United States Environmental Protection Agency

Office of Research and Development

Office of Solid Waste and Emergency Response

EPA/540/5-96/500
December 1995

16305

EPA

Engineering Forum Issue

0000003

DETERMINATION OF BACKGROUND CONCENTRATIONS OF INORGANICS IN SOILS AND SEDIMENTS AT HAZARDOUS WASTE SITES

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INTRODUCTION

The National Engineering Forum is a group of U.S. Environmental Protection Agency (EPA) professionals representing EPA Regional Offices, committed to the identification and resolution of engineering issues affecting the remediation of Superfund sites. The forum has identified the need to provide remedial project managers (RPMs) and other state or private personnel working with hazardous waste sites a thought-provoking, technical-issue paper on how to determine background concentrations of inorganics in soils and sediments at hazardous waste sites. Mr. Frank Vavra and Mr. Bob Stamnes, Engineering Forum members, provided technical guidance and direction in the development of this Issue paper.

This paper was prepared by R. P. Breckenridge and A. B. Crockett. Support for this project was provided by the National Exposure Research Laboratory's Characterization Research Division with the assistance of the Superfund Technical Support Project's Technology Support Center for Monitoring and Site Characterization. For further information, contact Ken Brown, Technology Support Center Director, at (702) 798-2270, or R. P. Breckenridge at (208) 526-0757, U.S. Department of Energy, Idaho National Engineering Laboratory.

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Technology Support Center for Monitoring and Site Characterization, Characterization Research Division
Las Vegas, NV 89193-3478

Technology Innovation Office
Office of Solid Waste and Emergency Response, U.S. EPA, Washington, D.C.

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PURPOSE AND SCOPE

The purpose of this paper is to provide RPMs and others investigating hazardous waste sites a summary of the technical issues that need to be considered when determining if a site (i.e., hazardous waste site/area of concern) has elevated levels of inorganics relative to the local background concentrations. This issue paper is narrowly focused and is for **educational use only** by project managers. It is not meant to be a formal guidance document or "cookbook" on determination of background concentrations of inorganics at hazardous waste sites. This issue paper provides the investigator with information needed to determine whether activities conducted at a site have resulted in elevated concentrations of inorganic contaminants in soils or sediments compared with naturally occurring and off-site anthropogenic concentrations of the same contaminant.

The first portion of this paper provides a definition for and discusses factors that influence background concentrations. The second portion is separated into Part A, "Comparing the Concentrations of Inorganics in Soils and Sediments at Hazardous Waste versus Background Sites," and Part B, "Guidance for Addressing High Background Concentrations of Inorganics at CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act) Sites." Part A is a modification of the State of Michigan guidance on conducting soil surveys (Michigan 1991a, 1991b) and discusses issues that need to be considered by investigators attempting to establish background concentrations for hazardous waste sites. It can be used to provide potentially responsible parties a summary of issues they need to consider when determining whether a hazardous waste site has elevated concentrations of inorganics compared to a background site. Part B presents a summary of a draft issue paper titled, "Options for Addressing High Background Levels of Hazardous Substances at CERCLA Sites" (EPA 1992a) and includes updated information and approaches.

This paper addresses **technical issues** for scientists and engineers faced with how to determine background concentrations. It is **not** intended to address agency policy-related decisions on how to use background data to achieve cleanup levels or achieve applicable or relevant and appropriate requirements (ARARs). Technical issues discussed here include selection of background sampling locations, considerations in the selection of sampling procedures, and statistical analyses for determining whether contaminant levels are significantly different on a potential waste site and a background site. How to statistically define background for purposes of remediating a hazardous waste site to background levels is **not** addressed.

This paper focuses on **inorganics** and, in particular, metals. Radionuclides are not specifically addressed; however, metals with radioactive isotopes (e.g., cobalt-60) that may be encountered at hazardous waste sites are included. This paper does not specifically address background concentrations of organics at a site, but the approach would be very similar in many respects (except for partitioning), and some unique aspects regarding organics are noted.

Statistics play a major role in establishing background concentration levels, and methods vary widely in their degree of complexity. No specific recommendations regarding statistical techniques are provided because they could be misused or have policy implications. However, some general guidance is presented to acquaint the reader with issues that should be discussed with a statistician early in the design of a study. Statistics should be used throughout the development of a sampling plan in the same manner as quality assurance. Sampling objectives, design, data analysis, and reporting can all be influenced by statistical considerations.

To provide recommendations that can be used at a variety of sites, information was gleaned from several different approaches to the background issue. The approach employed by the State of Michigan (Michigan 1990, 1991b) provides one of the most straightforward and scientifically sound strategies that, in combination with EPA documents (EPA 1989a, 1989b) and scientific literature (Underwood 1970; Kabata-Pendias and Pendias 1984), form the basis for this issue paper. This paper discusses the generic issues from various strategies that should be

considered when addressing the background issue. However, information presented here may need to be modified to meet site-specific soil and sediment or data-quality objective concerns.

STATEMENT OF ISSUE

Hazardous waste sites may pose a threat to human health and the environment when toxic substances have been released. The hazardous substances at a site may originate from either "on-site" (i.e., resulting from releases attributable to site-specific activities) or "off-site" (i.e., resulting from sources not on-site). These "off-site" substances may result either from natural sources (e.g., erosion of naturally occurring mineral deposits) or anthropogenic sources (e.g., widespread lead contamination from automobile exhaust in urban areas) (EPA 1992a). To determine the appropriate action to take at a hazardous waste site, EPA must distinguish between substances directly attributable to the hazardous waste site (i.e., "site" contaminants) and those attributable to "natural background" concentrations.

Definitions

Soils and sediments for this issue paper are defined as all mineral and naturally occurring organic material located at a site and will mostly be related to the material <2 mm in size because it is usually the finer material that has a greater affinity for inorganic contaminants. The U.S. Department of Agriculture and the International Soil Science Society use the 2-mm breakpoint to differentiate between soils or sediment (consisting of sands, silts, and clays) and gravel (Breckenridge et al. 1991; Lewis et al. 1991). When establishing background concentration levels, it is usually more cost effective to focus on the finer materials; however, some bias is introduced. Large particles can be rinsed and the rinsate analyzed if necessary. Soils and sediments are heterogeneous and contain a wide range of sizes from fine clays to larger gravel and coarse fragments (Soil Science Society of America 1978).

In the soils literature, the term "background" usually refers to areas in which the concentrations of chemicals have not been elevated by site activities. In the sediment literature, terms such as "background sediment" (in the Code of Federal Regulations (CFR)—40 CFR 131.35-91) and "reference sediment" (ASTM 1990) are used in similar manners and are often interchangeable.

To minimize confusion, the term "background concentration" is defined in this document as **the concentration of inorganics found in soils or sediments surrounding a waste site, but which are not influenced by site activities or releases**. A "background site" should be a site that is geologically similar and has similar biological, physical, and chemical characteristics (e.g., particle size, percent organic carbon, pH) as the contaminated site (ASTM 1990) but also should be upstream, upgradient, or upwind of the site. Samples taken from a site to determine background concentrations will be referred to as background samples.

Almost anyone involved with hazardous waste site evaluations will at some time be involved in determining background concentrations of inorganics at a site. There are two issues to be considered when addressing background. The first is whether the site and local area have a high natural variability in concentrations of inorganics. The second is to differentiate between natural and anthropogenic sources at a site with high background concentrations (e.g., lead in soil due to automobile emissions). The broad range in concentrations of naturally occurring inorganics may lead to the erroneous conclusion that an area has been contaminated with inorganics. Establishment of background concentrations based on adequate site-specific sampling data and comparison to normal background ranges for a specific area and land use can help resolve the confusion.

EPA in its *Risk Assessment Guidance for Superfund: Volume 1, Human Health Evaluation Manual (Part A)* (often referred to as RAGS) (EPA 1989c) discusses two categories of background:

1. Naturally occurring--substances present in the environment in forms that have not been influenced by human activity.

2. Anthropogenic--natural and man-made substances present in the environment as a result of human activities not specifically related to the CERCLA site.

Figure 1 shows the relationship between the on-site-related and off-site-related "populations" of substances that contribute to concentrations at a site. In some locations, the background concentrations resulting from naturally occurring or anthropogenic sources may exceed contaminant-specific standards promulgated to protect human health (EPA 1992a). The background concentration defined in this document includes both the naturally occurring and local/regional anthropogenic contributions (see Figure 1).

Background concentrations are needed when deciding whether a site is contaminated. Knowledge of background concentrations helps address issues such as (a) the effects of past land use practices on levels of inorganics in soil and sediment, and (b) establishing lower limits when conducting risk assessments for soil and sediment contamination.

Figure 2 illustrates a process for determining whether contaminant concentrations in soil and sediments at a hazardous waste site are elevated relative to background concentrations.

Determining the effect of past land use practices on levels of inorganics in soils and sediments is an important initial step towards quantifying the potential threat to human health and the environment. Information obtained from this step can provide the first indication that background concentrations may be elevated. Preliminary site investigations should be carefully planned so that high-quality data can be gathered to gain an understanding of the nature and degree of threat posed by a site and to determine whether immediate response is required.

Usually, remedial action is taken only on sites that exceed a 10^{-4} incremental cancer risk or exceed a hazard index of 1.0 for systemic effects. Superfund cleanups are generally conducted to 10^{-6} incremental cancer risk or to a safe hazard index. However, many states have developed statutes (ARARs) that require more stringent cleanup levels than risk-based levels and sometimes require cleanup to natural background concentrations.

It is often best to compare mean concentrations between groups of similar samples from the hazardous waste and background sites. Mean values can be developed for a soil series or an operable unit. The operable unit is usually the smallest area that would be considered under a remediation plan (e.g., 10 m × 10 m if a bulldozer is used to remove the top 6 inches of soil). However, there may be cases when it is important to know if a single sample has a high probability of exceeding background. In this case, the single value can be compared to the background maximum limit (mean background concentration plus three standard deviations), which is discussed later.

Background Concentration

Numerous natural and anthropogenic sources influence background concentrations and need to be accounted for during an initial hazardous waste site investigation. Proper accounting of these sources is important when establishing cleanup standards and are critical if discussions about ARARs develop.

