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Office of Solid Waste

Guidance on Demonstrating Compliance With the Land Disposal Restrictions (LDR) Alternative Soil Treatment Standards

Final Guidance

Disclaimer

The United States Environmental Protection Agency's Office of Solid Waste (EPA or the Agency) has prepared this document to provide guidance to EPA, the states, the public, and the regulated community regarding how to measure attainment of the alternative LDR soil treatment standards. Alternative approaches for planning and implementing a sampling program and for assessing the data may be appropriate where waste or facility-specific circumstances do not match the underlying assumptions, conditions, and models of the guidance.

This guidance is not a final Agency action; it is intended solely as guidance. This guidance does not amend or otherwise alter any promulgated regulation. This guidance is not intended to and cannot be relied upon, to create any rights enforceable by any party in litigation with the United States, or create any rights enforceable by the United States. EPA officials may decide to follow the guidance provided in this document, or to act at variance with the guidance, based on an analysis of specific site or facility circumstances. The Agency also reserves the right to change this guidance at any time without public notice.

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List of Acronyms

AOC	Area of Contamination
ASTM	American Society for Testing and Materials
BTU	British Thermal Unit
CFR	Code of Federal Regulations
CMI	Corrective Measures Investigation
DQA	Data Quality Assessment
DQO	Data Quality Objective
EPA	Environmental Protection Agency
FR	Federal Register
HSWA	Hazardous and Solid Waste Amendments of 1984
LDRs	Land Disposal Restrictions
mg/kg	milligrams per kilogram
mg/L	milligrams per Liter
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
TC	Toxicity Characteristic
TCLP	Toxicity Characteristic Leaching Procedure
TSDF	Treatment, Storage, or Disposal Facility
UHC	Underlying Hazardous Constituent
USACE	United States Army Corps of Engineers
UTS	Universal Treatment Standard
WAP	Waste Analysis Plan

1. INTRODUCTION AND BACKGROUND

1.1 What Is the Purpose of This Guidance?

The purpose of this guidance is to provide suggestions and perspectives on how you, as members of the regulated community, states, and the public, can demonstrate compliance with the alternative treatment standards for certain contaminated soils that will be land disposed and, therefore, will be subject to the RCRA land disposal restrictions (LDR) regulations. On May 26, 1998, EPA promulgated land disposal restriction treatment standards specific to contaminated soils (see 63 FR 28555 and 40 CFR 268.49). Under these regulations, when disposing of contaminated soils, you may elect to comply with either the alternative soil treatment standards at 40 CFR 268.49 or the generic treatment standards at 40 CFR 268.40 which apply to all hazardous wastes.[1] The LDR alternative treatment standards require that contaminated soils which will be land disposed must be treated to reduce concentrations of hazardous constituents by 90 percent or meet hazardous constituent concentrations that are 10 times the universal treatment standard (UTS), whichever is greater.

You should use this guidance only in connection with compliance with the LDR alternative treatment standards that apply to contaminated soil which will be land disposed (e.g., soil generated during a cleanup), and you should not use it to establish site-specific cleanup standards.

This guidance document first describes the alternative treatment standards in some detail and then explains why they were developed, and their implementation. It then presents step-by-step guidance on approaches that can assist you in achieving compliance with the Agency's alternative soil treatment standards.

This guidance document also can be used to assess attainment of the Corrective Action Management Unit treatment standards. Corrective Action Management Units, or "CAMUs," are special units created under RCRA to facilitate treatment, storage, and disposal of hazardous wastes managed for implementing cleanup, and to remove the disincentives to cleanup that the application of RCRA to these wastes can sometimes impose (see 67 FR 2961, January 22, 2002). Similar to the LDR alternative soil treatment standards, the CAMU minimum national treatment standards require a 90-percent reduction in constituent concentrations, capped at 10 times the UTS.

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[1] A site-specific LDR treatment variance from otherwise applicable LDR treatment standards for contaminated soil under 40 CFR 268.44(h) also may be an option. See Appendix A, "Management of Remediation Waste Under RCRA."

1.2 What Are the LDR Alternative Soil Treatment Standards?

Under the LDR alternative soil treatment standards in 40 CFR 268.49(c)(1), there are two approaches to achieving compliance:

- hazardous constituents must be reduced by at least 90 percent through treatment so that no more than 10 percent of their initial concentration remains or comparable reductions in mobility for metals, **OR**

- hazardous constituents must not exceed 10 times the universal treatment standards (10 x UTS) at 40 CFR 268.48.

If you treat the soil to achieve the 90-percent reduction standard, or the treatment reduces constituent concentrations to levels that achieve the standard of 10 x UTS, then further treatment is not required.

Under 40 CFR 268.49(c), treatment for non-metals must achieve 90-percent reduction in *total* constituent concentrations. Treatment for metals must achieve 90-percent reduction as measured in leachate from the treated soil (testing according to the *TCLP*) when a metal stabilization treatment technology is used, and as measured in total constituent concentrations when a metal removal technology is used.

