Chapter 3
Useability Criteria for Baseline Risk Assessments

This chapter applies data useability criteria to data collection planning efforts to maximize the useability of environmental analytical data in baseline risk assessments. It also addresses preliminary issues in planning sampling and analysis programs.

The chapter has two sections. Section 3.1 discusses data useability criteria involved in risk assessment and suggests ways they can be applied to ensure data are useable. Section 3.2 presents preliminary sampling and analysis issues including identification of chemicals of potential concern, available sampling and analytical strategies or methods, and probable sources of uncertainty.

Before scoping the RI, it is critical for successful planning that the RPM develop a conceptual site model (Exhibit 6) in consultation with the risk assessor and all appropriate personnel. This chapter provides the background information necessary to plan for the acquisition of environmental data for baseline risk assessments. The quality of a risk assessment is intimately tied to the adequacy of the sampling and analysis plan (SAP) developed during the RI.

> ☛ *Effective planning improves the useability of environmental analytical data in the final risk assessment.*

Data needs for baseline risk assessments are not necessarily met by data the RPM acquires to identify the nature and extent of contamination at a Superfund site. For example, a sampling strategy designed to determine the boundaries of a contaminated area may not provide data to quantitate concentrations within an exposure area. The risk assessment may also require more precision and accuracy, and lower detection limits. Accordingly, the risk assessor should be an active member of the team planning the RI and must be consulted from the start of the planning process.

Four fundamental decisions for risk assessment are to be made with the data acquired during the RI, as discussed in Chapter 2.

- If the sampling design is representative, the question of what contamination is present and at what concentration is an analytical problem. Key concerns are the probability of false negatives and false positives. The selection of analytical methods, laboratory performance, and type and amount of data review affects these issues for both site and background samples.
- Assuming that chemicals of potential concern have been identified, the second question involves background levels of contamination. Are site concentrations sufficiently elevated from true background levels to indicate an increased risk for human health due to site contamination?
- All exposure pathways and exposure areas must be identified and examined. The two decisions concerning exposure pathways and areas primarily involve identifying and sampling the media of concern.
- The final decision involves characterizing exposure areas. Sampling and analysis must be representative and satisfy performance objectives determined during the planning process.

RI planning and implementation of RI plans affect the certainty of chemical identification and quantitation. Therefore, the RI needs to collect useable environmental analytical data to enable the risk assessor to make these decisions.

Acronyms

AA	atomic absorption
CLP	Contract Laboratory Program
CRDL	contract required detection limit
CRQL	contract required quantitation limit
DQI	data quality indicator
DQO	data quality objective
GC	gas chromatography
HRS	Hazard Ranking System
ICP	inductively coupled plasma
IDL	instrument detection limit
LOL	limit of linearity
LOQ	limit of quantitation
MDL	method detection limit
MS	mass spectrometry
OVA	organic vapor analyzer
PA/SI	primary assessment/site inspection
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PQL	practical quantitation limit
QA	quality assurance
QC	quality control
QAPjP	quality assurance project plan
QTM	Quick Turnaround Method
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RPM	remedial project manager
RRF	relative response factor
RRT	relative retention time
SAP	sampling and analysis plan
SOP	standard operating procedure
SQL	sample quantitation limit
TIC	tentatively identified compound
TRIS	Toxic Release Inventory System
XRF	X-ray fluorescence

3.1 DATA USEABILITY CRITERIA

Exhibit 12 lists the six data useability criteria involved in planning for the risk assessment, summarizes the importance of each criterion to risk assessment, and suggests actions to take during the planning process to improve the useability of data. The following sections define each criterion and describe its effect on risk assessment.

3.1.1 Data Sources

The data sources selected during the RI planning process depend on the type of data required and their intended use. Data collected prior to the RI are considered historical; data collected during the RI are considered current and are usually specified in the RI planning process. Data may be analytical or non-analytical. The same analytical data requirements apply, whether the data are current or historical. Field screening methods can be used, and sufficient documentation produced, to act as an initial source of data. The minimum criteria for analytical data are discussed in Chapter 5.

Exhibit 13 identifies available data sources and their primary uses in the risk assessment process. Historical and current analytical data sources are briefly discussed below.

Data sources prior to remedial investigation. Historical data sources are useful for determining sampling locations and analytical approaches in the RI. Early site inspections may locate industrial process information that suggests chemicals of potential concern. Historical data indicate industry-specific analytes and general levels of contamination and trends that are useful for identifying exposure pathways, for developing the sampling design, and for selecting analytical methods. Historical analytical data are often available from the preliminary assessment/site inspection (PA/SI), including reports on the physical testing, screening, and analysis of samples. Other sources of analytical data for baseline risk assessment include the Hazard Ranking System (HRS) documentation, site records on removal and disposal, and industry-specific systems for chemical discharge permits. Results from analyses by state or local governments may also indicate chemicals of potential concern. Exact locational data for historical samples should be obtained whenever possible.

> ☛ *Use historical analytical data and a broad spectrum analysis to initially identify the chemicals of potential concern or exposure areas.*

The quality of historical data must be determined prior to their use in the RI. For historical analytical data to be

EXHIBIT 12. IMPORTANCE OF DATA USEABILITY CRITERIA IN PLANNING FOR BASELINE RISK ASSESSMENT

Data Useability Criterion	Importance	Suggested Action
Data Sources (3.1.1)	Data sources must be comparable if data are combined for quantitative use in risk assessment. Plans can be made in the RI for use of appropriate data sources so that data compatibility does not become an issue.	Use data from different data sources together to balance turnaround time, quality of data, and cost. Consult with a chemist or statistician to assess compatibility of data sets.
Documentation (3.1.2)	Deviations from the SAP and SOPs must be documented so that the risk assessor will be aware of potential limitations in the data. The risk assessor may need additional documentation, such as field records on weather conditions, physical parameters and site-specific geology. Data useable for risk assessment must be linked to a specific location.	Review the workplan and SAP and, if appropriate, SOPs. As the data arrive, check for adherence to the SAP so that corrective action such as resampling may be taken and still adhere to the project timetable. Stress importance of chain-of-custody for sample point identification in RI planning meetings.
Analytical Methods and Detection Limits (3.1.3)	The method chosen must test for the chemical of potential concern at a detection limit that will meet the concentration levels of concern in applicable matrices. Samples may have to be reanalyzed at a lower detection limit if the detection limit is not low enough to confirm the presence and amount of contamination.	Participate with chemist in selecting methods with appropriate detection limits during RI planning. Consultation with a chemist is required when a method's detection limit is at or above the concentration level of concern.