It is not feasible to establish a single universal background concentration for soils or sediments; it is more useful to discuss the **range** of background concentrations for a contaminant. Single values are hard to establish because concentrations vary depending on how physical, chemical, and biological processes, and anthropogenic contributions have affected parent geological material at a site. If a site has various soil or sediment textures (e.g., sands, loams), a range in inorganic concentrations should be developed for different soil series or textural groupings. Thus, physical and chemical parameters need to be identified when investigating a site to ensure that soils or sediments with similar parameters are compared. This is important because there are often different soil types at a site, and sediments differ depending on where (e.g., in a pool or main channel) and when samples are collected. The following parameters should be similar when

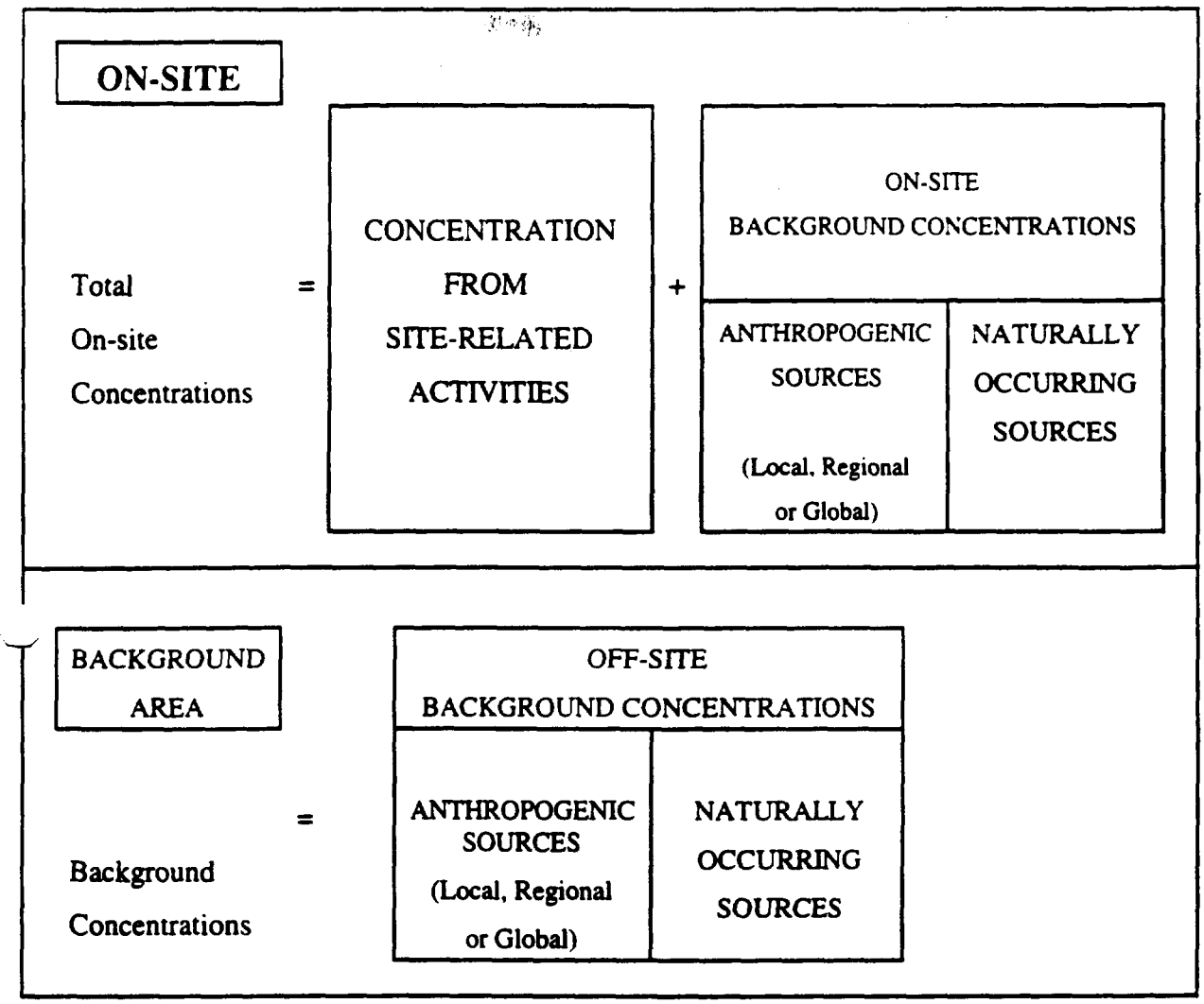


Figure 1. Relationship between on- and off-site concentration groupings when defining background concentrations for hazardous waste sites.

comparing paired hazardous waste site samples to background samples:

- pH/Eh
- salinity
- cation exchange capacity (CEC)
- percent organic carbon
- particle size and distribution
- thickness of horizon (soil)
- soil type, structure (soil)
- sample design
- depth of sampling
- sampling equipment and compositing regime (if applicable)
- number of samples
- digestion/analytical method
- acid volatile sulfide concentrations (sediment)
- simultaneously extracted metal concentrations (for determining sediment toxicity)

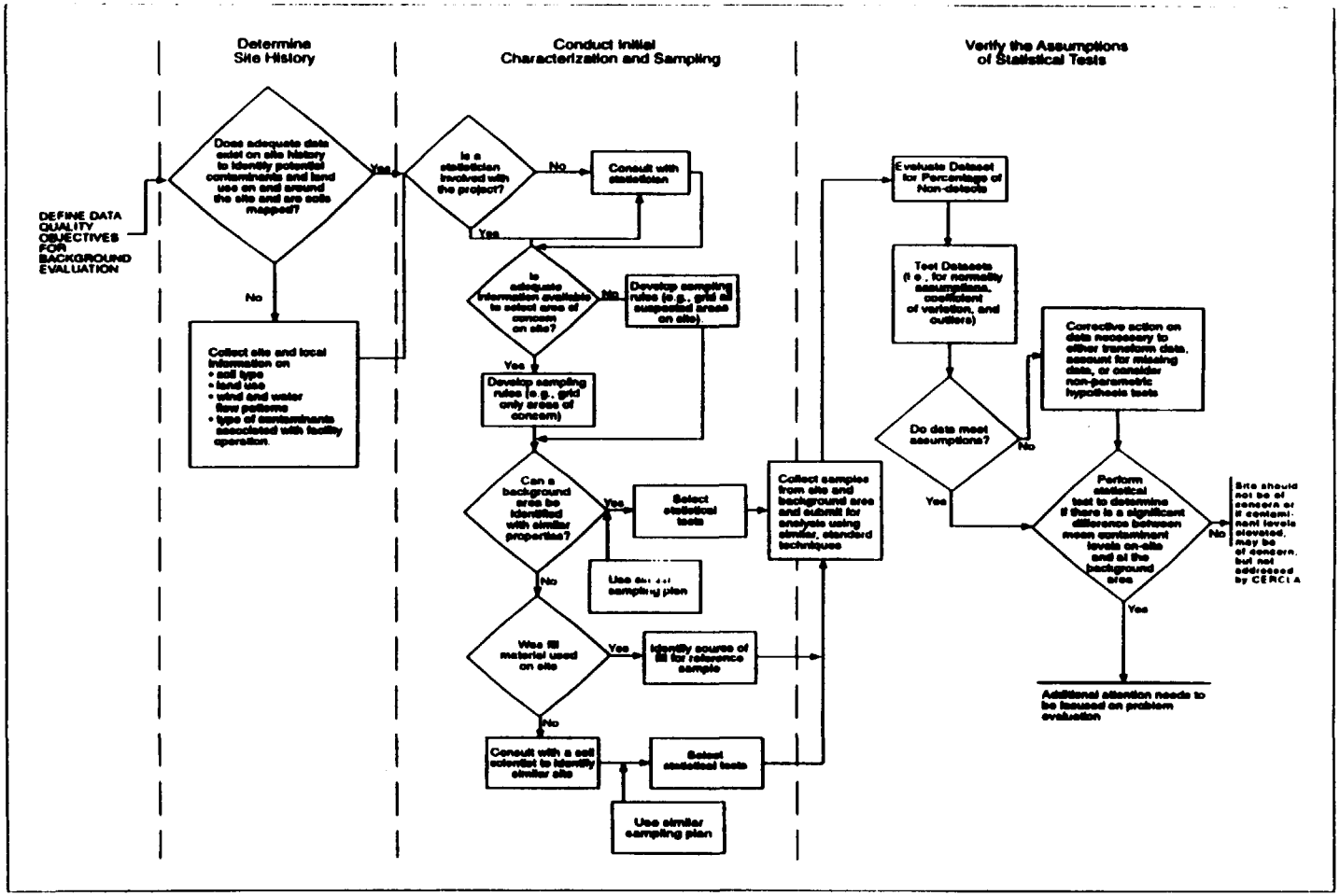


Figure 2. Process for determining if contaminant concentrations at a hazardous waste site are above background concentrations in soil and sediments.

At times some of these soil parameters such as percent organic carbon, pH and salinity may be altered by hazardous waste site activities. These changes in soil chemistry could falsely imply that the hazardous waste site and background site soil/sediment matrices are totally very comparable. For example, if oil were released at a hazardous waste site where mercury is of a concern, the percent organic carbon values could be much higher than at the background site. This could lead to an incorrect conclusion that the sites are not similar for comparison of inorganic concentrations.

Many of these soil parameters can be obtained by contacting the local Natural Resources Conservation Service (NRCS) Office and requesting a soil survey report for the county (usually free of charge) where the site is located. Most soils on private lands in the U.S. have been mapped by the NRCS. By using a soil survey report, the field personnel can evaluate how the soils were originally classified and gain access to average values for the soil series located at the site. By consulting with a soil scientist and comparing current site soils to those previously mapped, an assessment can be made of the amount of change and disturbance that has occurred to the soil profile. Aerial photographs used to map soils are also helpful in evaluating past land use, locating stream channels, determining parent material for sediment loading, and determining site factors that affect movement of contaminants (e.g., low percolation rate). More detail on how and why to characterize soils at hazardous waste sites can be found in a companion issue paper (Breckenridge et al. 1991).

A special case occurs for hazardous waste sites that contain fill. "Fill areas" may be present around construction or disposal areas and should be suspected if the site is located in areas frequently inundated with water. Sites where dredge material (e.g., sediments from shipping areas) is suspected to have been used as fill should be given additional attention because the dredge material may have elevated levels of contaminants. A soil scientist can usually identify fill locations and areas disturbed by construction because of the disturbed nature of the soil profile.

Natural and Regional Anthropogenic Contributions to Background Concentrations

Table 1 presents concentration ranges and mean values of inorganics in selected surface soils of the United States. Most of this contribution is due to natural and regional/global anthropogenic sources. The soil types presented are general, but cover many of the major categories found in the United States. There is one omission from the table and that is for cadmium, since cadmium mobility is strongly dependent on soil pH and percent organic carbon. The mean global content of cadmium in soils is between 0.07 and 1.1 ppm (ppm-dry weight ~ mg/kg for SI units); for the United States, values range from 0.41 to 0.57 ppm, but values of up to 1.5 ppm have been documented in some forest soils (Kabata-Pendias and Pendias 1984). In all cases, the higher cadmium values reflect anthropogenic contributions (from local and regional sources) to topsoils.

