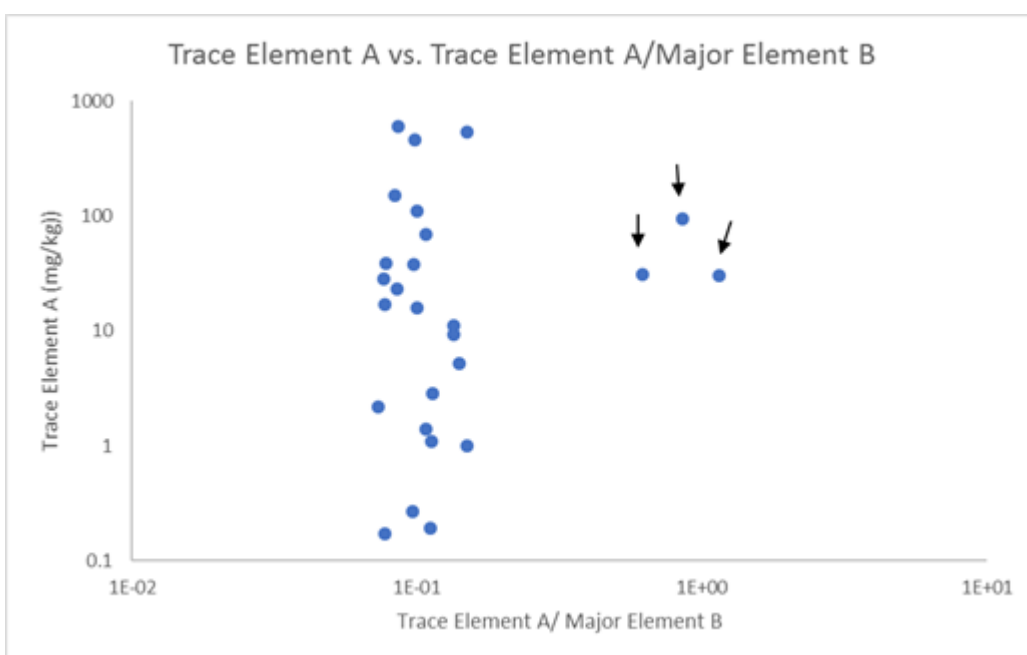


Figure 6-2. Ratio plot of Trace Element A vs. Trace Element A/Major Element B.

6.1.2 Example #2: Samples confirmed to be unrepresentative of background

In this simplified example shown in [Figure 6-3](#) and [Figure 6-4](#), the majority of samples were identified as being consistent with background based on the covariance of trace element A concentrations with aluminum concentrations; however, a subset of the samples (circled here on [Figure 6-3](#) and [Figure 6-4](#) for illustration purposes) lies above the trend formed by most samples in the scatter plot and is shifted to the right of the other samples in the ratio plot. They have anomalously high elemental ratios, indicating potential input of trace element from site-related contamination. In this example scenario, further evaluation of the suspect samples had confirmed that there was no natural source to explain their anomalous ratios ([Section 5.3](#) and [Section 5.5](#)). Therefore, their trace element concentrations could be compared to risk-based screening criteria in the COPC selection step, and the other data (along the main trend) could be excluded from the COPC selection process as being consistent with background. This example also illustrates how low-level site-related chemical concentrations may be distinguished from background concentrations that have a much wider concentration range.