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EXHIBIT 12. IMPORTANCE OF DATA USEABILITY CRITERIA IN PLANNING FOR BASELINE RISK ASSESSMENT (Cont'd)

Data Useability Criterion	Importance	Suggested Action
Data Quality Indicators (3.1.4)		
Completeness	Completeness for critical samples must be 100%. Unforeseen problems during sample collection (as defined in Chapter 4) and analysis can affect data completeness. If a sample data set for risk assessment is not complete, more samples may have to be analyzed, affecting RI time and resource constraints.	Define completeness in the SAP for both the number of samples and quantity of useable data needed to meet performance objectives. Identify critical samples during scoping. The SAP should be reviewed by the RPM before initiation of sampling.
Comparability	The risk levels generated in quantitative risk assessment may be questionable if incompatible data sets are used together.	Plan to use comparable methods, sufficient quality control, and common units of measure for different data sets that will be used together, to facilitate data compatability. Consult with a chemist to ensure comparibility of data sets.
Representa-tiveness	Sample data must accurately reflect the site characteristics to effectively represent the site's risk to human health and the environment. Hot spots and exposure area media must have representative data.	Discuss plans for collection of sufficient number of samples, a sample design that accounts for exposure area media, and an adequate number of samples for risk assessment during scoping and document plans in the SAP. This guidance may be modified by Region-specific guidelines.
Precision	If the reported result is near the concentration of concern, it is necessary to be as precise as possible in order to quantify the likelihood of false negatives and false positives.	Plan for the use of QC samples (duplicates, replicates and/or collocated samples) applicable to risk assessment before sampling activities begin. Assess confidence limits from the QC data on the basis of the sampling design or analytical method used.
Accuracy	Quantitative accuracy information is critical when results are reported near the level of concern. Contamination in the field, during shipping, or in the laboratory may bias the analytical results. Instruments that are not calibrated or tuned according to Statement of Work requirements may also bias results. The use of data that is biased may affect the interpretation of risk levels.	Plan and assess QC data (blanks, spikes, performance evaluation samples) to measure bias in sampling and analysis. Consult a chemist to interpret data qualified as "estimated" that are near a concentration of concern.
Data Review (3.1.5)	Use of preliminary data or partially reviewed data can conserve time and resources by allowing modification of the sampling plan while the RI is in process. Critical analytes and samples used for quantitative risk assessment require a full data review.	Decisions regarding level and depth of review will conserve time and project resources and should be made in conjunction with the RPM and analytical chemist. "Non-detect" results require a full review.
Reports to Risk Assessor (3.1.6)	Data reviewers should report data in a format that provides readability as well as clarifying information. SQLs, a narrative, and qualifiers that are fully explained reduce the time and effort required in interpreting and using the analytical results. Limitations can be readily identified and documented in the risk assessment report.	Prescribe a report format during scoping, and include it in the SAP. Communicate with the potential data reviewer to aid the definition of a specific report format. Region-specific guidelines may apply.

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EXHIBIT 13. DATA SOURCES AND THEIR USE IN RISK ASSESSMENT

Available Data Sources	Data Type	Primary Use(s)
PA/SI data	Analytical	• Scoping and planning • Identifying data trends • Determining historical background levels
HRS documentation	Site records, manifests, PA/SI, analytical	• Quantitating the risk assessment • Identifying trends • Planning (by identifying the chemicals present)
Site records on removal and disposal	Administrative	• Planning (by identifying the chemicals present)
Toxic Release Inventory System (TRIS) (Industry-Specific)	Chemical discharge	• Planning (by identifying the chemicals present)
Site, source and media characteristics as found in PA/SI data and reference materials	Physical parameters (e.g., meteor-ological, geological)	• Determining fate and transport • Defining exposure pathways
Field screening	Analytical	• Performing a preliminary assessment • Characterizing the site
Field analytical	Analytical	• Quantitating the risk assessment • Characterizing the site
Fixed laboratory,* both CLP and non-CLP (EPA, state, PRP, commercial)	Analytical	• Quantitating the risk assessment • Providing a reference • Broad screen • Confirming screening data • Characterizing a site

* Mobile laboratories often have the same instrumentation available as fixed laboratories, with the exception of ICP or MS.

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useful in the quantitative risk assessment, sampling design, sampling and analytical techniques, and detection limits must be documented, and the data must have been reviewed.

Historical analytical data of unknown quality may be used in developing the conceptual model or as a basis for scoping, but not in determining representative exposure concentrations. Analytical data from the PA/SI that meet minimum data useability requirements (see Section 5.1.1) can be combined with data from the RI to estimate exposure concentrations. Similarly, historical data of lower quality may be used if the concentrations are confirmed by subsequent RI analyses.

Data sources for the remedial investigation. It may be efficient to use a variety of data sources during an RI. For example, analytical services providing a rapid turnaround of estimated data can be used to estimate the three-dimensional extent of contamination or to "chase" a groundwater pollutant plume. Rapid turnaround analytical services include field analysis or Quick

Turnaround Method (QTM) analyses under the Contract Laboratory Program (CLP). On the other hand, if an unexpected situation arises, such as the discovery of buried drums on the site, it may be appropriate to procure the analytical services of a local commercial laboratory. Data requiring a rapid turnaround are typically produced from streamlined analytical methods, and a certain percentage should be analyzed using a confirmatory method, such as CLP analytical services.

The planning process for the RI identifies gaps in the available analytical data and determines additional data collection requirements. Three types of analytical data sources can be used during the RI to acquire analytical data for a risk assessment. These include field screening, field analyses, and fixed laboratory analyses.

- Field screens are performed using chemical field test kits, ion-specific probes, and other monitoring equipment, but should be confirmed by other techniques. Field screening is usually performed to provide a preliminary assessment of the type and level of concentration of the chemicals of potential concern.
- Field analyses are performed using instruments and procedures equivalent to fixed laboratory analyses; they produce legally defensible data if QC procedures are implemented. Field analyses are usually performed as part of an integrated sampling and analysis plan to quantitate risk assessment and site characterization.
- Fixed laboratory analyses are particularly useful for broad spectrum and confirmation analyses. They often provide more detailed information over a wider range of analytes than field analyses. Fixed laboratory analyses are critical to quantitative risk assessment and site characterization.

A discussion of issues related to field and fixed laboratory analyses is presented in Section 3.2.9.

Analytical services constitute a significant portion of the Superfund budget and should be conserved when possible. CLP costs do not appear on the remedial investigation/feasibility study (RI/FS) project budget. Analyte-specific methods may be used for chemicals identified after a broad spectrum analysis by CLP or other fixed laboratory analysis, and may provide more accurate results. Site samples analyzed by CLP routine analytical services take an average of 35 days to produce results and data review will add to the overall turnaround time. Other data sources, such as a mobile laboratory or CLP QTM or special analytical services, can quickly produce good "first look" results which can be followed up immediately while on site. Mobile laboratory services can replace some CLP services if analytical capabilities are adequately demonstrated by method validation data and if minimum QC requirements are met (see p. 59). At least 10% of sample analyses should be confirmed by fixed laboratory analysis in all situations.