Table 2 provides average, range, and no-effect levels for selected inorganics in sediment and soils that can be used to compare to background concentrations for a site. The no-effect levels are the metal concentrations in **sediment** that have a low probability of causing a measurable impact on benthic populations. The control values for soils and sediments approximate the average concentrations of metals contributed by natural and anthropogenic (local and global) values (Lee et al. 1989; EPA 1992b). These values should not be used as background concentrations but can be used to guide investigators in determining whether elevated levels of contaminants may be present at a hazardous waste site.

Local Anthropogenic Sources that Influence Background Concentrations

Note: Some of the activities discussed here may not be waste handling or disposal activities; however, they could qualify as releases under Superfund (e.g., mining activities may result in releases that can be addressed under Superfund).

Numerous local anthropogenic activities can contribute to the inorganic concentrations at a hazardous waste site yet are not directly related to site activities. Local soils and sediments may be contaminated by ore deposits or mining, by

TABLE 1. CONCENTRATION OF INORGANICS IN SURFACE SOILS OF THE U.S. [IN PPM-DRY WEIGHT, DW), EQUIVALENT TO mg/kg-dw] (SOURCE: KABATA-PENDIAS AND PENDIAS 1984).

	Elements											
	As		Ba		Co		Cr		Cu		Hg	
Soil	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Sandy soils and lithosols on sandstones	<0.1–30.0	5.1	20–1500	400	0.4–20	3.5	3–200	40	1–70	14	<0.01–0.54	0.08
Light loamy soils	0.4–31.0	7.3	70–1000	555	3–30	7.5	10–100	55	3–70	25	0.01–0.60	0.07
Loess and soils on silt deposits	1.9–16.0	6.6	200–1500	675	3–30	11.0	10–100	55	7–100	25	0.01–0.38	0.08
Clay and clay loamy soils	1.7–27.0	7.7	150–1500	535	3–30	8.0	20–100	55	7–70	29	0.01–0.90	0.13
Alluvial soils	2.1–22.0	8.2	200–1500	660	3–20	9.0	15–100	55	5–50	27	0.02–0.15	0.05
Soils over granites and gneisses	0.7–15.0	3.6	300–1500	785	3–15	6.0	10–100	45	7–70	24	0.01–0.14	0.06
Soils over volcanic rocks	2.1–11.0	5.9	500–1500	770	5–50	17.0	20–700	85	10–150	41	0.01–0.18	0.05
Soils over limestones and calcareous rocks	1.5–21.0	7.8	150–1500	520	3–20	9.5	5–150	50	7–70	21	0.01–0.50	0.08
Soils on glacial till and drift	2.1–12.0	6.7	300–1500	765	5–15	7.5	30–150	80	15–50	21(a)	0.02–0.36	0.07
Light desert soils	1.2–18.0	6.4	300–2000	835	3–20	10.0	10–200	60	5–100	24	0.02–0.32	0.06(a)
Silty prairie soils	2.0–12.0	5.6	200–1500	765	3–15	7.5	20–100	50	10–50	20(a)	0.02–0.06	0.04(a)
Chernozems and dark prairie soils	1.9–23.0	8.8	100–1000	595	3–15	7.5	15–150	55	10–70	27	0.02–0.53	0.10
Organic light soils	<0.1–48.0	5.0	10–700	265	3–10	6.0	1–100	20	1–100	15	0.01–4.60	0.28
Forest soils	1.5–16.0	6.5	150–2000	505	5–20	10.0	15–150	55	7–150	17(a)	0.02–0.14	0.06(a)
Various soils	<1.0–93.2	7.0	70–3000	560	3–50	10.5	7–1500	50	3–300	26	0.02–1.50	0.17

TABLE 1. (CONTINUED)

Soil	Elements											
	Mn		Ni		Pb		Se		Sr		Zn	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Sandy soils and lithosols on sandstones	7–2000	345	<5–70	13.0	<10–70	17	0.005–3.5	0.5(a)	5–1000	125	<5–164	40.0
Light loamy soils	50–1000	480	5–200	22.0	<10–50	20	0.02–1.2	0.33(a)	10–500	175	20–118	55.0
Loess and soils on silt deposits	50–1500	525	5–30	17.0	10–30	19	0.02–0.7	0.26(a)	20–1000	305	20–109	58.5
Clay and clay loamy soils	50–2000	580	5–50	20.5	10–70	22	<0.1–1.9	0.5	15–300	120	20–220	67.0
Alluvial soils	150–1500	405	7–50	19.0	10–30	18	<0.1–2.0	0.5	50–700	295	20–108	58.5
Soils over granites and gneisses	150–1000	540	<5–50	18.5	10–50	21	<0.1–1.2	0.4	50–1000	420	30–125	73.5
Soils over volcanic rocks	300–3000	840	7–150	30.0	10–70	20	0.1–0.5	0.2	50–1000	445	30–116	78.5
Soils over limestones and calcareous rocks	70–2000	470	<5–70	18.0	10–50	22	0.1–1.4	0.19(a)	15–1000	195	10–106	50.0
Soils on glacial till and drift	200–700	475	10–30	18.0	10–30	17(a)	0.2–0.8	0.4	100–300	190	47–131	64.0(a)
Light desert soils	150–1000	360	7–150	22.0	10–70	23	<0.1–1.1	0.5	70–2000	490	25–150	52.5
Silty prairie soils	200–1000	430	<5–50	16.0	10–30	21(a)	<0.1–1.0	0.3	70–500	215	30–88	54.3(a)
Chernozems and dark prairie soils	100–2000	600	7–70	19.5	10–70	19	<0.1–1.2	0.4	70–500	170	20–246	83.5
Organic light soils	7–1500	260	5–50	12.0	10–50	24	<0.1–1.5	0.3	5–300	110	<5–108	34.0
Forest soils	150–1500	645	7–100	22.0	10–50	20(a)	<0.1–1.6	0.4	20–500	150	25–155	45.7(a)
Various soils	20–3000	490	<5–150	18.5	<10–70	26	<0.1–4.0	0.31	7–1000	200	13–300	73.5

a. Data for whole soil profile.

TABLE 2. AVERAGE RANGE AND LOW- TO NO-EFFECT LEVELS OF SELECTED INORGANICS IN SEDIMENTS AND SOILS (mg/kg UNLESS OTHERWISE NOTED).

Media and source	Ag	As	Ba	Cd	Cr	Cu	Fe%	Hg	Mn	Ni	Pb	Zn
SEDIMENTS[a,b]												
Non-polluted, Great Lakes (U.S. Army Corps of Engineers 1977)	—	<3	<20	—	<25	<25	<1.7	<1.0	<300	<20	<40	<90
No effect level (Persaud et al. 1989)[b]	—	4.0	—	0.6	22	15	2.0	0.1	400	15	23	65
	0.5	8	—	1.0	33	28	—	0.1	—	—	21	68
Effects range low, marine sediments (Long et al. 1995)[b]	1.0	8.2	—	1.2	81	34	—	0.15	—	20.9	46.7	150
No adverse biological effects, marine sediments (WDOE 1991)[b]	6.1	57		5.1	260	390	—	0.41	—	—	450	410
Control sediments, Southern California (Lee et al. 1989)[a]	0.06–2.0	3–15	—	0.001–2	6.5–40	2.8–30	—	<1.0	—	<20.0	<10.0	<70.0
Control sediments, Puget Sound (Lee et al. 1989)[a]	1.2	3–15	—	3.1–18.3	20.9	10–50	—	0.02–0.12	—	13.0	8	
Control sediments, Yaquina Bay (Lee et al. 1989)[a]	0.55	—	—	0.47	19.3	6.3	—	—	—	14.5	5.5	26.3
No effect threshold, freshwater sediments[b] (Environment Canada 1992)	—	3.0	—	0.2	55	28	—	0.05	—	—	23	100
Lowest effect level, freshwater sediments (Persaud et al. 1992)	0.5	6	—	0.6	26	16	—	0.2	460	16	31	120
Threshold effect levels for freshwater sediments (Environment Canada 1994)	—	5.9	—	0.596	37.3	35.7	—	0.174	—	18.0	35.0	123.1
Threshold effect levels for marine sediments (Environment Canada 1994)	0.73	7.24	—	0.676	52.3	18.7	—	0.13	—	15.9	30.2	124
Effects range low, freshwater (Ingersoll et al. 1995)	—	13	—	0.70	39	41	20	—	730	24	55	110
SOILS (control values)[a]												
Average and common range in natural soils (summarized in Shields 1988)	0.05 0.01–5	5 0.1–40	430 100–3500	0.06 0.01–7	100 5–3000	30 2–100	— —	0.11 0.01–0.8	600 100–4000	40 5–1000	10 2–200	50 10–300
Average concentration in earth's crust (Merck 1989)	—	0.5	500	0.1–0.2	100–300	70	5	0.5	850	180	20	200
Average concentration in earth's crust (CRC 1992)	0.07	1.8	425	0.2	100	55	5.63	0.08	950	75	12.5	70
Relative abundance in soils (Martin and Whitfield 1983)	0.05	6.0	—	0.35	70	34	4.0	—	1000	50	35	90

a. Control values approximate natural background.

b. No-effect refers to no measurable impact to benthic organisms when exposed to sediments with stated levels of metals.

agricultural application of pesticides or sewage sludge, and by emissions from motor vehicles. In urban areas, sites may become contaminated by air emissions from home heating, automobiles, and industry. Table 3 provides ranges of contaminant levels in surface soils from some local anthropogenic sources of inorganics that could contribute to background concentrations at or near a hazardous waste site. Table 4 provides a review of some of the more common agricultural sources of inorganics associated with practices such as sludge, pesticides, and fertilizer applications.

These tables identify elements that could be associated with different land uses at or around a hazardous waste site. For example, if the site is located in an area with high agricultural chemical usage, elevated background concentrations of arsenic, bromine, lead, vanadium, and zinc could be expected. To determine what background concentrations might be without the agricultural contribution, the investigator needs to rely on some investigative skills. These skills are detailed in Part A of this document.

Accessing Data and Methods for Establishing Background Concentrations

The previous discussion presented information on ranges of background concentrations that could be expected for inorganics of greatest concern at hazardous waste sites. Additional information sources that should be consulted include soil scientists from the NRCS and county extension agents who may have conducted soil surveys that describe the natural soils' physical, chemical, and biological status. However, many of these surveys were conducted for purposes such as mineral development, farming, and soil conservation; the data focus on properties of soils. The NRCS maintains the SOILS-5 data base that provides attributes of soils (e.g., texture, pH, CEC, salinity, clay content) that can be accessed at the local NRCS Office or through the NRCS Office of Technology, Cartography and Geographic Information System Division at (202) 447-5421. Many data sets are available on World Wide Web (WWW). The U.S. Geological Survey (USGS) Global Land Information (GLI) system is another source for most land-based data and can be located on WWW at *http://edcwww.cr.usgs.gov/glis/glis.html*. The Agricultural Stabilization and Conservation Service can also be a good source of aerial photographs for hazardous waste site assessment. Information on soil surveys, aerial photographs, and other sources that may be useful for identifying soil types and land use in the United States is presented in Table 5.