In addition to the treatment required by § 268.49(c)(1), under § 268.49(c)(2) prior to land disposal, soils that exhibit the characteristic of ignitability, corrosivity, or reactivity must be treated to eliminate these characteristics.

A hazardous constituent is a regulated constituent specified in the treatment standard at 40 CFR 268.40, or it may be an underlying hazardous constituent (UHC). Any constituent that is listed in the UTS Table at § 268.48, except for fluoride, selenium, sulfides, vanadium, and zinc, can be a UHC. You, as a facility owner or operator, may use knowledge of the waste to identify those UHCs reasonably expected to be present when hazardous soils are generated. You should use such a waste knowledge determination judiciously in identifying which UHCs are reasonably expected to be present in a volume of soil. For more information on appropriate use of knowledge of the waste, see EPA's *Waste Analysis At Facilities That Generate, Treat, Store, And Dispose Of Hazardous Wastes: A Guidance Manual*, April 1994, available at http://www.epa.gov/epaoswer/hazwaste/ldr/wap330.pdf. If you choose to use the soil treatment standards, all UHCs present at levels greater than 10 x UTS must be treated regardless of whether the soil contains a listed waste or exhibits a characteristic when the soil is generated.

A hazardous waste contaminated soil that is going to be used in products which are subsequently used in a manner constituting disposal must meet the treatment standards developed for as-generated industrial waste at 40 CFR 268.40.

1.3 Why Did EPA Develop Alternative Soil Treatment Standards?

The alternative soil treatment standards are designed to encourage more cost-effective cleanup of hazardous contaminated soils subject to LDRs and to address the unique characteristics of soils. Before these treatment standards were developed, soils subject to LDRs were required to comply with traditional technology-based treatment standards developed for industrial hazardous waste (see 40 CFR 268.40). Aside from potentially discouraging some remediations, these treatment standards sometimes proved to be inappropriate (e.g., impracticable or not cost-effective) or unachievable (e.g., did not account for heterogeneous soil matrices) when applied to hazardous constituents present in soils. The soil treatment standards at 40 CFR 268.49 continue to minimize threats to human health and the environment (as required by RCRA section 3004(m)), but provide for more flexible treatment requirements that consider the unique characteristics of soils and applicable treatment technologies, and can be achieved by using non-combustion treatment technologies.

1.4 When Are Alternative Soil Treatment Standards Available in Authorized and Unauthorized States?

Like all LDR treatment standards, the soil treatment standards are promulgated pursuant to the Hazardous and Solid Waste Amendments of 1984 (HSWA). Because the alternative soil treatment standards are generally less stringent than the general federal LDR standards, as applied to soils, they would not be available in states authorized for the land ban until the state had adopted them.

EPA encourages states to implement the revised soil standards as rapidly as possible. If a state – through implementation of State waiver authorities or other State laws – were to allow compliance with the soil treatment standards in advance of adoption or authorization, EPA generally would not consider such application of the soil treatment standards for purposes of enforcement or State authorization. Thus, by using State law to waive authorized or non-authorized State requirements, a State can allow immediate implementation of the soil treatment standards without jeopardizing its RCRA authorization. (See EPA guidance memorandum from Elizabeth A. Cotsworth to RCRA Senior Policy Advisors, Regions I - X, “Phase IV Land Disposal Restrictions Rule – Clarification Of Effective Dates” October 19, 1998 at: http://www.epa.gov/epaoswer/hazwaste/ldr/ldrmetal/memos/effectiv.pdf, especially page 13). To date, according to EPA records, 29 states have adopted the LDR Phase IV rule, and five of these have received authorization (see http://www.epa.gov/epaoswer/hazwaste/state/charts/chart2.pdf). Because the availability of the soil treatment standards will vary from state to state, EPA recommends that you contact your state regulatory agency if you have any questions.

1.5 When Do LDR Treatment Standards Apply to Hazardous Soils?

LDR treatment standards apply to hazardous soils that are “generated” and managed in a manner that qualifies as “placement” on the land for the purposes of the Land Disposal Restriction Program. Soils to which the standards apply are those soils that: (1) are removed from the area of contamination or are “placed” within the area of contamination (i.e., “generated”); (2) are a hazardous waste (either because they contain a listed hazardous waste or because they exhibit a hazardous waste characteristic); (3) are prohibited from land disposal (e.g., because they do not meet the applicable LDR treatment standard(s) and they are not eligible for a variance, extension, or exemption); and (4) are destined for land disposal.

Whether a soil is both generated and managed in a unit that qualifies as placement is dependent on a number of factors. For example, if hazardous soil is consolidated within an area of contamination, it would not be considered generated under the LDR program. If the soil is removed from the area, it is considered to be generated for the purposes of LDRs, and it may not be managed in a manner that qualifies as placement without prior treatment. For more specific information about when LDR treatment standards apply to the soil due to placement on the land, see the Phase IV Land Disposal Restrictions (63 FR 28556, May 26, 1998, especially pages 28617 through 28620). See also the memo entitled "Management of Remediation Waste Under RCRA" (EPA/530-F-98-026, Office of Solid Waste and Emergency Response), which can be found in Appendix A of this document.