3.1.2 Documentation

Data collection and analysis procedures must be accurately documented to substantiate the analysis of the sample, conclusions derived from the data, and the reliability of the reported analytical data. Plans should be prepared during the RI scoping to document data collection activities. This RI documentation can be used later to evaluate completeness, comparability, representativeness, precision, and accuracy of the analytical data sets. Four major types of documentation are produced during an RI:

- The sampling and analysis plan, including a quality assurance project plan (QAPjP),
- Standard operating procedures (SOPs),
- Field and analytical records, and
- Chain-of-custody records.

Sampling and analysis plan. The scoping meetings and the SAP must clearly establish the end use requirements for data. The data quality indicators for assessing results against stated performance objectives should also be documented in the SAP (see Section 3.1.4). The SAP includes the QAPjP and information required in the SOPs, field and analytical records, and chain-of-custody records (EPA 1989a).

Standard operating procedures and field and analytical records. SOPs for field and analytical methods must be written for all field and laboratory processes. Adherence to SOPs provides consistency in sampling and analysis and reduces the level of systematic error associated with data collection and analysis. Exhibit 14 lists the types of SOPs, field records, and analytical records that are usually associated with RI data collection and analyses, and relates the importance of each to the risk assessment.

All deviations from the referenced SOPs should be pre-approved by the RPM and documented. Samples that are not collected or analyzed in accordance with established SOPs may be of limited use because their quality cannot be determined.

Chain-of-custody. The technical team must decide during scoping what data may be used for cost recovery actions, and plan accordingly for the use of full-scale chain-of-custody or less formal chain-of-custody procedures. Full-scale chain-of-custody is required for

EXHIBIT 14. RELATIVE IMPORTANCE OF DOCUMENTATION IN PLANNING AND ASSESSMENT

Documentation	Importance
Sampling and Analysis Plan	
• Selection and identification of sampling points	Critical
• Sample collection SOP	High
• Analytical procedures or protocols	High
• SOP for data reporting and review	High
• QA project plan	High
• Method-specific QC procedures	Medium
• QA/QC procedures	Medium
• Documented procedures for corrective action	Medium
• SOP for corrective action and maintenance	Medium
• Sample preservation and shipping SOP	Medium
• SOPs for sample receipt, custody, tracking and storage	Low
• SOP for installation and monitoring of equipment	Low
Chain-of-Custody	
• Documentation records linking data to sample location	Critical
• Sampling date	Critical
• Sample tags	High
• Custody seals	Low
• Laboratory receipt and tracking	Low
Field and Analytical Records	
• Field log records	High
• Field information describing weather conditions, physical parameters or site-specific geology	High
• Documentation for deviations from SAP and SOPs	High
• Data from analysis -- raw data such as instrument output, spectra, chromatograms and laboratory narrative	High
• Internal laboratory records	Low

KEY
Critical = Essential to the useability of data for risk assessment.
High = Should be addressed in planning for risk assessment.
Medium = Primarily impacts how data are qualified in risk assessment.
Low = Usually has little effect on useability of data for risk assessment.

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cost recovery and enforcement actions, but does not affect a quantitative determination of risk. Full-scale chain-of-custody includes sample labels and formal documentation that prove the sample was not tampered with or lost in the data collection and analysis process. Sample identity must be verifiable from the collector's notebook and laboratory data sheets, as well as from a formal chain-of-custody.

3.1.3 Analytical Methods and Detection Limits

The choice of analytical methods is important in RI planning. Appropriate analytical methods have detection limits that meet risk assessment requirements for chemicals of potential concern and have sufficient QC measures to quantitate target compound identification and measurement. The detection limit of the method directly affects the useability of data because chemicals reported near the detection limit have a greater possibility of false negatives and false positives. The risk assessor or RPM must consult a chemist for assistance in choosing an analytical method when those available have detection limits near the required action level. Whenever possible, methods should not be used if the detection limits are above the relevant concentrations of concern.

3.1.4 Data Quality Indicators

Data quality indicators (DQIs) are identified during the development of data quality objectives (DQOs), to provide quantitative measures of the achievement of quality objectives. This section discusses each of five DQIs as they relate to the assessment of sampling and analysis.

- Completeness
- Comparability
- Representativeness
- Precision
- Accuracy

These indicators are evaluated through the review of sampling and analytical data and accompanying documentation. The risk assessor may need to communicate with a chemist or statistician after the data collection process has been completed to evaluate DQIs. Therefore, the SAP, field and analytical records, and SOPs should be accessible. Exhibits 15 and 16 summarize the importance of DQIs to sampling and analysis in risk assessment and suggest planning actions.

Each DQI is defined in this section. Note that the specific use of the indicators to measure data useability is different for sampling and analysis. For example, completeness as applied to sampling refers to the number of samples to be collected. Completeness as applied to analytical performance primarily refers to the number of data points that indicate an analytical result for each chemical of interest (e.g., 10 samples analyzed for 25 chemicals will produce a total of 250 data points, 10 data points for each chemical).

EXHIBIT 15. RELEVANCE OF SAMPLING DATA QUALITY INDICATORS

Data Quality Indicators	Importance	Suggested Planning Action
Completeness	Complete materials enable assessment of sample representativeness for identification of false negatives and estimation of average concentration.	Stipulate SOPs for sample collection and handling in the SAP to specify requirements for completeness.
Comparability	Comparable data give the ability to combine analytical results across sampling episodes and time periods.	Use the same sample design across sampling episodes and similar time periods.
Representativeness	Representative data avoid false negatives and false positives (field sampling contamination). Non-representative data may result in bias of concentration estimates.	Use an unbiased sample design. Collect additional samples as required. Prepare detailed SOPs for handling field equipment.
Precision	Variability in concentration estimates may increase uncertainty.	Increase number of samples. Use appropriate sample designs. Use QC results for monitoring.
Accuracy	Contamination during sampling process, loss of sample from improper collection or handling (loss of volatiles) may result in bias, false negatives, or false positives and inaccurate estimates of concentration.	Use SOPs for sample collection, handling, and decontamination. Use QC results for monitoring.