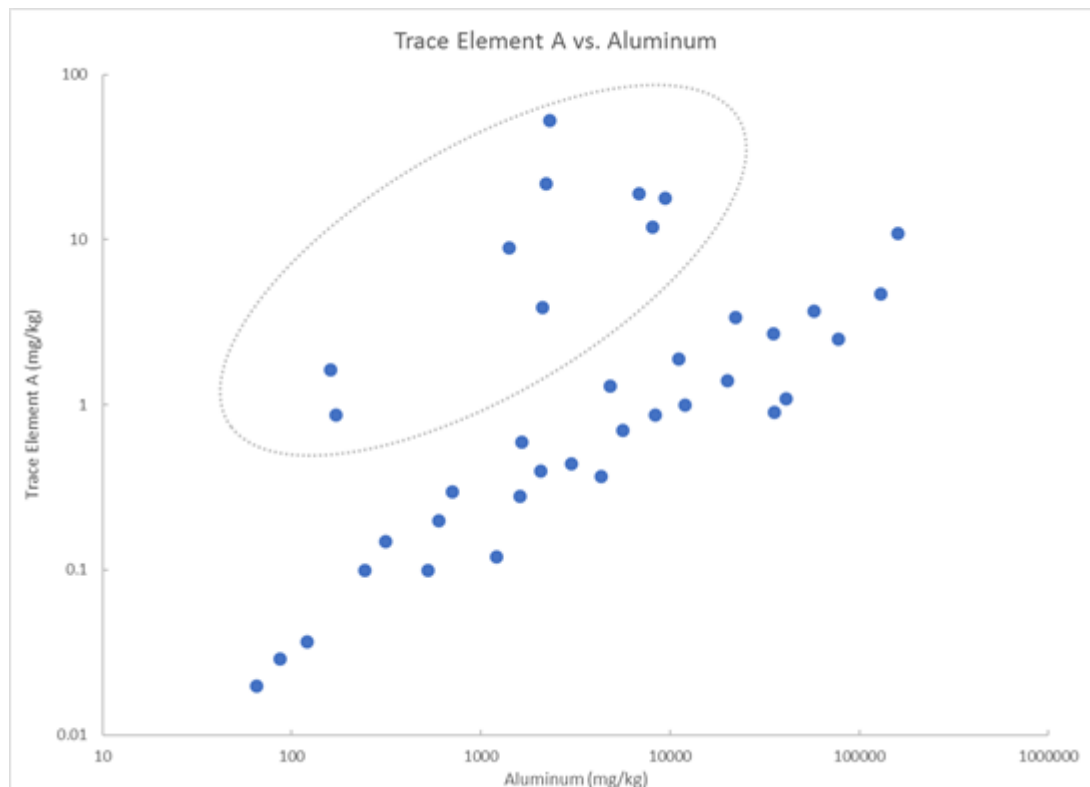


Figure 6-3. Scatter plot of Trace Element A vs. aluminum.

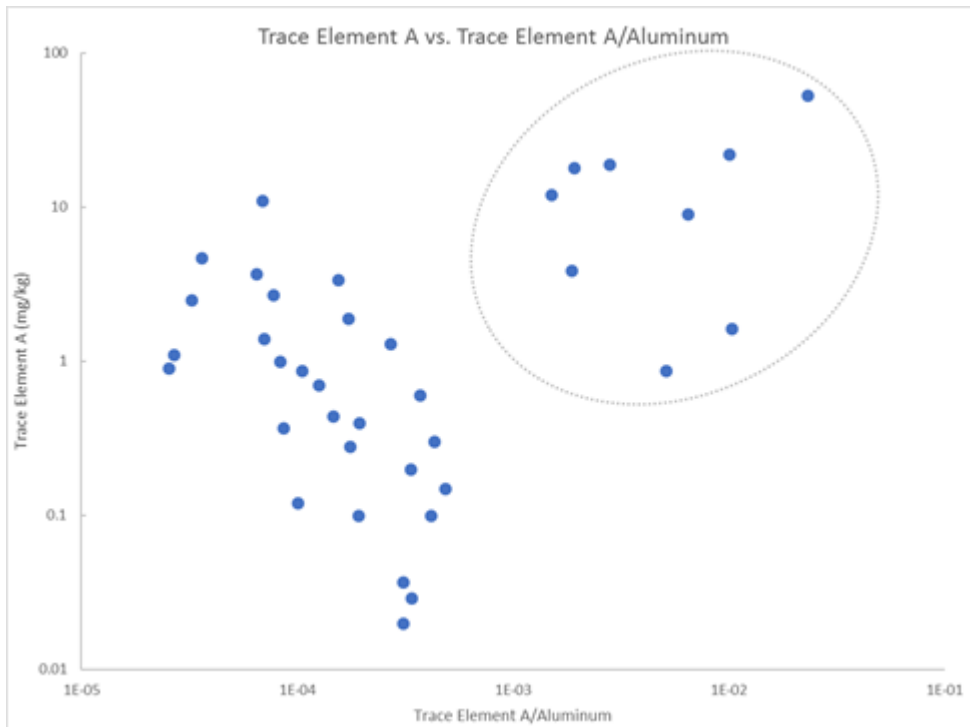


Figure 6-4. Ratio plot of Trace Element A vs. Trace Element A/aluminum.

6.2 Using Geochemical Evaluations During Risk Characterization

If geochemical evaluations are not used during the screening stage to select COPC, then geochemical evaluation results can be used during the risk characterization stage. The overall goal is to determine whether element-related risks can be attributed to site impacts or represent naturally occurring or anthropogenic ambient conditions.

Using the typical human health risk assessment outline terminology of ITRC-Risk-3 (ITRC 2015), this evaluation would likely occur as a subsequent refinement presentation step following initial presentation of risk estimates. In the ecological risk assessment outline terminology ((USEPA 1997), (USEPA 1998)), this synthesis of risk estimation occurs under risk description. In either case, the geochemical evaluation is typically provided as its own stand-alone chapter or appendix in the risk assessment, or in the referenced remedial investigation report or background study report.