1.6 Can the Alternative Soil Treatment Standards Be Used to Establish Site-Specific Cleanup Standards?

The alternative soil treatment standards should not be used to establish site-specific soil cleanup standards. The purpose of the land disposal restriction treatment standards is to ensure that prohibited hazardous wastes are properly treated before disposal (i.e., treated so that short- and long-term threats to human health and the environment posed by land disposal are minimized). The soil treatment standards, like other land disposal restriction treatment standards, are based on the performance of specific treatment technologies. In contrast, most soil cleanup levels are based not on the performance of specific treatment technologies but on an analysis of risk. Technology-based treatment standards are not necessarily appropriate surrogates for site-specific risk-based cleanup levels. In a circumstance where the soil treatment standards result in constituent concentrations that are higher than those determined on a site-specific basis to be required for soil cleanup, existing remedial programs such as RCRA Corrective Action, CERCLA and state cleanup programs could be applied to ensure that remedies are adequately protective (e.g., require a site-specific cleanup standard that is lower than the soil treatment standard). Conversely, for contaminated soil only, under 40 CFR 268.44(h)(3), a site-specific, risk-based variance may be an option where treatment to the soil treatment standards would result in concentrations of hazardous constituents that are lower than concentrations necessary to minimize short- and long-term risks to human health and the environment.

2. GUIDANCE FOR DETERMINING COMPLIANCE WITH THE ALTERNATIVE TREATMENT STANDARDS FOR CONTAMINATED SOIL

If LDR treatment standards apply to your soil, or if you think the standards *will* apply (for example, because hazardous soils will be excavated as part of the remedy), then you can use the guidance in this section to help determine how to comply with the standards.

The first step is to identify whether contaminated soil is hazardous and if so, what constituents require treatment under the LDR program. With the exception of transporters, every hazardous waste handler along the cradle-to-grave spectrum has waste analysis requirements.

Hazardous Waste Handler	**Waste Analysis Requirements**
Generators	§ 262.11 for hazardous waste identification § 268.7(a)(1) to determine if the soil has to be treated before it can be land disposed
Generators that treat in their tanks, containers, or containment buildings	In addition to the requirements above, § 268.7(a)(5) requires a written waste analysis plan (WAP)
Treatment Facilities	§ 264.13 (permitted facilities) and § 265.13 (interim status facilities) require a written WAP § 268.7(b) requires treatment facilities to test for LDR requirements according to the WAP
Disposal Facilities	§ 264.13 (permitted facilities) and § 265.13 (interim status facilities) require a written WAP § 268.7(c) requires disposal facilities to test for LDR requirements according to the WAP

Compared to TSDFs, generators are not required to maintain a written waste analysis plan unless they are treating in their tanks, containers, or containment buildings. However, generators are required to characterize their waste with a high degree of certainty and maintain records showing how they made their determinations (under § 262.40 and §268.7(a)(8)).

For detailed information about how to develop a waste analysis plan, see EPA's *Waste Analysis At Facilities That Generate, Treat, Store, And Dispose Of Hazardous Wastes: A Guidance Manual*, April 1994, available at http://www.epa.gov/epaoswer/hazwaste/ldr/wap330.pdf. To briefly summarize, compliance with the waste analysis requirements can be demonstrated by sampling and analysis, by using acceptable knowledge or by a combination of sampling and laboratory analysis and acceptable knowledge. You can show acceptable knowledge by using:

- process knowledge, or detailed information on the wastes obtained from existing published or documented waste analysis data or studies conducted on hazardous wastes generated by similar processes;

- waste analysis data obtained from facilities which send wastes off-site for treatment, storage, or disposal (e.g., generators); or

- facility records, which must be current and accurate, of analyses performed before or after the effective date of RCRA regulations.

The waste knowledge approach(es) may be particularly useful if hazardous constituents in wastes from specific processes are well documented or if discarded wastes are unused commercial chemical products or reagents with known physical or chemical constituents. Also, you may choose to use waste knowledge if conditions are not conducive to sampling and analysis due to health and safety risks or the physical nature of the actual wastes. However, consider that if you are excavating a site with unclear historical sources of contamination, it is unlikely you will be able to characterize the soil using acceptable knowledge. If you choose to use waste knowledge or a combination of waste knowledge and sampling and analysis, documentation is essential to demonstrate that the information used identifies the waste accurately and completely.

Compliance is best ensured through sampling and analysis. Because RCRA is a self-implementing program, the burden is on you, the individual facility owner/operator, to demonstrate that you are operating in compliance with all applicable regulations.