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EXHIBIT 16. RELEVANCE OF ANALYTICAL DATA QUALITY INDICATORS

Data Quality Indicators	Importance	Suggested Planning Action
Completeness	Poor data quality or lost samples reduces the size of the data set and decreases confidence in supporting information.	Prepare SOPs to support sample tracking and analytical procedures, review, and reporting aspects of laboratory operations.
Comparability	Comparable data allow the ability to combine analytical results acquired from various sources using different methods for samples taken over the period of investigation.	Reference analyte-specific method performance characteristics. Reference applicable fate and transport documentation. Anticipate field and laboratory variability.
Representativeness	Non-representative data or non-homogeneity of sample increases the potential for false negatives or false positives. Potential for change in sample before analysis may decrease representativeness.	Include requirement for broad spectrum analyses across site area. Ensure sample is mixed and adequately represents the environment (not applicable to volatiles). Include provision for blank (transport, storage and analytical) QC monitoring. Use field methods when applicable, since they have an advantage in minimizing variability from transport and storage.
Precision	Monitoring can indicate the level of precision. Precision provides the level of confidence to distinguish between site and background levels of contamination. It is of primary importance when the concentration of concern approaches the detection limit.	Method QC component and site-specific QC samples that use external reference are the best monitoring techniques. Consider in method selection whether anticipated site levels are near the MDL and above action limits.
Accuracy	Accuracy also provides the level of confidence to distinguish between site and background levels of contamination. As concentration of concern approaches the detection limit, the differentiation includes confidence in determining presence or absence of chemical of potential concern.	Broad spectrum screening methods may have significant negative bias for chemicals of potential concern. Consider method accuracy and detection limits if site levels approach concentrations of concern.

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Completeness. Completeness is a measure of the amount of useable data resulting from a data collection activity. The required level of completeness should be defined in the QAPjP for the number of samples required in the sampling design and for the quantity of useable data for chemical-specific data points needed to meet performance objectives. All required data items must be obtained for critical samples and chemicals, which are identified in the QAPjP. Incompleteness in any data item may bias results as well as reduce the amount of useable data.

Problems that occur during data collection and analysis affect the completeness of a data set. Fewer samples may be collected and analyzed than originally planned because of site access problems. Laboratory performance may be affected if capacity is exceeded, causing data to be rejected. Some samples may not be analyzed due to matrix problems. Samples that are invalid due to holding time violations may have to be re-collected or the data set may be determined as useable only to a limited extent. Therefore, both advance planning in identifying critical samples and the use of alternative sampling procedures are necessary to ensure completeness of a data set for the baseline risk assessment.

Comparability. Comparability expresses the confidence with which data are considered to be equivalent. Combined data sets are used regularly to develop quantitative estimates of risk. The ability to compare data sets is particularly critical when a set of data for a specific parameter is applied to a particular concentration of concern.

Comparability for sampling primarily involves sampling designs and time periods. Typical questions to consider in determining sampling comparability include:

- Was the same approach to sampling taken in two sampling designs?
- Was the sampling performed at the same time of year and under similar physical conditions in the individual events?
- Were samples filtered or unfiltered?
- Were samples preserved?

Typical questions to consider in determining analytical comparability include:

- Were different analytical methodologies used?
- Were detection limits the same or at least similar?
- Were different laboratories used?
- Were the units of measure the same?
- Were sample preparation procedures the same?

Use routine available methods and consistent units of measure when data collection will span several different sampling events and laboratories, to increase the likelihood that analytical results will be comparable. For field analyses confirmed by laboratory analyses, careful attention must be taken to ensure that the data from field and fixed laboratories are comparable or equivalent (see Section 3.2.9). When precision and accuracy are known, the data sets can be compared with confidence. Planning ahead for comparable sampling designs, methods, quality control, and documentation will aid the risk assessor in combining data sets for each exposure pathway.

Representativeness. For risk assessment, representativeness is the extent to which data define the true risk to human health and the environment. Samples must be collected to reflect the site's characteristics and sample analyses must represent the properties of the field sample. The homogeneity of the sample, use of appropriate handling, storage, preservation procedures, and the detection of any artifacts of laboratory analyses, such as blank contamination, are particularly important. For risk assessment, sampling and analyses must adequately represent each exposure area or the definition of an exposure boundary.

Representativeness can be maximized by ensuring that sampling locations are selected properly, potential hot spots are addressed, and a sufficient number of samples are collected over a specified time span. The SAP should describe sampling techniques and the rationale used to select sampling locations.

Precision. Precision is a quantitative measure of variability, comparing results for site samples to the mean, and is usually reported as a coefficient of variation or a standard deviation of the arithmetic mean. Results of QC samples are used to calculate the precision of the analytical or sampling process. Measurement error is a combination of sample collection and analytical factors. Field duplicate samples help to clarify the distinction between uncertainty from sampling techniques and uncertainty from analytical variability. Analytical variability can be measured through the analysis of laboratory duplicates or through multiple analyses of performance evaluation samples. If analytical results are reported near a concentration of concern, the standard deviation or coefficient of variation can be incorporated in standard statistical evaluations to determine the confidence level of the reported data. A statistician or

a chemist should be consulted to make this determination. Total variability must be evaluated to assess the precision of data used to define parameters in risk assessment.

Accuracy. Accuracy is a measure of the closeness of a reported concentration to the true value. This measure is usually expressed as bias (high or low) and determined by calculating percent recovery from spiked samples. The risk assessor should know the required level of certainty for the end use of the data, expressed as DQOs, when reviewing accuracy information. When results are reported at or near a concentration of concern, accuracy information is critical.

Accuracy of identification may be affected by sample contamination introduced in the field, during shipping, or at the laboratory. Field and trip blanks should be used during the RI to identify contamination and the associated bias related to sample collection or shipment. Method blanks, audit samples, and calibration check standards should be used to monitor laboratory contamination. Accuracy information may be of less importance if the precision (bias) is known.

3.1.5 Data Review

This section discusses the importance of alternative levels of data review to the risk assessment. The two major effects of data review on data useability are:

- The timeliness of the data review and
- The level and depth of review (e.g., entire site, specific sample focus, specific analyte focus, amount of QC data assessed).

A tiered approach involving combinations of data review alternatives is recommended so that the risk assessor can use preliminary data before extensive review. The RPM, in conjunction with the risk assessor and the project chemist, must reach a consensus on the level and depth of data review to be performed for each data source, to balance useability of data and resource constraints. Exhibit 17 summarizes the characteristics and uses of different levels of data review.

Timing of review. Plans for the timing of the data review should be made prior to data collection and analysis. The risk assessor uses preliminary data in a qualitative manner to identify compounds for toxicity studies and, initially, to ascertain trends in concentrations and distributions of the analytes of concern, to plan for additional sampling, and to request additional analyses. Using data as they become available will usually reduce the time needed to complete the risk assessment. However, all data must receive a minimum level of review before use in the quantitative aspects of risk assessment. Iterations on data review is resource intensive; if they are used, they should be planned carefully as part of a structured process.