Several large projects have been conducted to address the issue of characterizing background soil concentrations. For example, the Oak Ridge Reservation (a U.S. Department of Energy facility) conducted a background soil characterization project to establish a database, to recommend how to use the data for contaminated site assessments, and to provide estimates of the potential health and environmental risks associated with the background level concentrations of potentially hazardous constituents (see Table 5, ORNL 1993). This source provides a detailed approach for those faced with conducting a detailed background investigation.

Approach for Establishment of Background Reference Values

The approaches described in this document, for the most part, combine discussion of issues generic to soils and sediments. However, when warranted, attributes unique to the two different media are discussed in separate sections. One such section discusses sediments that require sampling through overlying water.

PART A

COMPARING THE CONCENTRATIONS OF INORGANICS IN SOILS AND SEDIMENTS AT HAZARDOUS WASTE VERSUS BACKGROUND SITES

The objective of Part A is to determine whether hazardous waste site-related activities have caused an increase in the levels of inorganic contaminants in soils and sediments compared to background concentrations.

SOILS

Step 1—Evaluation of Land Use History and Existing Data

Purpose: This effort is designed to identify land use history both on and near the hazardous waste site (i.e., within the air and watershed connected to

TABLE 3. INORGANIC CONTAMINATION OF SURFACE SOILS, AVERAGE VALUES FROM VARIOUS ANTHROPOGENIC SOURCES IN THE UNITED STATES (PPM-DW)[a] (SOURCE: KABATA-PENDIAS AND PENDIAS 1984).

Element	Site and pollution source	Mean or range of content
Arsenic (As)	Metal-processing industry	10-380
	Application of arsenal pesticides	31-625
Cadmium (Cd)	Metal-processing industry	26–160
	Urban garden	0.02–13.6
	Vicinity of highways	1–10
Cobalt (Co)	Mining or ore deposit	13–85
	Metal-processing industry	42–154
	Roadside or airport area	7.9
Copper (Cu)	Urban gardens, orchards, and parks	3-140
	Sludged farmland	90
Lead (Pb)	Metal processing industry	500–6,500
	Urban garden and urban vicinity	218–10,900
	Roadside soil	960–7,000
	Non-ferric metal mining	15–13,000
Mercury (Hg)	Hg mining or ore deposit	0.1–40
	Urban garden, orchard, and parks	0.6
Zinc (Zn)	Non-ferric metal mining	500-53,000
	Metal processing industry	155-12,400
	Urban gardens and orchards	20-1,200

a. Equivalent to mg/kg-DW.

or in proximity to the site) to determine what contribution the anthropogenic activities from previous land use at or near the hazardous waste site have had on background concentrations.

Approach: Early in a hazardous waste site investigation, site history should be determined by examining available records and by interviewing personnel familiar with the site. This information can be used to assess the types of contaminants associated with past operations that may be of concern and may be compared to Appendix IX, Superfund and Priority Pollutant Compounds, lists which identify the inorganic contaminants of concern. Evaluation of site history can provide important data when determining those compounds for which background concentrations need to be established. For example, if releases of cadmium and lead are suspected at a hazardous waste site and the site is located in a heavily industrialized area, there is high potential that metals like mercury, lead, and cadmium may be present and elevated in soils and sediment from off-site contributions. An initial evaluation of on-site data should be sensitive to the issue of elevated background so that off-site contributions can be properly accounted for.

Another advantage of evaluating existing hazardous waste site data is to determine if pre-site operation values are available for inorganics in sediments or soil. These data can be obtained from site records or other existing sources discussed later in this paper. NRCS soil surveys should be checked both for aerial photographs that show previous land use on or near the site and for average physical and chemical properties for soils at and around the hazardous waste site. Local county agricultural

TABLE 4. AGRICULTURAL SOURCES OF INORGANIC CONTAMINATION IN SOILS (PPM DW)[a] (KABATA-PENDIAS AND PENDIAS 1984).

Element	Sewage sludges	Phosphate fertilizers	Limestones	Nitrogen fertilizers	Manure	Pesticides (%)
As	2–26	2–1,200	0.1–24.0	2.2–120	3–25	22–60
B	15–1,000	5–115	10	–	0.3–0.6	–
Ba	150–4,000	200	120–250	–	270	–
Be	4–13	–	1	–	–	–
Br	20–165	3–5	–	185–716	16–41	20–85
Cd	2–1,500	0.1–170	0.04–0.1	0.05–8.5	0.3–0.8	–
Ce	20	20	12	–	–	–
Co	2–260	1–12	0.4–3.0	5.4–12	0.3–24	–
Cr	20–40,600	66–245	10–15	3.2–19	5.2–55	–
Cu	50–3,300	1–300	2–125	<1–15	2–60	12–50
F	2–740	8,500–38,000	300	–	7	18–45
Ge	1–10	–	0.2	–	19	–
Hg	0.1–55	0.01–1.2	0.05	0.3–2.9	0.09–0.2	0.8–12
In	–	–	–	–	1.4	–
Mn	60–3,900	40–2,000	40–1,200	–	30–550	
Mo	1–40	0.1–60	0.1–15	1–7	0.05–3	
Ni	16–5,300	7–38	10–20	7–34	7.8–30	–
Pb	50–3,000	7–225	20–1,250	2–27	6.6–15	60
Rb	4–95	5	3	–	0.06	–
Sc	0.5–7	7–36	1	–	5	–
Se	2–9	0.5–25	0.08–0.1	–	2.4	–
Sn	40–700	3–19	0.5–4.0	1.4–16.0	3.8	–
Sr	40–360	25–500	610	–	80	–
Te	–	20–23	–	–	0.2	–
U	–	30–300	–	–	–	–
V	20–400	2–1,600	20	–	–	45
Zn	700–49,000	50–1,450	10–450	1–42	15–250	1.3–25
Zr	5–90	50	20	–	5.5	–

a. Equivalent to mg/kg-DW.

TABLE 5. SOURCES OF INFORMATION FOR IDENTIFYING SOIL TYPES, LAND USE, AND DETERMINING BACKGROUND LEVELS OF INORGANICS IN SOILS AND SOME SEDIMENTS IN THE U.S.

Source	Supporting background information	Locations	Contact point
Bureau of Land Management—BLM	Provides data on areas in the country that have naturally occurring substances that pose a hazard to humans or the environment.	Mostly western U.S.	BLM Service Center Denver Federal Center Lakewood, CO 80225 (303) 236-0142
National Park Service (NPS)	Inventory and monitoring of trace levels of inorganics in soils in natural areas.	Nationwide	Local NPS Headquarters
U.S. Geological Survey	Several reports on the concentration of inorganics in the environment;	Nationwide	Water Resources Information Center: (703) 648-6818
	Background geochemistry of some rocks, soils, plant, and vegetables in the conterminous U.S. "Geological Survey," professional paper 574-F, 1975—Summary of determination between natural and anthropogenic contributions—shows natural values vary widely and are highly site specific and regionally dependant.	Nationwide	National Technical Information Service (NTIS) U.S. Department of Communication: (703) 487-4650
	An accounting of pesticides in soils and ground water in the Iowa River Basin, 1985-88 (IA 86-055).	Midwest	NTIS
U.S. Geological Survey	Aerial photographs of sites.	Nationwide	USGS, Salt Lake City ESIC 8105 Federal Bldg. 125 South State St. Salt Lake City, UT 84138-1177 (801) 524-5652/Fax: (801) 524-6500
USDA-Agricultural Stabilization and Conservation Service (ASCS/SCS)	Aerial photographs of current and previous land use and soils types including erosion potential.	Nationwide	ASCS/SCS Aerial Photography Field Office, P.O. Box 30010 Salt Lake City, UT 84130-0010 (801) 975-3503/Fax: (801) 975-3532
National Ocean Service (NOS)	Coastal and Geodetic Surveys including aerial photographs.	Coastal areas	National Ocean Service Coast and Geodetic Survey Support Sec. N/CG236 SSMC#3, Rm. 5212 1315 East-West Highway Silver Spring, MD 20910 (301) 713-2692/Fax: (301) 713-0445

TABLE 5. (CONTINUED)

Source	Supporting background information	Locations	Contact point
National Archives Research Administration/National Air Survey (NARA/NASC)	Series of infrared Landsat photographs for mid-1970s by state.	Nationwide	NARA/NASC National Air Survey 4321 Baltimore Ave. Bladensburg, MD 20710 (301) 927-7180/Fax: (301) 927-5013
U.S. Forest Service (FS)	Often have data on trace elements as part of soils inventory and monitoring program.	Nationwide	Nearest FS experiment station
U.S. Department of Energy (DOE)	Collects and publishes data on trace metals and radionuclide concentrations around DOE facilities and for reference sites.	Nationwide	Nearest DOE office, Environmental Monitoring Division
Oak Ridge National Laboratory	The background soil characterization project provides background levels of selected metals, organic compounds, and radionuclides in soils from uncontaminated sites at the Oak Ridge Reservation. Also a good approach for evaluating background for use in baseline risk assessments	Local - Roane County, TN Approach useful nationwide	D.R. Watkins Oak Ridge Reservation Environmental Restoration Div. P.O. Box 2003 Oak Ridge, TN 37831-7298 (615) 576-9931 See ref. ORNL 1993.
National Climatic Data Center	Provide data on wind roses and climate parameters for most areas of the country.	Nationwide	User Service Branch Asheville, NC (704) 259-0682
EPA	Most complete source of data that includes EPA and other Agency information on Hazard ID, Dose-Response, and Risk Characterization.	Nationwide	EPA/540/1-86/061 (EPA 1986)
	STORET (physical and chemical parameters in soils and sediments).		EPA Office of Water and Hazardous Material (202) 382-7220 Commercial product—more user friendly, EarthInfo: (303) 938-1788
Journal Articles	Can provide local, regional, or national background concentration values. Can be accessed via literature searches, but usually need to be searched by element or media.	Local to National	Selected references: (1) Metals in Determining Natural Background Concentrations in Mineralized Areas, 1992 (Runnells et al. 1992), and (2) Sediment Quality and Aquatic Life Assessment (Adams et al 1992).

agents and state, county, and federal environmental quality officials are also sources of information on local emissions or previous sampling data that may be used to establish background concentrations. EPA or state regulators of chemical storage, use, and emission data bases of local industries may be a good source of chemicals used or stored in the local area. EPA's STORET data base should be checked

Step 2—Establishment of Data Quality Objectives

Purpose: The purpose of Step 2 is to establish data quality objectives (DQOs) (EPA 1993) for the decision-making process.