You should determine as early as possible in the site characterization process whether LDRs might apply to your soils. To do this, you will need to integrate site characterization, hazardous waste determination, and LDR compliance activities early in the corrective action. If you anticipate that generation of hazardous soils will occur and that those soils will be subject to LDRs due to land placement, then you could plan to generate site characterization data that also meet the performance and acceptance criteria for LDR compliance. This strategy could minimize redundant waste analyses, reduce costs, and save time.

As discussed earlier in Section 1.2, the alternative soil treatment standard under 40 CFR 268.49(c)(1) includes treatment of soil to one of two standards, whichever is higher:

- hazardous constituents must be reduced by at least 90-percent through treatment, **OR**

- hazardous constituents must not exceed 10 x UTS at 40 CFR 268.48.

The data collection and assessment methods needed to demonstrate attainment of the 90-percent reduction standard will differ from those needed to demonstrate attainment of 10 x UTS. Specifically, if you plan to use sampling and analysis to determine compliance with the 90-percent reduction standard, then you may need to obtain TWO sets of samples as part of the sampling strategy:

- Obtain one set of samples *prior* to treatment to estimate concentrations of contaminants of concern in the soil for comparison to LDR standards and to determine if treatment is needed, **AND**

- If treatment is needed, obtain another set of samples *after* treatment to estimate concentrations of contaminants of concern in the same volume of soil and to determine if the treatment has attained the standard.

If you elect to use the UTS or 10 x UTS (rather than 90-percent reduction), then it will not be necessary to obtain an initial set of samples from the untreated soil for comparison to the samples obtained from the treated soil.

Note also that the regulations at 40 CFR Part 268.44(h)(4) allow EPA and authorized states to grant site-specific LDR treatment variances for contaminated soil if the level or the method specified in the soil treatment standards would result in concentrations of hazardous constituents that are below (i.e., lower than) natural background concentrations at the site where the contaminated soil will land disposed. Natural background concentrations are constituent concentrations that are present in soil which have not been influenced by human activities or releases. Because natural background concentrations may vary across geographic areas, and to ensure that LDRs will only be capped at background where appropriate, EPA requires that individuals who wish to cap LDR treatment at natural background concentrations apply for and receive a treatment variance. Information on how to determine background concentrations can be found in an issue paper entitled *Determination of Background Concentrations of Inorganics in Soils and Sediment at Hazardous Waste Sites* (USEPA 1996) published by EPA's Office of Research and Development and the Office of Solid Waste and Emergency Response (http://www.epa.gov/nerlesd1/pdf/engin.pdf). In addition, consultation with a professional statistician may be necessary before preparing a request for a variance from LDR treatment standards for soil based on background concentrations.

2.1 What Steps Should I Use to Plan the Sampling and Analysis Program?

Prior to conducting any sampling or data collection activities, we suggest you use a systematic planning process such as EPA's Data Quality Objectives (DQO) process (Figure 1), followed by development of a quality assurance project plan (QAPP) and waste analysis plan (WAP).[2] The DQO process is a systematic data collection planning process developed by EPA to ensure that the right type, quality, and quantity of data are collected to support decision making. The DQO Process is intended to be flexible, and the depth and detail of DQO

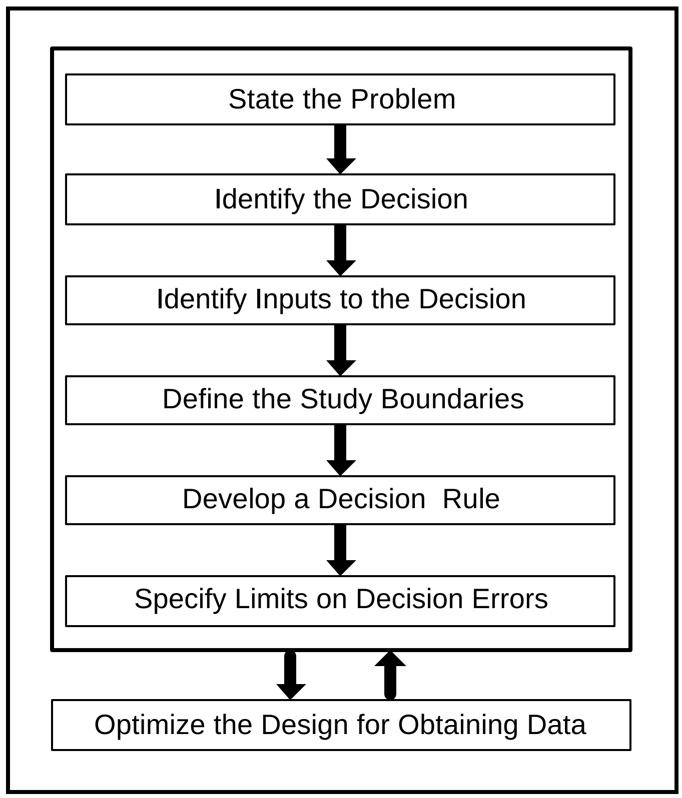

Figure 1: The Seven Steps in the DQO Process (from USEPA 1994a).