EXHIBIT 17. ALTERNATIVE LEVELS OF REVIEW OF ANALYTICAL DATA

Level of Review	Samples	Analytes	Parameters	Potential Uses
None	Initial	All	Analytical results	Qualitatively identify risk assessment analytes. Modify SAP.
Full	Initial samples analyzed for broad spectrum components	All	All analytical results, QC, and raw data	Quantitatively perform risk assessment. Modify SAP. Modify review process.
Partial	Critical samples for all analytes or All samples for critical analytes		Selected analytical results, QC, or raw data	Improve timeliness, overall efficiency, save resources. Focus on chemicals of potential concern.
Automated	All	All	Parameters available to the automated system. No raw data are evaluated.	Improve timeliness, consistency, cost effectiveness. If data are electronically transferred to a database, eliminates transcription errors.

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☛ *To expedite the risk assessment, preliminary data should be provided to the risk assessor as soon as they are available.*

Level and depth of review. The RPM may select different levels of data review, in consultation with the risk assessor or other data users and the project chemist. All data must have a minimum level of review. Data review levels can range from all site samples with all reported data to specific key analytes and samples and may be specified in EPA Regional policies. Careful consideration is required in selecting a level of review that is consistent with data quality requirements.

A full data review minimizes false positives, false negatives, calculation errors, and transcription errors. "Non-detect" results must be reviewed to avoid "false negative" conclusions. Partial review should be utilized only after broad spectrum analysis results have undergone full review; it may be useful after chemicals of potential concern have been identified. A flexible approach to data review alternatives allows the RPM to balance time and resource constraints.

Depth of data review refers to which evaluation criteria are selected, ranging from generalized criteria that may affect an entire data set (e.g., holding time) to analyte-specific criteria that may affect only a portion of results from one sample (e.g., recovery of a surrogate spike for organics or analyte spike recovery for inorganics). The RPM decides the depth of review for each data source, to provide a balance between useability of data and resource constraints. Chemicals of potential concern in the quantitative risk assessment should not be eliminated from concern without a full data review.

Automated data review systems. Automated data review systems can be used to assess all samples and analytes for which there are computer-readable data in the format required by the automated system. The depth of review depends on both the data and the assessment system. The primary advantages of automated data review systems for the risk assessor are timeliness, the elimination of transcription errors that can be introduced during manual review processes, and computer-readable output which usually includes results and qualifiers. This information can be transferred to computer-assisted risk assessment and exposure modeling systems. Exhibit 18 provides a list of software that aid data review and evaluation.

EXHIBIT 18. AUTOMATED SYSTEMS* TO SUPPORT DATA REVIEW

System	EPA Contact	Description
CADRE Computer Assisted Data Review and Evaluation	Gary Robertson Quality Assurance Div. USEPA, EMSL-LV (702) 798-2215	An automated evaluation system that accepts files from CLP format disk delivery or mainframe transfer and assesses data based on *National Functional Guidelines for Organic (or Inorganic) Data Review* (EPA 1991e, EPA 1988e) (default criteria). System accepts manual entry of other data sets, and rules for evaluation can be user-defined to reflect specific information needs. (Inorganic system is in development.)
eDATA Electronic Data Transfer and Validation System	William Coakley USEPA, Emergency Response Team (908) 906-6921	An automated review system developed to assist in rapid evaluation of data in emergency response. May be applicable for both CLP and non-CLP data. System combines DQOs, pre-established site specifications, QC criteria, and sample collection data with laboratory results to determine useability.

* Both systems operate on an IBM-compatible PC AT with a minimum of 640K RAM. A fixed disk is recommended.

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3.1.6 Reports from Sampling and Analysis to the Risk Assessor

Preliminary data reports assist the risk assessor in identifying sampling or analytical problems early enough so that corrective actions can be taken during data collection, before sampling or analysis resources are exhausted. The risk assessor should request preliminary data during RI planning and formalize the request in the SAP. The use of such information may reduce the overall time required for the risk assessment and increase the quality of a quantitative risk assessment.

Exhibit 19 lists the final data and documentation needed to support risk assessment, and rates the importance of each item. Data are most useable when reported in a readable format and accompanied by additional, clarifying information. Regional policy usually defines report structures which specify the format for manual summaries, for machine-readable data (where required), and for summary tables from data review. The RPM can request the data reviewers to provide a data summary table listing sample results, sample quantitation limits, and qualifiers on diskette for downloading into Risk* Assistant (an automated tool to support risk assessment), spreadsheets, or other software programs that the risk

EXHIBIT 19. DATA AND DOCUMENTATION NEEDED FOR RISK ASSESSMENT

Data and Documentation	Importance
• Site description with a detailed map indicating site location, showing the site relative to surrounding structures, terrain features, population or receptors, indicating air and water flow, and describing the operative industrial process if appropriate.	Critical
• Site map with sample locations (including soil depths) identified.	Critical
• Description of sampling design and procedures including rationale.	Critical
• Description of analytical method used and detection limits including SQLs and detection limits for non-detect data.	Critical
• Results given on a per-sample basis, qualified for analytical limitations and error, and accompanied by SQLs. Estimated quantities of compounds/tentatively identified compounds.	Critical
• Field conditions and physical parameter data as appropriate for the media involved in the exposure assessment.	Critical
• Narrative explanation of qualified data on an analyte and sample basis, indicating direction of bias.	High
• QC data results for audits, blanks, replicates and spikes from the field and laboratory.	High
• Definitions and descriptions of flagged data.	High
• Hardcopy or diskette results.	Medium
• Raw data (instrument output, chromatograms, spectra).	High
• Definitions of technical jargon used in narratives.	Low

KEY
Critical = Essential to the useability of data for risk assessment.
High = Should be addressed in planning for risk assessment.
Medium = Primarily impacts how data are qualified in risk assessment.
Low = Has little effect on useability of data for risk assessment.

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assessor may use. An example of a recommended report format for tabular results appears in Appendix I.

The data reviewer should provide a narrative summary, which is comprehensible to a nonchemist, describing specific sampling or analytical problems, data qualification flags, detection limit definitions, and interpretation of QC data. This summary must always be followed and supported by a detailed commentary that explicitly addresses each item from the narrative on a technical basis. The explanation for data qualification in the commentary facilitates data use. If a nontechnical narrative is unavailable, the risk assessor must (at a minimum) be provided with explanations of qualification flags, detection limits, and interpretation of QC data (see Appendices I, V and VI for examples). A chemist familiar with the site can be requested to interpret the analytical review with site-specific information, such as physical site conditions that affect sample results.