Approach: The DQO process is described in "Standard Practice for Generation of Environmental Data Related to Waste Management Activities: Development of Data Quality Objectives" (ASTM 1995) and is summarized in a companion issue paper titled, "Characterizing Soils for Hazardous Waste Site Assessments" (Breckenridge et al. 1991). The companion issue paper explains how to classify soils when faced with different classification systems and what soils data need to be considered when establishing DQOs. EPA's external working draft, "Guidance for Data Quality Assessment" (EPA 1995), is helpful in discussing the role of statistics in the DQO process. This document has a companion PC-based software program to help support the document. Since this is designed as a "living document," contact the Quality Assurance Division [Fax number (202) 260-4346] in the Office of Research and Development (401 M Street, S.W., Washington, D.C. 20460) to obtain the latest version.

Step 3—Determining Sample Location and Numbers to Collect

Purpose: The purpose is to design a statistically valid approach that yields representative samples from areas of concern and from background areas and to factor judgement (bias sampling) into selecting sampling locations to maximize the possibility of detecting elevated levels of contaminants on-site.

Approach: There are a number of options in sampling design that determine where to collect samples from a hazardous waste site to compare against a background site. The investigator needs to discuss the DQOs with a statistician to select the appropriate design. Numerous design options are available. One option is for those areas where the sites' soil and sediment matrix and distribution of suspected contaminants appear to be homo-geneous. Establishing a consistent grid (i.e., systematic sampling grid) across the entire site and sampling at set locations should provide a reasonable characterization of the contamination values across the site. A second option may apply if certain parts of a site are suspected of being contaminated due to historical use. In this case, bias sampling or intensifying the grid in highly suspected areas could be considered. This approach maximizes the possibility of determining whether contaminant concentrations at a site are above background and minimizes the risk of not taking action at a hazardous waste site.

There is a wealth of guidance on soil sampling. One document that is useful because of its coverage of soil sampling methods and design for reducing various sources of sampling error is titled, "Preparation of Soil Sampling Protocols: Sampling Techniques and Strategies" (EPA 1992c). This document also provides information for those uncertain about sampling design options and composite collection techniques.

The following discussion points should be considered when selecting and designing the sampling plan.

Point A—For a given site, there may be several areas of concern based on known or suspected past site activities. Once these areas are identified, a sampling plan can be developed. Historical data should be identified and evaluated early in the process to determine their use in identifying areas of concern or if the entire site needs to be sampled. Historical and land use information identified from Step 1 plays a key role in determining the degree of **bias** in the sampling plan. Factors such as location of tanks, piping, staging areas, disposal ponds, and drainage areas (e.g., sumps) should be considered when designing a sampling plan. Several soil properties or processes that govern the mobility of contaminants can also bias sample location:

Soil pH: A quick check using a field test kit can identify if the pH of the soil is in a range to mobilize contaminants. In acid soils (pH <6.5), inorganics

such as zinc, manganese, copper, iron, cobalt, and boron are easily leached. However, if soil pH is above 7.0, these inorganics form stable compounds. Other inorganics, such as molybdenum and selenium, are mobilized in alkaline soils, whereas in acid soils they become almost insoluble. Thus, pH and contaminants of concern need to be factored into the selection of sampling depth in soils.

Soil Texture: Most soils are a combination of the following grain sizes:

Medium to large grain size material has moderate to high porosity (15 to 40 percent) and low capacity for adsorbing inorganics. These soils have low capacity to hold contaminants in the grain interstices due to low cation exchange capacity and low capillary action. Investigators should look for surface staining and consider sampling at deeper depths.

Fine sands to silt materials have a stronger capillary action, and silts are capable of sorbing inorganics. Special attention should be given to sampling at the interface between fine material layers and larger grains, or where fine sand lenses are mixed in clay soils (these often form conduits for contaminant movement).

Clays are fine particles and possess a net negative charge, and most have high cation exchange capacities. This may cause heavy metal cations (e.g., Cr^{+6}, Cd^{+2}, Pb^{+2}) to adsorb to the clay surface. Clays also form large cracks and fractures due to shrink/swell and freeze/thaw effects. Investigators should look at the profile in clay soils to determine if inorganics (e.g., iron and manganese) have oxidized or been reduced in fractures causing a color change (e.g., under oxidation, iron changes to a red/yellow/brownish color compared to the natural blue/gray color). The sample design should consider these factors by collecting samples from fractures and especially from areas that show signs of oxidation.

Soil Organic Carbon Content: Organic carbon content plays a key role in the sorption of contaminants. Special attention should be given to sampling layers that have excessive organic carbon (e.g., darker soils, upper soil layers, peat).

Cation Exchange Capacity (CEC): The ability of the solid soil phase to exchange cations is one of the most important soil properties governing movement of inorganics in soils. In general, the CEC is related to the surface area of the soils and sediments (Kabata-Pendias and Pendias 1984). Soils and sediments that have larger surface areas (e.g., clays) have a greater CEC, while those with smaller surface areas (e.g., sands) have a lower CEC.

Transport: The transport of dissolved or colloidal inorganics takes place through the soil solution (diffusion) and with the moving soil solution (leaching) (Kabata-Pendias and Pendias 1984). Investigators should be aware that in cool, humid climates, inorganics generally leach downward through the profile; in warm, dry climates and hot, humid areas, the movement is often upward. However, specific soil properties, mainly the soil's CEC and moisture availability, control the rate of migration of inorganics in a soil profile.

Point B—A grid system can be used to establish the locations to be sampled. A grid will also help define the total population from which a subset may be selected using a statistical approach (e.g., systematic random, random, or stratified random) to identify the specific sample population. If the site has excavations or steep depressions, sample points along both sidewalls and the base of any excavations should be included in the grid. If samples are collected from excavations, similar soils (i.e., same depth, type, and horizon) should be sampled from the background site for evaluation. However, soils are heterogenous and spatial patterns do exist. Some soil types exhibit spatial correlations that should be considered by the project's statistician. The area represented by each grid point should be proportional to the size of the area for equal weighting and be equal to or greater than the operable unit (discussed earlier). One of the following equations may be used to determine grid intervals for three different size categories (Michigan 1991b):

$$\frac{\sqrt{A/\pi}}{2} = GI \qquad \text{Small site (0 to 0.25 acre)} \qquad (1)$$

$$\frac{\sqrt{A/\pi}}{4} = GI$$ Medium site (0.25 to 3 acre) (2)

$$\sqrt{\frac{A\pi}{GL}} = GI$$ Large site (>3.0 acre) (3)

where:

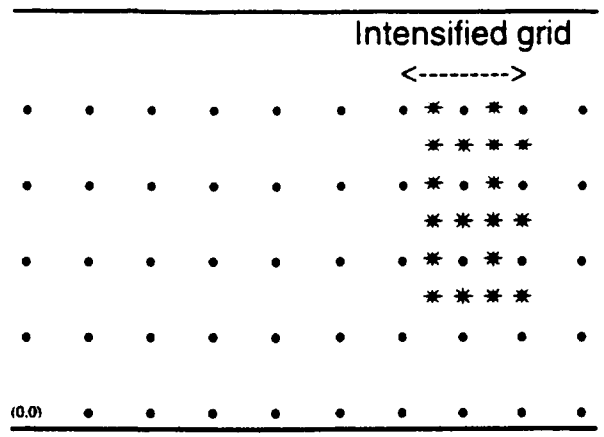
GI = grid interval
A = area to be gridded (in square feet)
GL = length (or longest side) of area to be gridded.

For example, for a 1.5-acre site (the longest side being 280 feet), and given that 1 acre = 43,560 square feet, substituting values in Equation (2) above, we have:

$$\frac{\sqrt{65{,}340/3.14}}{4} = 36 \text{ feet between grid points}$$

Grid systems are useful but have limitations. An option is to select a sampling area that is equal to an operable unit (i.e., the size of the smallest remedial action unit) and divide the site into equal units. Samples can then be collected, following a statistical design that represents the unit.

Point C—After the grid point interval is determined, a scaled grid overlay can be made and superimposed on a map of both the hazardous waste and background sites. Some specified point (e.g., the southwest corner) should be designated as the (0,0) coordinate. The grid can then be oriented to maximize sampling coverage. Some grid orientation may be necessary for unusually shaped areas. Also, the site can be subdivided with different calculated grid intervals so that proportional sampling can be intensified for suspect areas, such as sumps or sinks or low-lying drainage areas where contaminants have a higher probability of concentrating. The following is an example of a grid:



Point D—Several options exist for collecting samples: (a) collect a sample at all (or a minimum of four) grid points as discussed under Point B, (b) use the systematic random sampling approach referenced in SW-846, Third Edition, Section 9.1.1.3.3, or (c) use a stratified random design with an intensified grid for suspected problem areas. The selected number of sample locations are determined by sampling objectives, number of analytes to be evaluated per sample, the analytical techniques to be used, and budget constraints.

Point E—The determination of depth sampling increments are dependent on DQOs and the capacity of different soil layers to hold (sorb) metals. Recommended depth sampling increments are for the following: clay and organic soils on-site, 0.25 to 0.5 feet or by major horizon; silts and loams, 1.0 to 2.5-foot intervals or by master horizons; and sands, 1.0 to 5.0 feet. The selection of depth sampling increments also depends on the suspected amount of contamination released, mobility of contaminant, amount of water or liquid available for transport (e.g., ponding), and funding. Samples collected from specified depths can be either single or in multiple replicates, depending on the statistical method used for background data comparison (see Step 5). At locations where soil type is the same, compositing can be considered to save costs and more precisely estimate the mean value. However, compositing may be a concern if the data are used for future enforcement purposes.

Point F—For a background site, a minimum of four samples collected from the same soil type are needed to establish "background" concentration for a soil type (Michigan 1991a). These sample numbers will help account for natural constituent occurrences and inherent variability (i.e., range)

within each distinctive soil type. When determining if contaminants have moved into a profile (i.e., by depth), samples should be taken at comparable depths from similar soil types for both the background site and the hazardous waste site. If site environmental conditions have resulted in leaching of contaminants into the soil profile, the major soil horizons (i.e., O, A, and B) for a soil type may need to be sampled at both the contaminated and background site. If the site is sampled by major horizon, a minimum of four samples should be collected from each horizon) (see Figure 3). Sample size (e.g., weight) at all locations at the hazardous waste and background sites should be the same.