[2] For treatment, storage, or disposal facilities (TSDFs), the sampling and analysis procedures typically are documented in a waste analysis plan (WAP). For RCRA corrective actions or Superfund remedies, sampling and analysis procedures may be described in any of a number of planning documents (e.g., RFI Work Plan, CMI Work Plan, Remedial Action Plan, etc.) which we refer to generically as the quality assurance project plan (QAPP).

development should be scaled to the study's size and complexity. While one output of the DQO Process typically is a statistical/probabilistic sampling design, not every sampling problem must be resolved with a probabilistic sampling design (e.g., a nonprobabilistic or judgmental method may suffice).

You can find detailed guidance on the DQO process in *Data Quality Objectives Process for Hazardous Waste Site Investigations, EPA QA/G-4HW* (USEPA 2000a) and the *Guidance for the Data Quality Objectives Process, EPA QA/G-4* (USEPA 1994a).

To help you get started, you can use the following seven-step DQO process to plan a sampling program to demonstrate compliance with the alternative soil treatment standards. Based on these general steps, you should develop detailed DQO outputs for your specific project.

Step 1: State the Problem – The outputs of this step will include a list of members of the planning team, the resources available, the schedule, and a concise description of the problem. For the purpose of a 90-percent reduction or 10 x UTS attainment determination, the "problem" is to identify those soils that attain the 90-percent reduction standard or that have concentrations less than 10 x UTS.

Step 2: Identify the Decision – The decision is to determine whether the concentrations of contaminants of concern in a given volume of soil after treatment have been reduced by at least 90 percent from the concentrations prior to treatment or whether they have concentrations less than 10 x UTS. If either condition has been satisfied, then the treatment standard has been attained. If not, then the soils must be re-treated or an alternative waste management option must be found.

Step 3: Identify Inputs to the Decision – This step of the DQO process requires a list of informational inputs needed to resolve the decision statement. For the purpose of complying with the alternative soil treatment standards, these inputs would include, at a minimum, a list of the underlying hazardous constituents, the units of measure (e.g., mg/kg or mg/L), and a listing of appropriate analytical methods, method performance criteria (e.g., for precision and accuracy), required quantitation limits, and other existing soil characterization data.

If you elect to use 10 x UTS as the treatment standard, then the analytical methods must be capable of measuring the concentration of constituents of concern at quantitation limits less than 10 x UTS. Data of sufficient quality to measure attainment of 10 x UTS also should be adequate to measure attainment of the 90-percent reduction standard.

Note that under 40 CFR 268.49(c), treatment for non-metals must achieve 90-percent reduction in *total* constituent concentrations. Treatment for metals must achieve 90-percent reduction as measured in leachate from the treated soil (testing according to the *TCLP*) when a metal stabilization treatment technology is used, and as measured in total constituent concentrations when a metal removal technology is used.

Step 4: Define the Boundaries – Under 40 CFR 268.49(d), the treatment standards apply to "any *given volume* of contaminated soil" that meets the definition of a hazardous waste when generated (e.g., is a hazardous waste upon excavation), does not already meet applicable LDR treatment requirements, **AND** will be land disposed. The decision to generate a hazardous soil usually will be made within a risk-based corrective action decision-making context.[3] For additional information regarding hazardous soil generation, see the memo in Appendix A of this document, entitled "Management of Remediation Waste Under RCRA" (EPA/530-F-98-026, Office of Solid Waste and Emergency Response).

If the remedy involves excavation of soil, you must determine whether the soil or identifiable portions of that soil (i.e., "any given volume") are subject to the LDRs. In practice, site characterization data or waste knowledge may allow you to determine *a priori* which soils will be subject to LDRs upon excavation. The volume of soil subject to LDRs could be defined as:

- single volumes of soil (e.g., soil contained in a drum),
- manageable subsets, strata, or units of soil with distinct characteristics (e.g., cleanup units consisting of ½-acre lots at 6-inch intervals), or
- one or more "hot spots" (that is, localized areas of high contamination).[4]

You, as the generator, should determine the physical size of each "given volume" of soil on a site-specific basis. Note that each volume of hazardous soil that will be treated using the alternative standards does not necessarily need to remain segregated from other similarly classified hazardous soil for the purpose of treatment. If a given volume of soil is a mixture of hazardous soils from different locations at a site, then the entire mixed volume must be treated to meet the applicable standard.