3.2 PRELIMINARY SAMPLING AND ANALYTICAL ISSUES

This guidance cannot encompass sampling design in the assessment of environmental sampling and analysis procedures; however, this section does sketch a framework for these activities. It discusses key issues for determining the potential impact of sampling and analysis procedures on data useability for risk assessment and for identifying situations that require statistical or methodological support. The sampling discussion primarily focuses on soil issues, but some generalizations can be made to other media such as sediment or groundwater. Rules of thumb, reference tables, statistical formats and checklists support the statistical understanding and sophistication of RPMs and risk assessors. A Sampling Design Selection Worksheet, a Soil Depth Sampling Worksheet, and a Method Selection Worksheet are tools, presented with step-by-step instructions in Chapter 4, to focus planning efforts.

Sampling issues. Resolving statistical and non-statistical sampling issues provides the risk assessor, project chemist, and QA personnel with a basis for identifying sampling design and data collection problems, interpreting the significance of analytical error, and selecting methods based on the expected contribution of sampling and analytical components to total measurement error. Comprehensive discussions of environmental sampling procedures are given in *Principles of Environmental Sampling* (Keith 1987), *Environmental Sampling and Analysis* (Keith 1990a), *Methods for Evaluating the Attainment of Cleanup Standards* (EPA 1989e), *and the Soil Sampling Quality Assurance User's Guide* (EPA 1989f).

Several assumptions concerning sampling and associated statistical procedures have been made to simplify the discussion in this section:

- The RPM and risk assessor are familiar with basic environmental sampling and statistical terms and logic and have access to a statistician.
- Sampling designs are mainly based on stratified random or systematic random sampling (grid), or variations thereof. Systematic sampling requires special variance calculations for estimating statistical performance parameters such as power and confidence level; these calculations are not provided in this guidance.
- Statisticians are consulted for any significant problems or issues not covered in this guidance.
- Superfund contaminant concentrations for a site generally fit a log-normal distribution. Measurements of variability are generally given in log-transformed units. Overviews of statistical methodology include Gilbert (1987) and Koch and Link (1971). Parametric tests in transformed units (Aitchison and Brown 1957) have logarithmic forms (Seichel 1956). Graphical methods of determining re-transformed means and their 95% confidence levels are available (Krige 1978).
- Quality assurance procedures for sampling and analysis are not separate, even though the discussion addresses them separately.

Exhibit 20 summarizes the importance of each of the preliminary sampling planning issues to the risk assessment, proposes planning actions to reduce or eliminate their effect on data useability, and refers the reader to further discussion in the text. Information relevant to preliminary sampling planning can be obtained by collecting site maps, photographs and other historical and current documents which depict production, buildings, sewage and storm drains, transport corridors, dump sites, loading zones, and storage areas. A reliable and current base map is particularly important.

Data adequacy. All data users should clearly state the level of data adequacy they desire. These statements, and the resources that will be committed, should be incorporated into the sampling plan objectives. If an appropriate level of uncertainty cannot be determined at this stage, an initial goal should be agreed on for the final level of reliability, which may be revised during the iterative sampling process. Since each site is unique, it may be extremely difficult to attain a given level of data adequacy. An iterative sampling program may

EXHIBIT 20. IMPORTANCE OF SAMPLING ISSUES IN RISK ASSESSMENT

Issue	Importance	Suggested Action
Chemicals of Potential Concern (3.2.1)	Chemicals have different rates of occurrence and coefficients of variation. This impacts the probability of false negatives and reduces confidence limits for estimates of concentration.	Increase the number of samples for chemicals with low occurrence and/or high coefficients of variation.
Sampling and Analytical Variability versus Measurement Error (3.2.5)	Sampling variability can exceed measurement error by a factor of three to four (EPA 1989c). Sampling variability increases uncertainty or variability; measurement error increases bias.	Reduce sampling variability by taking more samples (using less expensive methods). This allows more samples to be analyzed. Use QC samples to estimate and control bias. Prepare SOPs for handling all field equipment.
Media Variability (3.2.5)	Sampling problems vary widely by media as do variability and bias.	Design media-specific sampling approaches.
Sample Preparation and Sample Preservation (3.2.6)	Contamination can be introduced during sample preparation, producing false positives. Filtering may remove contaminants sorbed on particles.	Use blanks at sources of potential contamination. Collect filtered and unfiltered samples.
Identification of Exposure Pathways (3.2.7)	Not all samples taken in a site characterization are useful for risk assessment. Often only a few samples have been taken in the area of interest.	Specifically address exposure pathways in sampling designs. Risk assessors should participate in scoping meeting.
Use of Judgmental or Purposive Sampling Design (3.2.8)	Statistical sampling designs may be costly and do not take advantage of known areas of contamination.	Use judgmental sampling to examine known contaminated areas, then use an unbiased method to characterize exposure.

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allow a realistic appraisal of the variability present at the site; a phased investigation may be warranted, with an increase in data adequacy at each phase.

Natural variation. It is important to realize that natural variation (environmental heterogeneity) in both soil and water systems may be so great that variation due to field sampling is significantly greater than that due to laboratory analysis. For example, laboratory sample-sample precision is commonly of the order of less than 1%, whereas soil sample-sample precision is commonly between 30% to 40%. Sampling variation is influenced by the homogeneity of material being sampled, the number of samples, collection procedures, and the size of individual samples.

Uncertainty in sampling measurements is additive. Exhibit 21 lists the components of sampling variability and measurement error. The final error associated with an estimate is the sum of the errors associated with natural variation (intrinsic randomness, microstructure, macrostructure), plus sampling error, plus laboratory measurement error. Poor sampling techniques can swamp the natural phenomenon that is being evaluated. Therefore, sampling options must be fully reviewed and the probable uncertainty from sampling must be acceptable.

Initial survey sampling plan. A preliminary sampling plan should be chosen that provides a basis for evaluation of overall sampling goals, sampling techniques, feasibility, and statistical analysis techniques. General categories of sampling plans include simple random, stratified random, systematic, judgmental/purposive, and spatial systematic. The features of these different plans are discussed in more detail in Chapter 4.

Statistical analysis of the survey data allows evaluation of how well the sampling program is doing. Depending on the contaminant, current technology may allow on-site "laboratory" analysis of the samples using portable microcomputers and telecommunications. On-site statistical analysis is also possible. On-site analysis reduces project completion time and costs. In a truly

EXHIBIT 21. SAMPLING VARIABILITY AND MEASUREMENT ERROR

Sampling variability: The variation between true sample values that is a function of the spatial variation in the pollutant concentrations.

Measurement error: The variation resulting from differences between true sample values and reported values. Measurement error is a function of uncertainty due to the following:

- Sample collection variation
- Sample preparation/handling/ preservation/storage variation
- Analytical variation
- Data processing variation

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iterative sampling campaign, on-site statistical analysis can guide the sampling teams, maximizing information capture and minimizing time-related costs.