GROUND SURFACE	
1st major horizon—Brown medium-coarse SAND	4 samples
2nd major horizon—Lt. brown silty fine SAND	4 samples
3rd major horizon—Gray silty CLAY w/trace of fine-medium sand	4 samples

Figure 3. Approach for sampling sites where comparison is needed between major soil horizons or layers within a soil type.

Point G—Background samples should be taken from areas unaffected by site activities. If similar soils cannot be found in areas unaffected by site activities, possible locations for determining background are areas on-site, such as under stationary objects like storage sheds or porches, large flagstones, and old trees.

Point H—Wind rose data can be used to identify background sample locations in the predominant upwind direction from the hazardous waste site. Wind rose data usually provide monthly averages (based on hourly observations) on the percentage of time the wind blew from the 16 compass points or was calm. Wind rose data can be obtained for the area from the local weather station or the National Oceanic and Atmospheric Administration (NOAA).

Generally, if airborne deposition is the primary method of contaminant release from sites in arid environments, the investigator should focus on sampling the soils near the surface. However, consideration must be given to the mobility of the contaminant and texture of the soil.

Step 4—Sample Collection, Preservation, Handling, Analysis, and Data Reporting

Purpose: The purpose is to ensure that all samples are handled in a manner that protects their integrity and are analyzed using comparable, standard methods.

Approach: The following is the recommended approach:

1. All sample collection, preservation, preparation, handling, and analytical methods should follow standard methods [e.g., U.S. EPA SW-846, "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods" (EPA 1986)]. It is important that all samples are handled using comparable methods when preparing for and during analysis. For example, using different digestion methods can change results significantly.

2. For inorganics, it is recommended to use a total metals procedure with results reported in mg/kg (or percent for iron) on a dry weight basis. This minimizes additional sources of variation, since these constituents are often naturally occurring. To assess the bioavailability of metals in anoxic sediments, acid volatile sulfide and simultaneously extracted metals should be determined (Di Toro et al. 1990, 1992).

Step 5—Statistical Comparison of Hazardous Waste and Background Sites

Purpose: The objective is to determine if concentrations of inorganics from a hazardous waste site are elevated compared to those from a background site.

Approach: The following discussion outlines some basic statistical concepts in the context of background data evaluation. A general statistics textbook such as *Statistical Methods for Environmental Pollution Monitoring* (Gilbert 1987) should be consulted for additional detail. Also, the following list of published statistical guidance may be useful (Figure 4). There are numerous statistical approaches that are applicable when collecting, assessing, and analyzing background data. The approaches presented here have been adopted by the State of Michigan (Michigan 1990, 1991b) and modified based on the authors' experience. They are readily understandable and easy to use. However, it is recommended that investigators consult a

statistician to assist in the design or review of a sampling plan prior to collecting samples.

1. Careful consideration must be given to the selection of a statistical procedure based on site-specific factors. These include the size of the background data base and the number of samples available for comparison, variability of soil type, and coefficient of variation of data. The following are some statistical methods that can be used **if data from the site follow a normal distribution**. Some environmental sample sets are normally distributed. However, the majority of environmental contamination data sets are not normally distributed. Some of the more commonly used tests of normality are presented in Table 6. Tests should be conducted on all data to determine if the data meet the assumption of normality. If the data are not normally distributed, log or other types of transformations should be conducted to approximate normality prior to using the data sets in statistical comparisons, such as t-tests or analysis of variance procedures (ANOVA).

If the data **cannot be normalized**, additional attention needs to be given to selecting appropriate statistical tests, and the situation needs to be discussed with a statistician. Special statistical consideration may be warranted if samples are composited and the data are needed to support regulatory requirements discussed in Part B.

Statistical Methods Guidance[a]

Basic

Statistical Methods for Environmental Pollution Monitoring, Van Nostrand Reinhold Company (Gilbert 1987).

Guidance for Data Quality Assessment (EPA 1995).

Soils Sampling Quality Assurance Guide (EPA 1989d).

Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (EPA 1988).

EPA's *Guidance Manual: Bedded Sediment Bioaccumulation Tests*, pp. 82-91 (Lee et al. 1989).

Statistical Guidance for Ecology Site Managers, Washington State Department of Ecology (WDOE 1992).

Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A), pp. 4-5 to 4-10 (EPA 1989c).

Advanced

Estimation of Background Levels of Contaminants (Singh and Singh 1993).

Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities (EPA 1992d).

Background and Cleanup Standards

Methods for Evaluating the Attainment of Cleanup Standards, Volume 1: Soils and Solid Media (EPA 1989b) (detailed statistical discussion).

[a]If time and resources are limited, Gilbert (1987), Hardin and Gilbert (1993), and EPA (1995) provide some of the most relevant statistical information.

Figure 4. Statistical Methods Guidance.

TABLE 6. TESTS FOR EVALUATING NORMALITY OF DATA SETS. SOURCE: EPA (1995).

Test[a]	Sample Size (N)	Notes on Use	Reference
Shapiro Wilk W Test	≤ 50	Highly recommended	Gilbert (1987) EPA (1992c)
Filiben's Statistic	≤ 100	Highly recommended	EPA (1995)
Studentized Range Test	≤ 1000	Highly recommended	EPA (1995)
Lilliefors Kolmogorov-Smirnoff Test	> 50	Useful when tables for other tests are not available	Madansky (1988)
Coefficients of Skewness and Kurtosis Tests	> 50	Useful for large sample sizes	EPA (1995)
Geary's Tests	> 50	Useful when tables for other tests are not available.	EPA (1995)
Coefficient of Variation Test	≤ 50	Use only to discard assumption of normality quickly.	EPA (1995)
Chi-Square Test	Large[b]	Useful for group data and when the comparison distribution is known.	Introductory Statistics Books

[a]By order of Recommendation.
[b]The necessary sample size depends on the number of groups formed when implementing this test Each group should contain at least five observations.

When comparing a contaminated site with a background site, a null hypothesis should be developed. For example, a null hypothesis could be: *There is no difference between the mean contaminant concentration of the hazardous waste site and background site.* The alternate hypothesis would be: *The mean concentration for the contaminated site is different from that of the background site.* If parametric statistics are used for this assessment, such as a t-test or ANOVA, the data can be normalized to selected parameters (e.g., organic carbon, particle size). Many parametric and non-parametric statistical procedures exist to compare a background site with one or more hazardous waste sites. A variety of such procedures are reviewed in Lee et al. (1989), EPA's *Risk Assessment Guidance for Superfund, Volume 1* (EPA 1989c), and EPA's Guidance for Data Quality Assessment (EPA 1995). The latter source provides examples and a discussion of most of the tests needed to conduct comparisons between data sets.

a. Empirical Rule. (Note: Many of the following calculations can be performed using calculators that are preprogrammed.) Use mean ($\bar{x}_b$) and variance (S_b^2) of background concentrations to establish an "upper limit"for delineating significant concentrations, such as:

1) Calculate the background mean ($\bar{x}_b$) by dividing the sum of the total background readings by the total number of background readings for each element of concern:

$$\bar{x}_b = \frac{x_1 + x_2 + \ldots x_n}{n}$$

2) Calculate the background variance (S_b^2) by taking the sum of the squares of the difference between each reading and the mean, and dividing by the degrees of freedom (the total number of background samples minus one):

$$S_b^2 = \frac{(x_1 - \bar{x}_b)^2 + (x_2 - \bar{x}_b)^2 + \ldots (x_n - \bar{x}_b)^2}{n-1}$$

3) Calculate the background standard deviation (S_b) by taking the square root of the variance:

$$S_b = \sqrt{S_b^2}$$

4) The Coefficient of Variation Test (CV) where $CV = s_b / \bar{x}_b$ is used to evaluate data distribution. The background data should have a CV of less than 0.5 for sandy soils, less than 0.75 for finer soils, or an explanation accounting for higher CV values. The maximum recommended CV is 1.00. If the data distribution exceeds a CV of 1.00, then a thorough evaluation should be made to account for this variability (e.g., laboratory QA/QC, soil classification, sample location, outlier classification, and sample location), and the outlier data addressed (see EPA 1989c). Additional samples may need to be analyzed to ensure that a sufficient data base population (n) is achieved.

There are several classical procedures (Gilbert 1987; EPA 1995) and robust outlier tests (Singh and Nocerino 1994) available in the statistical literature. Consult *Outliers in Statistical Data* by Barnett and Lewis (1994) for a full account of this issue. Outliers often distort statistical estimation, and resulting inferences and can lead to incorrect conclusions. The solution is to consult a statistician who understands outliers and knows how to use robust procedures to identify multiple outliers.

If an outlier is found, an option is to take a substitute sample, have it analyzed, and repeat the statistical process. (To avoid costly delays, it is recommended to collect extra samples for laboratory analysis.)

For example, four background samples are collected from a site for lead analysis. The lead values from the laboratory analysis were 56, 25, 18, and 35 mg/kg. The investigator wants to examine the data set to determine if the 56-mg/kg sample is an outlier. The summary statistics for these samples are:

$$\bar{x}_b \text{ (mean)} = \frac{56 + 25 + 18 + 35}{4} = 33.5$$

$$S_b^2 \text{ (variance)} = \{ (56 - 33.5)^2 + (25 - 33.5)^2 + (18 - 33.5)^2 + (35 - 33.5)^2 \} / 3 = \frac{821}{3} = 273.67$$

$$S_b \text{ (standard deviation)} = \sqrt{S_b^2} = \sqrt{273.67} = 16.5$$

$$CV \text{ (coefficient of variation)} = \frac{S_b}{\bar{x}} = \frac{16.5}{33.5} = 0.49$$

The test for a single outlier in a normal sample with the population mean and variance unknown (Barnett and Lewis 1994, p. 218-222) is appropriate for the above identified sample. The test statistic is:

$$\frac{X_{max} - \bar{x}}{s} = \frac{56 - 33.5}{16.5} = 1.36$$

The theoretical cut-off point (Barnett and Lewis (1994), Table XIII, p. 485) for $\alpha = 0.05$ is 1.46. Since the calculated value of the test statistic (1.36) is less than the theoretical cut-off point (1.46), the 56 mg/kg sample is not an outlier.

Background concentrations should be determined for major soil types at the hazardous waste site. If this is not feasible, then a mean background concentration should be determined on the soil type at the hazardous waste and background sites with the lower absorption capacity (usually the sandiest soil) and those with the higher absorption capacity (usually silts and clays). The finer-texture soils (silts and clays) will usually sorb the most contaminants and provide a good value for comparison. If the mean concentration from the fine textured soils from the hazardous waste site is above similar values for the background site, there is a high probability that the site is contaminated.