Subject to some limited exceptions, you should not mix hazardous soil (e.g., soil that exhibits the TC) with nonhazardous soils prior to treatment. To do so may be impermissible dilution. For example, once a hazardous contaminated soil has been generated and becomes subject to LDR treatment standards, dilution of that soil solely as a substitute for adequate treatment to achieve compliance with LDR treatment standards is considered impermissible dilution and is prohibited under 40 CFR 268.3.[5] However, there are exceptions:

(1) If mixing occurs through the normal consolidation of contaminated soil from various portions of a site that typically occurs during the course of remedial activities or in the course of normal earthmoving and grading activities, then the Agency does not consider this to be intentional mixing of soil with nonhazardous soil for the purposes of evading LDR treatment standards. Therefore, it is not viewed as a form of impermissible dilution. See 63 FR 28605 and 28621 (May 26, 1998). Indeed, if a contaminated soil is consolidated within an area of

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[3] Note that the treatment standards do not apply to *in situ* soils, nor do they force soils to be excavated. If contaminated soil is managed within an area of contamination (AOC) and is being treated *in situ* or consolidated within an AOC, then the LDR treatment requirements do not apply.

[4] For guidance on how to identify "hot spots," see Gilbert (1987, page 119), USEPA (1989), and the ELIPGRID software (Davidson 1995).

[5] In addition, per 40 CFR 268.2(k) hazardous waste may not be deliberately mixed with soil solely to change its treatment classification from waste to soil.

contamination before it is removed from the land (i.e., generated), the determination as to whether the soil exhibits a characteristic of hazardous waste may be made after such consolidation. If the soil is determined not to be hazardous when removed, neither Subtitle C nor the land disposal restriction requirements would apply.

(2) Some situations may require soil mixing, as part of a pre-treatment process, to facilitate and ensure proper operation of the final treatment technology to meet the LDR treatment standards. If the mixing or other pre-treatment is necessary to facilitate proper treatment in meeting the LDR standards, then dilution is permissible. For example, addition of less contaminated soil may be needed to adjust the contaminated soil BTU value, water content, or other properties to facilitate treatment. These adjustments would be for meeting the energy or other technical requirements of the treatment unit to ensure its proper operation. The Agency views this type of pre-treatment step as allowable, provided the added reagents or other materials produce chemical or physical changes and do not (1) merely dilute the hazardous constituents into a larger volume of waste so as to lower the constituent concentration or (2) release excessive amounts of hazardous constituents to the air. See 51 FR 40592 (November 7, 1986) and 53 FR 30911 (August 16, 1988).

In addition, the Agency recognizes that it may be advantageous to over-excavate contaminated soils to implement a cost-effective cleanup and to minimize the need for multiple mobilizations of a field team for sampling, analysis, and soil excavation/removal. Because each site-specific situation is unique, the extent to which over-excavation can be performed, if at all, must be determined on a site-specific basis. Gross over-excavation, however, could be viewed as impermissible dilution and should be avoided.

In practice, without sampling all of the soil mass, it is not statistically possible to ensure that all portions of soil submitted for treatment have concentrations greater than 10 x UTS. Thus, you should have sufficient data or waste knowledge to indicate that a large proportion of the soil in a given volume has concentrations greater than 10 x UTS for one or more of the UHCs of interest. You will need to use educated judgment to avoid unnecessary treatment.

If you plan to determine the volume of soil subject to the treatment standard prior to excavation (i.e., *in situ* soils), then you could delineate the soils using a spatial analysis (for example, by using geostatistical techniques). For assistance with application of geostatistical methods, consult a professional geostatistician or see Myers (1997), Isaaks and Srivastava (1989), Journel (1988), USACE (1997), and USEPA (1991a).

If you plan to determine the volume of soil subject to the treatment standard when the soil is excavated (i.e., at the point of generation) and placed in temporary piles, or stored (e.g., in drums or roll-off boxes), then the piles, drums, and/or roll-off boxes could define the boundaries.

Note that if the 90-percent reduction standard is used, then the estimate of post-treatment concentrations should apply to the *same* unit of soil characterized initially. Even though handling and treatment of the soil may significantly change its volume and/or mass between its point of generation and final treatment, the “identity” of the soil should remain intact throughout to facilitate consistent comparison of the soil before and after treatment. One approach is to track each batch of soil through the characterization and treatment process. As an alternative, you could conduct an initial study to demonstrate that the treatment process achieves at least 90-percent reduction. For subsequent treatment of the same type of contaminated soil, you should monitor the treatment process variables, controls, and operating conditions and establish waste and/or process knowledge, in lieu of testing, to support your claim that the standard has been achieved. For long-term treatment projects, you should retest periodically to confirm that the standard continues to be achieved. This strategy offers increased flexibility to operators and could reduce overall costs for sampling and analysis.

Hypothetical example of defining a "given volume" of contaminated soil subject to LDRs:

During a construction project at an active refinery, the facility identified soil contaminated with benzene. A risk-based cleanup level of 1.5 mg/kg was established for the site, and a decision was made to excavate all soil with concentrations exceeding the cleanup level. The UTS for benzene for nonwastewaters is 10 mg/kg. Note that soils with benzene concentrations less than 0.5 ppm in TCLP extract are not classified as hazardous under the Toxicity Characteristic for benzene (see 40 CFR 261.24), but may still be subject to cleanup requirements.