Analytical issues. The following assumptions concerning analytical procedures have been made in this section:

- The RPM and the risk assessor are familiar with standard analytical chemical procedures. Reference books on environmental issues in analytical chemistry are available and can be consulted (ASTM 1979, Manahan 1975, Dragun 1988, Baudo, *et. al.*, eds. 1990, Taylor 1987).
- Chemists are available and will be consulted for any significant problems or situations not covered in this guidance.
- Analytical QA procedures are used in conjunction with and affect sampling QA procedures, even though the discussion treats these procedures separately.

Exhibit 22 summarizes the importance of each analytical issue to risk assessment, lists suggested actions during the planning process, and refers the reader to further discussion in the text. Each issue is discussed in terms of its effect on data quality for risk assessment, and how to anticipate and plan for potential problems. The RPM should also consult the project chemist to determine the appropriate sample volumes or weights required for different types of analysis.

Biota sampling and analytical issues. The type of assessment (e.g., human health or ecological) determines the type of samples to be collected. An ecological assessment may require analysis of the whole body or of a specific organ system of a target species (because organic, and some inorganic, chemicals of concern are often concentrated in tissues with high lipid contents). Human health risk assessment usually concentrates on edible portions.

Typical sampling considerations for biota include specifying the species to be sampled, sampling locations, tissue to be analyzed, number of individuals to be sampled, and the method of analysis of the chemical of concern. Biota analyses should include a method validation that incorporates tissues or plant analyte spikes, and any available performance evaluation materials. The purpose of spiking is to determine whether the analytes are recoverable from the matrix or clean-up steps hinder detection of the analyte.

Spiking and duplicate information can be used to assess method precision and accuracy. The primary source of performance evaluation materials is the National Bureau of Standards repository. Samples and performance evaluation materials should be matched by matrix (species and whole/edible portions).

Volatile analytes are very difficult to measure in biota. Samples should be stored on dry ice immediately after collection. Fat and cholesterol can also block columns and impede chromatography for base/neutral/acid extractable tissue analysis. Gel permeation chromatography procedures may only be marginally effective in clean up, and the lipids present may retain analytes of concern, thereby reducing recoveries. Plant matrices are often difficult to digest, and a variety of digestion procedures using hydrogen peroxide or phosphoric acid may be warranted. Tissues for organic analysis should be wrapped in aluminum foil for shipment to the laboratory, and tissues for metals analysis should be wrapped in plastic film. All tissues should be sent frozen on dry ice.

Air sampling and analysis issues. Air sampling procedures should account for wind speed and direction as well as seasonal and daily fluctuations; they should also account for the influence of these factors on the exposed population (e.g., the largest population may be potentially exposed in the evening when the wind speed may be least). The definition of detection limits is very important for air analyses. For example, the same concentration will appear very different if expressed on a weight/volume basis than on a volume/volume basis.

Sampling strategies may need to distinguish between particulate and gaseous forms of chemicals of concern. It is important to collect media blanks to determine the type and amount of contamination that may be found. Blanks should also be provided to the laboratory for spiking to determine analytical precision and accuracy.

EXHIBIT 22. IMPORTANCE OF ANALYTICAL ISSUES IN RISK ASSESSMENT

Analytical Issue	Importance	Suggested Action
Chemicals of Potential Concern (3.2.1)	Chemicals of potential toxicological significance may be omitted.	Examine existing data and site history for industry-specific wastes to determine analytes for measurement. Perform broad spectrum analysis.
Tentatively Identified Compounds (3.2.2)	Identification and quantitation do not have high confidence.	Be prepared to request further analyses if potentially toxic compounds are discovered during screening. Compare results from multiple samplings or historical data.
Identification and Quantitation (3.2.3)	False negatives may occur when analytes are present near the MDL.	Use technique with definitive identification (e.g., GC-MS). Alternatively, use technique with definitive identification first, followed by another technique (e.g., GC) to achieve lower quantitation limits.
Detection Limits (3.2.4)	Significant risk may result at concentrations lower than measurable.	Review available methods for appropriate detection limit.
Media Variability (3.2.5)	Variability and bias may be introduced to analytical measurements.	Use environmental samples as QC samples to determine recovery and reproducibility in the sample media.
Sample Preparation (3.2.6)	Variability and bias may be introduced to analytical measurements.	Select analytical methods based on sample medium and strengths of the sample preparation technique.
Field Analyses versus Fixed Laboratory Analyses (3.2.9)	Tradeoffs required with regard to speed, precision, accuracy, personnel requirements, identification, quantitation and detection limits.	Consider options and set priorities.
Laboratory Performance Problems (3.2.10)	Quality of data may be compromised.	Select experienced laboratory and maintain communication.

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The sample medium should be checked to ensure that recovery rates are documented.

3.2.1 Chemicals of Potential Concern

Chemicals of potential concern are chemicals that may be hazardous to human health or the environment and are identified at the site, initially from historical sources. Chemicals identified at Superfund sites have varying rates of occurrence, average concentrations, and coefficients of variation. These differences are a function of fate and transport properties, occurrence in different media, and interactions with other chemicals, in addition to use and disposal practices. Information on frequency of occurrence and coefficient of variation determines the number of samples required to adequately characterize exposure pathways and is essential in designing sampling plans. Low frequencies of occurrence and high coefficients of variation mean that more samples will be required to characterize the exposure pathways of interest. Potential false negatives

occur as variability increases and occurrence rates decrease. From an ecological standpoint, chemicals of potential concern may be different from those for human health concerns. For example, copper is an analyte of high concern from an ecological perspective, but of low concern from a human health perspective. In addition, if water quality criteria are used as toxicological thresholds, it should be determined whether the criteria are based on ecological or human health effects.

> ☛ *To protect human health, place a higher priority on preventing false negatives in sampling and analysis than on preventing false positives.*

Data are available for volatiles, extractable organics, pesticides/PCBs, tentatively identified organic compounds, and metals (see Appendix II), for aqueous and soil/sediment matrices, and releases from industries known to produce waste commonly found at Superfund sites. Data from CLP Superfund sites are also available for calculating site-specific coefficients of variation. Exhibit 23 indicates the occurrence rates and coefficients of variation for selected chemicals of potential concern to risk assessors. Many other chemicals (which are not of concern) may be present without affecting the level of risk to the exposed population.

> ☛ *Use preliminary data to identify chemicals of potential concern and to determine any need to modify the sampling or analytical design.*

The need for risk assessment indicates that there is already some knowledge of contamination at the site. Based on available toxicological and site data, the risk assessor can recommend target chemicals (or chemical classes) for analysis and desired detection limits. For example, explosive chemicals are likely to be present at a former munitions site. Exhibit 24 presents data on munitions compounds, such as feasible detection limits and health advisory limits.