Once a mean background concentration is established, similar statistical tests should be conducted on the data from the hazardous waste site. After the data sets have met the assumptions for normality or have been corrected (see Figure 2), then statistical comparisons can be made between the site and background data sets.

b. t-Test. Any t-test should be discussed with a statistician prior to use since there are a number of variations and assumptions that can apply. The Gosset Student T-test has good application when comparing background sites to potentially contaminated sites (Michigan 1991a).

c. Cochran's Approximation to the Behrens-Fisher Student's t-test. This test is also available for evaluating background variance versus exceedances (i.e., contamination) as referenced in 40 CFR Part 264, Appendix IV. Note that this statistical comparison method does require that two or more discrete samples be taken at each sampling location.

d. In some cases, it may be of interest to establish an upper limit of background for the site. This would be useful if the investigator wanted to compare single values for a soil type from the hazardous waste site with the background population for a similar soil. The mean background concentration ($\bar{x}_b$) plus three standard deviations ($3S_b$) comprises a reasonable maximum allowable or upper limit.

2. Procedures for non-detect values. If more than 50 percent of the background analytical values are below the detection limit (DL), either of the

following procedures could be used with any of the preceding statistical methods:

a. For any <DL in a data set, alternate "0" and the detection limit (DL); this will result in a net value of half the detection limit, with a variance, or use b. For example:

Actual Value	Substitute Value
<DL	DL
<DL	0
<DL	DL
<DL	0

Note: This process assumes that values below the DL are normally distributed in a regulatory context; this may not be determined to be conservative enough. For regulatory cases, a more robust estimation of mean and variance with lowest DL values should be used. The restricted maximum likelihood (RMLD) method (Perrson and Rootzen 1977, Haas and Scheff 1990) is relatively simple and provides a good robust estimate.

If data are not normally distributed, which is often the case for environmental data [see Ott (1990) and McBean and Rovers (1992) for discussions of why environmental measurements follow a lognormal pattern], an alternative approach like the one discussed in EPA (1989e) or EPA (1995) could be used if data are lognormally distributed.

b. The Continuity Correction procedure with the t-test (EPA 1983). If the background data are non-detect (<DL), then the value can be determined to be $0.25 \times DL$ (consultation with a statistician is recommended to explain and perform the t-test with Continuity Correction). Other tests such as the Wilcoxon rank sum test [see Gilbert (1987), pp. 247-249] can be used to test for a shift in location between two independent populations even with non-detect values. There are also numerous other approaches/methods for handling non-detection limits that could be considered but need to be discussed with a statistician.

SEDIMENT

Step 1—Collection of Available Data for Use as Background Reference Sediment

Prior to implementing a sampling and analysis project, an effort should be made to determine whether useful background sediment concentration data are available. Samples may have been collected at the same site prior to the contaminated source, or data may have been collected at sites upstream by the state, EPA, USGS, or permittees and may be documented in STORET (Bolton et al. 1985) (also see Table 5) or the developing National Sediment Inventory (EPA 1994a).

The use of existing background site data for comparison with on-site data is valuable. However, it is critical to determine whether both sets of data are comparable. Questions that need to be addressed are:

1. Were comparable analytical methods used for both on-site and background site samples (e.g., acid-extractable metals or total digestion methods)?

2. Are the total organic carbon (for organic contaminants) and particle size (for metals and inorganics) data for both sites available and similar?

3. Is the background site acceptably representative of the chemical contamination levels immediately upcurrent of the hazardous waste site?

4. Were similar sample collection methods used [different sampling devices can produce greatly different results (Baudo 1990)]?

5. Were the depths of sampling similar (e.g., top 10 cm of sediment)?

6. How long ago were the background sediments collected compared to the contaminated site sediments?

7. Are contaminant levels expressed on the same basis (wet or dry weight)?

8. If data on acid volatile sulfides (AVS) and simultaneous extracted metals were collected, were both data sets collected during the same season of the year (AVS affects the biological availability of some metals in anoxic sediments)?

9. Is the quality of the data acceptable?

The levels of metals in sediments are strongly related to total organic carbon and sediment particle size, while organic contaminants in sediments are related primarily to total organic carbon. The higher the level of organic carbon in a sediment, the greater the potential concentration of non-ionic organic contaminants. For metals, the finer the particle size and the higher the organic carbon, the greater the potential for accumulating metals. Toxic effects are less likely as the organic carbon content increases for a given non-ionic organic contaminant level. For

metals, toxic potential is reduced as particle size decreases or organic carbon increases. If the particle size or organic carbon content of the background and contaminated site sediments differ significantly, it is not appropriate to directly compare contaminant residue levels without normalizing the data. Some organic contaminants can be normalized to organic carbon by dividing by the fraction of organic carbon (Adams et al. 1992); the same approach has been used for divalent cationic metals—lead, nickel, copper, cadmium, and zinc. Metals data can be normalized to acid volatile sulfide levels (Di Toro et al. 1990, 1992), a key element such as aluminum (Schropp and Windom 1988; Daskalakis and O'Conner 1995), or particle size (NOAA 1988). EPA is also refining its equilibrium partitioning approach, which could be used to normalize contaminant levels among different sediments (Adams et al. 1992; EPA 1992b). Further discussion of these procedures is beyond the scope of this paper, and expert assistance should be obtained.

Step 2—Comparison of On-site Data to Sediment Quality Criteria

Simply comparing the level of metals in bulk sediments, deposited under similar conditions, upstream and downstream from a suspected facility can provide an indication that a facility may have contaminated the downstream site. These data, however, provide no indication of bioavailability that may justify remediation. Indeed, bulk sediment contamination is only poorly correlated with adverse impacts. For metals, the key parameter in determining toxicity is the pore water concentration of a metal. In situations where no background site data exist, yet contaminated site data do, it may be useful to compare sediment contamination levels to various sediment quality criteria.

EPA is developing sediment quality criteria for metals, but the factors determining bioavailability are complex, and an approach has yet to be selected (Ankley et al. 1994). Research has shown that in anaerobic sediments, toxic impacts due to cadmium, copper, lead, nickel, and zinc are not present when the sum of the molar concentrations of these metals divided by the AVS concentration is less than one (Di Toro et al. 1990, 1992). Essentially, when excess sulfide is present, the metals are complexed and metal concentrations in pore water are low.

While bulk sediment contamination levels do not correlate well with toxic effects, a number of statistically based, sediment-quality indices have been developed. If resources are limited, and useful background site data do not exist, concentrations at the contaminated site can be compared with metal concentrations in bulk sediment known to have a low probability of causing adverse impacts on benthic organisms. Several "no-effect" levels are presented in Table 2. NOAA developed effects-based guidelines including no-effects, possible effects, and probable-effects levels (Long and Morgan 1990) based on National Status and Trends Program data, and MacDonald (1992) used the same approach with additional data to develop similar marine guidelines. The guidance for marine sediments was further updated by Long et al. (1995). The most recent guidance on metals is presented in Interim Sediment Quality Assessment Values (Environment Canada 1994), in which NOAA National Status and Trends Program data and spiked-sediment toxicity tests were used to develop threshold effects values for fresh and marine waters, presented in Table 2. If the contaminated site levels are below the no-effects levels, further investigation may not be required even if the site has been contaminated. If the no-observed-effects levels are exceeded, further investigation may be justified. Bulk sediment guidelines have also been developed by EPA Region V (U.S. Army Corps of Engineers 1977) for classifying sediments of Great Lakes harbors. The Ontario Ministry of Environment (Persaud et al. 1989) and other guidelines are summarized in EPA's *Guidance Manual: Bedded Sediment Bioaccumulation Tests* (Lee et al. 1989). In addition, these and other guidelines have been reviewed and summarized by Giesy and Hoke (1990).

In areas where an entire watershed has been impacted, such as from mining activities, it may not be possible to select a suitable background site. In such situations, historical data (Runnells et al. 1992) or archived samples may be the best source of data. Another approach would be to sample surficial sediments and compare them to deeper uncontaminated sediments (those laid down prior to the watershed being impacted).

No specific rules can be provided regarding the use of existing background reference data for sediments or soils. Judgement should be made with full knowledge of the specific objectives of the investigation, data limitations, and qualifications and with the help of appropriate experts (e.g., chemists,

hydrologists, statisticians, benthic ecologists, and sampling experts).

Step 3—Selection of Sites for Collection of Background Sediment

The ideal background site data for comparison with contaminated site data are obtained from samples:

1. Collected immediately upcurrent of the contaminated site in an area not impacted by the suspected contaminant source.

2. Collected at the same time the contaminated sediment is sampled.

3. Having very similar particle size and organic carbon content.

4. Collected using identical sampling equipment.

5. Collected using the same statistically based sampling design (i.e., numbers and configuration) and compositing handling procedures (if any).

6. Analyzed using identical analytical methods.

When comparing data sets, it is important that everything about the sampling and analytical procedures for the background and contaminated site sediments be as similar as practical. If both fine and coarse sediments are available for sampling at the contaminated site and the background site, the finer sediments are preferred because they have a greater affinity for metals.

The ideal situation is seldom achieved, and compromises may have to be made. For streams, it may be practical to sample directly opposite from the contaminant or contaminant source or even downstream as long as the background site is not impacted by the plume of concern. Contaminated and background site sediment characteristics will be most alike where the currents are similar, with fines being deposited in areas of low currents and coarser material being associated with faster currents. A significant complication of sampling streams is the potential for severe erosion, which may remove massive amounts of sediments during flood conditions. Thus, even the contamination observed in the sediments directly downstream of a point source may not be attributable to the existing source. The surface sediments after a flood may represent contamination deposited from upstream sources or historical contamination from another facility previously operating at the hazardous waste site. Knowledge of a suspected contaminated source's effluent, the processes generating the effluent, and historical stream flow information can be helpful to link the suspected source and the contaminated site's metal concentration. Since it is difficult to establish a background reference site after a major flood event has occurred, previous data or deep sediments may be the best source for background reference data.

For estuarine and marine sites, selection of a similar but unimpacted background site also can be difficult. The process may involve the use of hydrologic models to simulate tides and currents to avoid areas impacted by the contaminated plume. It may be necessary to select distant background sites when currents are highly variable. The same considerations need to be addressed in lakes with wind-driven currents. When questions arise about site selection, it is best to consult with an expert who is familiar with the hydrology of the area.

When it is not possible to obtain background sediment with the same particle size and organic carbon content, normalization procedures, discussed previously, should be considered. While it is beyond the scope of this document to recommend specific sampling and assessment methods, excellent comprehensive references for such information are *Procedures for the Assessment of Contaminated Sediment Problems in the Great Lakes* (IJC 1988), *Assessment and Remediation of Contaminated Sediments (ARCS) Program, Assessment Guidance Document* (EPA 1994b), and *Manual of Aquatic Sediment Sampling* (Mudroch and Azcue 1995). Additionally, EPA's Office of Science and Technology within the Office of Water is developing a methods manual that will cover all aspects of sediment monitoring, from sample collection to analytical methods to assessment techniques (EPA 1994c).