The site characterization determined that the contaminated soil was confined to a horizontal area 40 feet wide by 90 feet long. The depth of contamination was approximately six feet. To characterize the site, the soils were divided into a series of 10 ft x 10 ft x 3 ft "blocks" so that a remedial decision could be made for each block based upon sample analysis results. Using this approach, each block of contaminated soil was placed into one of the following three categories for subsequent removal, treatment, and disposal:

1. **Nonhazardous soils.** Nonhazardous soils were those soils with TCLP concentrations less than 0.5 ppm but with total concentrations exceeding the risk-based cleanup level of 1.5 mg/kg. To conserve analytical costs, TCLP benzene concentrations were estimated from total benzene concentrations by comparing each total result to 20 times the TC regulatory limit, or 10 mg/kg (to account for the 20:1 dilution used in the TCLP). Therefore, soils with total benzene concentrations between 1.5 mg/kg and 10 mg/kg were placed in this category. Based on the sample analysis results, the facility identified 52 "blocks" or approximately 578 cubic yards of soil in this category. The LDR treatment standards do not apply to these soils, and upon removal, the soils were treated and/or disposed in accordance with the state's risk-based corrective action program.

2. **TC hazardous soils with total concentrations less than 10 x UTS.** These soils exhibited the TC for benzene (using 10 mg/kg as a screening level) but had total benzene concentrations less than 10 x UTS (i.e., less than 100 mg/kg). Therefore, soils with total benzene concentrations between 10 mg/kg and 100 mg/kg were placed in this category. The facility identified six "blocks" or approximately 67 cubic yards of soil in this category. Upon removal, the facility considered the soil to meet the alternative soil treatment standard of 10 x UTS without further treatment, and upon removal, the soils were treated and/or disposed in accordance with the state's risk-based corrective action program.

3. **TC hazardous soils with total concentrations greater than 10 x UTS.** These soils exhibited the TC for benzene and had total benzene concentrations greater than 10 x UTS (i.e., greater than 100 mg/kg). The facility identified 14 "blocks" or approximately 155 cubic yards of soil in this category. This volume of soil (155 cubic yards) was designated as the "given volume" to which, upon generation, the facility elected to apply the alternative soil treatment standards at 40 CFR 268.49 (10 x UTS or 90% reduction).

Step 5: Develop a Decision Rule – In this step, you specify the parameter of interest, specify an action level, and develop a decision rule. A “parameter” is a descriptive measure of a population such as the population mean (or average), median, or some percentile (such as the 99^{th} percentile). An action level is a concentration limit that would cause you to choose between alternative actions.

If you elect to apply the 90-percent reduction standard, then the parameter of interest is the difference in the *mean* concentrations “before” treatment and “after” treatment. The action level is implicitly defined as the mean concentration in the untreated soil.

If you elect to use 10 x UTS as the action level, then the parameter of interest is the *maximum* (i.e., no sample analysis result can exceed 10 x UTS). Note that the standard of 10 x UTS is more practicable when there is relatively low variability in constituent concentrations in the treated soil and average concentrations are well below their applicable standards (see also Section 2.3.2).

The decision rule for contaminated soils subject to the alternative soil treatment standards is:

> If treatment of the contaminated soil has achieved on average at least 90 percent reduction in constituent concentrations, or maximum concentrations do not exceed 10 x UTS, then the alternative treatment standard for contaminated soil has been attained.

Step 6: Specify Limits on Decision Errors – You will use the sample analysis results to support a decision about whether a given volume of soil attains the standard. Because of variability in contaminant concentrations within a given volume of soil, practical constraints on the number of samples that can be obtained and analyzed, and random variability and biases that can be introduced in the sampling and measurement processes, the data collected may not be representative and may mislead the decision maker into making an incorrect decision. A decision error occurs when sampling data mislead the decision maker into choosing a course of action that is different from or less desirable than the course of action that would have been chosen with perfect information (i.e., with no constraints on sample size and no measurement error).

We recognize that data obtained from sampling and analysis are never perfectly representative and accurate, and that the costs of trying to achieve near-perfect results can outweigh the benefits. Uncertainty in data must be tolerated to some degree. The DQO process controls the degree to which uncertainty in data affect the outcomes of decisions that are based on those data. This step of the DQO process allows the decision maker to set limits on the probabilities of making an incorrect decision.