Information on industry-specific analytes is summarized in Exhibit 25 and detailed in Appendix II. If historical data are incomplete, a broad spectrum analysis should be performed on selected samples from each sampling location to provide necessary scoping information.

The RPM or risk assessor should inform the planning team about chemicals of potential concern at the site, exposure pathways, if known, concentrations of concern, and other pertinent information, particularly any requirement to distinguish specific states of the chemicals of potential concern. Some oxidation states of metals (e.g., chromium) are more easily absorbed or are more toxic than others, and organically substituted metals such as mercury are more toxic than their elemental states. If these concerns are important, analyses that determine metal specification rather than elemental analyses should be performed, if available. Similarly, for organic compounds, such as tetrachloroethane, degradation products or metabolites may be more toxic than the parent compounds. In this case, sampling procedures and analytical methods should include the parent compound, degradation products, and metabolites of chemicals of potential concern.

3.2.2 Tentatively Identified Compounds

Gas chromatography-mass spectrometry (GC-MS) analyses categorize organic compounds in two ways. Target compounds are those compounds for which the GC-MS instrument has been specifically calibrated using authentic chemical standards. A target compound in an environmental sample is identified by matching its mass spectrum and relative retention time (RRT) to those obtained for the authentic standard during calibration. Quantitation of a target compound is achieved by comparison of its chromatographic peak area to that of an internal standard compound, normalized to the relative response factor (RRF) which is the ratio of the peak areas of the authentic chemical standard and the internal standard measured during calibration.

> ☛ *Specific analysis for compounds identified during library search can be requested.*

Tentatively Identified Compounds (TICs) are any other compounds which are reported in the sample analysis, but for which the GC-MS instrument was not specifically calibrated. A TIC is identified by taking its mass spectrum from the environmental sample, and comparing it to a computerized library of mass spectra. Computerized comparison routines score the various library spectra for their similarity to the TIC and rank the spectra most similar to the TIC's spectrum. If the TIC is reported as a specific compound, it is usually reported to be one of the compounds whose spectra were retrieved in the library search. Quantitation of a TIC is less accurate than for target compounds, because the true RRF is not known (since no calibration for this specific compound was performed). The RRF is assumed to be 1.0; whereas, measured RRFs below 0.05 and above 10.0 are known.

Confidence in the identification of a TIC can be increased in several ways. The main steps in identifying and quantitating TIC data are summarized in Exhibit 26. An analytical chemist trained in the interpretation of mass spectra and chromatograms can review TIC data

EXHIBIT 23. MEDIAN COEFFICIENT OF VARIATION FOR CHEMICALS OF POTENTIAL CONCERN [1]

Chemical of Potential Concern	Soil/Sediment Median %CV[2]	Number of Sites at Which Chemical was detected[3]	Water Median %CV[2]	Number of Sites at Which Chemical was detected[3]
Chloromethane	16.7	61	50.0	134
Trichloromethane/Chloroform	53.9	392	45.2	519
Tetrachloromethane/Carbon tetrachloride	15.4	38	9.3	90
1,2-Dichloroethane	17.6	64	24.7	158
Tetrachloroethane	17.0	56	17.4	101
Vinyl chloride	11.0	55	15.7	197
Tetrachloroethene	24.5	392	33.3	367
Dichloropropane	19.0	29	13.3	79
Isophorone	0.7	74	18.4	72
Bis (2-chloroethyl) ether	0.5	10	20.1	34
1,4-Dichlorobenzene	0.9	120	17.3	119
Bis (2-ethylhexyl) phthalate	0.7	1197	29.5	782
Benzo(a) pyrene	0.5	1058	10.8	76
Styrene	16.9	117	33.3	69
N-nitrosodiphenylamine	0.5	142	30.5	96
DDE	4.5	329	813.0	40
DDT	2.9	521	588.2	125
Dieldrin	4.4	274	3.3	101
Heptachlor	4.8	249	351.9	151
Gamma-BHC (lindane)	6.3	142	454.1	134
PCB1260	0.21	251	41.7	23
Arsenic	40.3	1098	58.0	940
Beryllium	271.3	1091	100.0	931
Cadmium	134.6	1096	33.7	945
Chromium	11.9	1098	23.0	948
Mercury	1032.3	1098	500.0	948
Lead (Pb)	10.9	1098	97.3	939

[1] List of chemicals of potential concern is derived from health-based levels and frequency of occurence at Superfund sites listed in the CLP Statistical Database. (Number of sites for which data exist totals 8,900.)

[2] Median percent coefficient of variation of analyte concentrations.

[3] November 1988 to present.

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EXHIBIT 24. MUNITIONS COMPOUNDS AND THEIR DETECTION LIMITS

Health Advisory	Acronym	Compound Name[1]	Detection Limit[2] (ppb)
*	HMX	Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine	5.1
*	RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine	4.2
	---	Nitrobenzene	6.4
	TNB	1,3,5-Trinitrobenzene	5.9
**	DNB	1,3-Dinitrobenzene	9.1
	Tetryl	Methyl-2,4,6-trinitrophenylnitramine	4.4
*	TNT	2,4,6-Trinitrotoluene	6.3
**	2,4 DNT	2,4-Dinitrotoluene	2.3
	TAX	Hexahydro-1-(N)-acetyl-3,5-dinitro-1,3,5-triazine	
	SEX	Octahydro-1-(N)-acetyl-3,5,7-trinitro-1,3,5,7-tetrazocine	
**	2,6 DNT	2,6-Dinitrotoluene	5.1
*	2,4,5 TNT	2,4,5-Trinitrotoluene	
	2 Am DNT	2-Amino-4,6-dinitrotoluene	
	4 Am DNT	4-Amino-2,6-dinitrotoluene	
	2,4 DAmNT	2,4-Diamino-6-nitrotoluene	
	2,6 DAmNT	2,6-Diamino-4-nitrotoluene	
*	DIMP	Disopropyl-methylphosphonate	
*	TNG	Gylcerol trinitrate (Nitroglycerin)	
*	---	Nitrocellulose	
**	DMMP	Dimethyl methylphosphonate	
**	NG	Nitroguanadine	

* Health advisory complete.
** Health advisory in preparation (1990).

[1] Depending upon matrix and instrument conditions, these compounds may be chromatographable and may be tentatively identified as indicators of the presence of munitions during GC-MS library search procedures.

[2] Detection limits are provided where available. Specific compounds with complete health advisories are designated as target analytes with defined detection limits specified in a high performance liquid chromatographic method developed and provided by the U.S. Army Toxic and Hazardous Materials Agency.

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