Some *advantages* of considering geochemical evaluation results at the risk characterization stage are:

- At this stage of the risk assessment process, the need for, and implications of, geochemical evaluation may be well understood, resulting in a focused evaluation and efficient use of resources.
- These results aid in understanding the results of the risk assessment, which is a primary goal of risk characterization (ITRC 2015), including understanding what risks are with and without the element(s) included.
- Results assist risk managers in scoping appropriate remedial action for a site.

Some potential *challenges* when applying the results of geochemical evaluations in risk characterization are:

- These results add complexity to risk results presentation, which might hinder risk communication with stakeholders and risk managers.
- In some cases, geochemical evaluation conclusions may result in modification of the CSM (for example, through revision of background concentrations or redefinition of impacted areas). It is a best practice to conduct geochemical evaluations early, in order to focus the site assessment/risk assessment process and avoid revising the CSM at a late stage of the risk assessment process, which can result in inefficiency and additional cost.
- Geochemistry expertise is needed, along with additional cost, to perform the geochemical evaluation; in some cases, there can be a lack of expertise at regulatory agencies and thus a lack of understanding and acceptance of these methods.

These potential challenges can be addressed by involving an experienced geochemist in planning, evaluation, and presentation stages of the risk assessment process. The exact approach to incorporating the results of geochemical evaluations into risk characterization will differ depending on how the risk assessment plan is developed, as well as site-specific considerations. Some example scenarios are presented in the following sections. Depending on the applicable

guidance and specific circumstances, these approaches could be incorporated within the primary presentation of risk results or presented as subsequent evaluations for comparative purposes. The documentation of the geochemical evaluation could then be included in an appendix to the risk assessment report or in a stand-alone chapter.

6.2.1 Example #3: Point-by-point spatial evaluation for delineation

On a 100-acre site, sampling is conducted on a half-acre grid to evaluate a hypothetical residential exposure risk scenario. The end-product of risk characterization is a spatial grid of cancer risks for arsenic. A geochemical evaluation is performed, and it is determined that iron is the applicable major element with which to evaluate arsenic ([Section 5.5.2](#)). A map is prepared depicting sample locations, arsenic and iron concentrations, and the corresponding As/Fe ratios. The map shows that the As/Fe ratios inconsistent with background (anomalously high As/Fe ratios) are spatially clustered, whereas those that are consistent with background are distributed throughout the site. The spatial evaluation complements the geochemical evaluation and helps delineate areas of site-related arsenic impacts.

6.2.2 Example #4: Incorporation into site-specific risk-based cleanup levels or preliminary remediation goals

For some sites, the risk characterization portion of the risk assessment may conclude by establishing site-specific risk-based cleanup levels or preliminary remediation goals. To continue with the hypothetical site in Example 3 ([Section 6.2.1](#)), a separate examination of the site data finds that approximately 10% of the site samples show elevated arsenic concentrations greater than a site-specific BTV. The geochemical evaluation indicates that there are some locations where elevated arsenic concentrations appear to result from site impacts, but that there are other locations where arsenic concentrations are consistent with background. Because the geochemical evaluation identified additional locations as being consistent with background, both the data from these locations and the background dataset can be used to establish arsenic's site-specific cleanup levels (or preliminary remediation goals) for the site. The cleanup level based on this combined background dataset would then be compared to a risk-based cleanup level, and the higher of the two values would be used as the final cleanup level.

6.3 Considerations

Risk assessment guidance (for example, ([ITRC 2015](#))) incorporates the concept that level of effort in developing components of a risk assessment should be "fit for purpose." When contemplating incorporation of the results of a geochemical evaluation in a risk assessment, the following considerations are important (see also [Section 5](#)):

- Are the necessary analytical data ([Section 5.3](#)) available to perform geochemical evaluation?
- Is the sampling design robust and does it capture site and background geochemical variability?
- How does the geochemical evaluation contribute to the risk assessment, and to what extent does it inform the results and conclusions of the risk assessment? Does the geochemical evaluation have any implications relative to the usefulness of the risk assessment results?
- How do the results of the geochemical evaluation fit with the existing CSM? Are there inconsistencies that could lead to uncertainty in the risk assessment or to a reconsideration of what chemicals are site-related?
- Does assignment of data to "impacted" or "background," based on the results of a geochemical evaluation, change the overall risk assessment conclusions or interpretation?
- Based on professional judgment of the project team, are metals results and risk assessment results consistent with expected impacts (or lack thereof) based on site history or experience at similar sites?
- How does the uncertainty resulting from inclusion/exclusion of data being considered for reassignment as background based on geochemical evaluation compare to other sources of uncertainty in the risk assessment?

Discussion of some of these same considerations/questions in the risk characterization or uncertainty analysis sections of a risk assessment may be useful as lines of evidence supporting the results of a geochemical evaluation.