PART B

APPROACHES FOR DETERMINING BACKGROUND LEVELS OF INORGANICS THAT CAN BE COMPARED WITH CONCENTRATIONS OF INORGANICS AT CERCLA SITES

Part B was developed to address issues that need to be considered when the establishment of background under CERCLA is required. Part B also provides a summary of technical issues rather than an in-depth statistical evaluation of the topic. Those needing an in-depth level of statistical evaluation

should seek the expertise of a statistician and may benefit from a paper that addresses estimation of background concentrations of contaminants, for example Singh and Singh (1993) or Hardin and Gilbert (1993).

Step 1—Conduct On- and Off-site Reconnaissance as Preliminary Assessment Phase of CERCLA

Purpose: The initial reconnaissance is performed to identify concerns associated with on-site or off-site activities that may have resulted in contributing to enhanced inorganic background concentrations.

Approach: See Step 1 under Part A (a similar approach should be considered).

Step 2—Collect Preliminary Information and Samples About Background Levels of Concern

Purpose: During the preliminary assessment/ site investigation (PA/SI) stage, existing soil and sediment analytical data for contaminated sites and background sites can provide initial information to identify problems that might be encountered with establishing background values.

Approach: The PA/SI stage is not designed to evaluate all concerns at the site. However, an initial site visit can be advantageous to evaluate site condition, assess analytical data, or collect samples of equal number (i.e., number from contaminated site = number from background site) from media that have similar physical (e.g., texture) and chemical (e.g., pH, percent organic carbon, CEC) properties. During the SI phase, sufficient information is needed to support the hazard ranking score (HRS) to identify if a contaminated site should be nominated for inclusion to the National Priority List (NPL) due to high threat to humans or the environment (HRS scores ≥28.5 are usually nominated for inclusion to the NPL). The SI stage may present the first opportunity to actually measure background concentrations for assessing if observed releases have occurred. Section G of the preamble to the HRS final rule (55 FR 5/546) on "Observed Releases" states that an observed release is established when a sample measurement that equals or exceeds the sample quantitation limit is at least three times the background level (EPA 1992a, p. 2-3).

Step 3—Determine Potential Magnitude of a Problem by Combining Information from Steps 1 and 2

Purpose: Combining information on past land use and site operations with data from local, regional, and global contributions can help alert investigators that the issue of background concentration might require more attention when developing a sampling and analysis plan during the remedial investigation (RI) process.

Approach: Information sources other than chemical analysis (e.g., information or data obtained from other sources or Steps 1 and 2) may be used for characterizing the background concentrations for a site. A multi-tiered approach is often helpful to lump background concentrations, such as:

1. Global contributions—mostly atmospheric contributions from wet and dry deposition.

2. Regional contributions—influence of geological formations (e.g., increased selenium in western regions).

3. Local contributions—contributions due to land use (e.g., high arsenic, lead, and mercury values due to pesticide use in fruit production), local air emission sources, and nearly all industrial activities.

Step 4—Establish a Clear Statement of the Problems at the Site and Develop RI Sampling Strategy

Purpose: The RI process is the time to conduct detailed measurements of background concentrations at CERCLA sites. Section 300.430(b)(8) of the National Contingency Plan requires that a sampling and analysis plan (SAP) be developed during the scoping phase of the RI process.

Approach: A number of EPA guidance documents discuss the need to characterize background concentrations as part of the SAP formulation step. For example, according to the *Guidance for Data Useability in Risk Assessment* (Data Useability Guidance) (EPA 1989a), the SAP should be developed to resolve four fundamental risk assessment decisions, one of which is to determine "whether site concentrations are sufficiently different from background." Similarly, the *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (RI/FS Guidance) (EPA 1988) states that when determining the nature and extent of contamination at a site, background sampling should be conducted to help identify the

respective areas of both site-related contamination and the background concentrations.

Step 4a—Confidence Interval Determination

Purpose: The purpose is to develop confidence intervals for determining mean metals values and problem statements for a contaminated site.

Approach: Literature sources such as those presented in Table 5 can be useful to determine if a site has a potential contamination problem. However, literature values should be used only to support or help evaluate data from contaminated and background site samples. Site variability must be accounted for when conducting a characterization. Some sites have fairly homogenous soils, sediments, and areas impacted by emissions. More often, a site has a high degree of variability, and the problem statement and SAP need to reflect this. For many sites, a 95 percent confidence interval of the mean metals concentrations would be reasonable (i.e., if the mean for lead is 20 ppm-dry weight ±4, the 95 percent confident background value would be between 16 and 24 ppm-dry weight). However, if the site is complex due to different soils/sediments and areas of concern, a 90 percent confidence interval may be more acceptable due to an increased number of samples and cost. Once a confidence interval is developed, a problem statement for the site can be formulated to guide further effort. An example of a problem statement could be: "Are on-site concentrations of mercury, lead, arsenic, and zinc statistically different from off-site background concentrations?"

Step 4b—Develop Hypotheses for Testing

Purpose: EPA's RAGS "provides guidance on developing hypotheses to frame a problem in a manner that can be tested."

Approach: There are two types of hypothesis most often used: null hypothesis (a) — the site-related concentration is less than or equal to the background concentration, and null hypothesis (b) — the site-related contaminant concentration is greater than or equal to the background concentration. Additional guidance on selecting hypotheses is presented in the *Risk Assessment Guidance for Superfund, Volume I* (EPA 1989c).

Step 4c—Determine Level of Precision

Purpose: RI/FS guidance is that the level of precision be determined before sampling and analysis strategies are developed. This will guide the number and location of samples.

Approach: Determining the level of precision early in the development of a SAP will minimize many future problems. Two types of statistical errors are encountered when testing hypotheses about differences between on-site and off-site concentrations. The following definitions are true only if the null hypothesis (a) is used, but not with (b).

1. Type I error (α) (false positive): "Rejecting the null hypothesis when it is true." Because of the uncertainty related to sampling variability, an individual could falsely conclude that the site-related contaminant concentration is greater than background concentration when it actually is not. In this case, the null hypothesis is rejected, and the site-related concentration is considered to be statistically different from the background concentration.

2. Type II error (β) (false negative): "Accepting the null hypothesis when it is false." Alternatively, an individual might accept the null hypothesis that the contaminated site-related concentration is less than or equal to background concentration when it actually is not. In this case, the null hypothesis is accepted and the site-related concentration is considered to be no different from the background concentration.

A decision based on a Type I error could result in unnecessary remediation, while a Type II error could result in the failure to clean up the contaminated site when remediation is necessary. The Greek letter alpha (α) is used to represent the probability of a false positive, and beta (β) is used to represent the probability of a false negative decision.

Precision associated with hypothesis testing is defined by the parameters of confidence level and power. These are defined in EPA (1992a) and EPA (1989a) as:

1. Confidence level (100 percent - α)—One hundred percent minus the confidence level is the percent probability of concluding that the contaminated site-related concentration is greater than background when it is not (Type I error or "false positive"). As the confidence level is lowered (or alternatively, as α is increased), the likelihood of committing a Type I error increases.

2. Power (100 percent - β)—One hundred percent minus the power is the percent probability of concluding that the site-related concentration is less than or equal to background when it is not (Type II error or "false negative"). As the power is lowered (or alternatively, as β is increased), the likelihood of committing a Type II error increases.

Although a range of values can be selected for these two parameters, as the demand for precision increases, the number of samples and cost will generally also increase. The Data Useability Guidance states that for risk assessment purposes, the minimum recommended performance measures are: Confidence, 80 percent (α = 20 percent) and Power, 90 percent (β = 10 percent). These values can be interpreted to mean the following:

1. Confidence level = 80 percent—In 80 out of 100 cases, contaminated site-related concentrations would be correctly identified as being no different (statistically) from background concentrations, while in 20 out of 100 cases, site-related concentrations could be incorrectly identified as being greater than background concentrations.

2. Power = 90 percent—In 90 out of 100 cases, site-related contaminants would be correctly identified as being greater than background concentrations, while in 10 out of 100 cases, site-related concentrations would be incorrectly identified as being less than or equal to background concentrations.

If the site situation requires a higher level of precision to reduce the probability of committing a Type I or II error, it can only be accomplished by increasing the number of samples and overall cost [see guidance in EPA (1995)]. These decisions need to be made on a site-specific basis and are primarily related to remediation and risk reduction goals.

Step 5—Develop a Sampling Approach That Will Answer the Problem Statement and Meet the Established Level of Precision

Purpose: The environmental scientist can develop a range of costs and options for different ranges of probability values of committing either a Type I or II error. The guidance developed in Step 1 of conducting a preliminary background evaluation can be expanded, with the assistance of a statistician, to determine the number of samples, location of samples, and statistical test to employ.

Approach: Developing a full-scale SAP directed at determining if there is a difference between contaminated site and background values requires knowledge about how the inorganics of concern move in the environment, site variability, and level of precision. The environmental scientist should initially seek the support and guidance of scientists and a statistician familiar with the issues. A SAP can then be devised to evaluate questions about background where off-site concentrations are elevated due to off-site anthropogenic contributions. Guidance for reaching decisions in these cases can be obtained from the Draft Issue Paper (EPA 1992a).

CONCLUSIONS AND RECOMMENDATIONS

The issue of establishing background concentrations for inorganic metals for comparison to levels at a potentially contaminated site can be complicated by natural and anthropogenic contributions to total background concentrations. The issues presented in this paper are designed to provide investigators with sufficient knowledge to assess whether concentrations of inorganics at a hazardous waste site are statistically above background concentrations. There are also discussions on how to approach background determinations at a hazardous waste site if there is a high potential for regulatory enforcement action.

There are a wide variety of methods that are available in the literature and in various EPA documents for evaluating background. Each method is slightly different, but there are a number of common issues that are presented in this paper. The most important factor to consider when determining background concentrations is to ensure that the physical, chemical, and biological aspects of the media to be sampled at both the contaminated site and the background site are as similar as possible. There are references and data included in this paper that provide average concentrations and reference values for selected soils and sediments in the United States. Most of the values in the literature are for concentrations that include natural and global anthropogenic contributions. These should be considered but should not take the place of conducting a thorough site-specific investigation to determine the previous land use both on and in the vicinity of the hazardous waste site to determine local anthropogenic contributions. The time spent using well-documented investigative skills to identify unaffected background sites that are similar geologically to the contaminated site will be of great value when establishing background concentrations.

This paper presents the issues that are important to consider when comparing if inorganics at a hazardous waste site are statistically different from those found at a background site areas.

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