Hypothesis tests can be used to control decision errors. When performing a hypothesis test, a presumed or baseline condition, referred to as the "null hypothesis" (H_o), is established. This baseline condition is presumed to be true unless the data conclusively demonstrate otherwise, which is called "rejecting the null hypothesis" in favor of an alternative hypothesis (H_a). For the purpose of determining compliance with the 90-percent reduction alternative soil treatment standard, the baseline condition, or H_o, is that *the given volume of soil does not attain the* *standard*. Using the statistical notation for hypothesis testing[6], these hypotheses can be stated as follows:

$$H_o\!: m_{Treated} - 0.1m_{Untreated} > 0$$
$$H_a\!: m_{Treated} - 0.1m_{Untreated} \leq 0$$

When the hypothesis test is performed, one of two possible decision errors may occur:

1. Deciding the soil treatment achieves 90-percent reduction, when the correct decision (with complete and perfect information) would be "the soil treatment does not achieve 90-percent reduction," or

2. Deciding the soil treatment does not achieve 90-percent reduction, when the correct decision would be that the treatment does in fact achieve 90-percent reduction.

Because the soil is known to be contaminated and known to have concentrations greater than 10 x UTS, we can presume (as a “null hypothesis”) that the soil does not attain the standard. The sampling data must provide clear evidence that the soil treatment achieves 90-percent reduction or that the concentrations are less than 10 x UTS; otherwise, we must presume that the soil treatment standard has not been achieved. This presumption provides the basis for classifying the two types of decision errors. To decide that the soil treatment achieves the standard, when in fact it does not, is designated as a Type I decision error (also known as a “false rejection” of the null hypothesis). To decide that the soil treatment does not achieve the standard, when in fact it does, is designated as a Type II decision error (also known as a “false acceptance” of the null hypothesis). The probability of making a Type I error is denoted by *a* (“alpha”).[7]

We recommend you set the Type I error rate, *a* , equal to 0.10. Setting the error rate at this level will ensure there is only a 10% chance of falsely rejecting the null hypothesis. In other words, when the standard has not truly been met, the test will erroneously conclude it has been achieved only one time in 10.

Step 7: Optimize the Design for Obtaining the Data – The objective of this step is to develop a sampling and analysis plan that obtains the requisite information from the samples for the lowest cost and still satisfies the DQOs. The output of this step is the sampling design that will guide the development of QA project documentation such as a project-specific QAPP or WAP. Key activities in this step include reviewing the DQO outputs and existing environmental

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[6] The symbol “*:*” is used to represent the population arithmetic mean. The mean is the best parameter for determining 90-percent reduction. Where normality assumptions are grossly violated, however, another central tendency estimator such as the median may be used instead. For more information, see “Checking Data for Normality” in Section 2.3.3.

[7] It also is possible to specify a Type II error rate ($), however, specification of the Type II error rate is not required to perform the statistical tests described in this guidance. Additional guidance on decision errors can be found in EPA’s “G-4" and “G-9" guidance documents (USEPA 1994a and 1998c).

information, developing data collection design alternatives, calculating the optimal number of samples for each candidate sampling design, selecting the most resource-effective design that will satisfy the DQOs, and documenting the outputs of the DQO Process.

Key outputs of this step include documentation of the following:

- sample size (number of samples)
- sample type
- sample collection and handling techniques
- sample support (i.e., the size, shape, and orientation of soil to be collected for each sample)
- sample locations
- timing issues for sample collection, handling, and analysis
- analytical methods or the performance criteria for sample analysis
- QA and QC protocols.

Formulas for calculating the appropriate number of samples are given in *Data Quality Objectives Process for Hazardous Waste Site Investigations EPA QA/G-4HW Final* (USEPA 2000a) and described in depth in EPA's *Guidance for Data Quality Assessment, EPA QA/G-9* (QA00 Update, revised July 2000) (USEPA 1998c).

You can find detailed guidance on the development and optimization of a sampling plan in the following references: ASTM (1998a), Mason (1992), Myers (1997), and USEPA (2000a and 2000b).

2.2 How Do I Implement the Sampling and Analysis Program?

To implement the sampling and analysis program, you should develop and follow a project-specific QAPP or WAP. Guidance for developing a QAPP can be found in *EPA Guidance For Quality Assurance Project Plans, EPA QA/G-5* (USEPA 1998b). Guidance for developing a WAP can be found in *Waste Analysis at Facilities That Generate, Treat, Store, and Dispose of Hazardous Wastes, a Guidance Manual* (USEPA 1994b) available at: http://www.epa.gov/epaoswer/hazwaste/ldr/wap330.pdf

Detailed guidance on implementing a field sampling program to characterize soil can be found in *Preparation of Soil Sampling Protocols: Sampling Techniques and Strategies*, EPA/600/R-92/128 (Mason 1992), and in a variety of other publications including ASTM (1995, 1998b, 1998c, 1999), Myers (1997), and USEPA (1991b).

Again, as emphasized in the beginning of section 2.1, the DQO process, including development of QAPPs or WAPs, is intended to be flexible, and the degree of detail should be commensurate with the study size and complexity.

2.3 How Should I Evaluate the Data to Determine Attainment of the Treatment Standards?

You should perform two data assessment activities to evaluate your sample analysis results: (1) data verification and validation and (2) data quality assessment. Perform data verification and validation in accordance with procedures specified in the QAPP or WAP to ensure that the sampling and analysis protocols specified in the planning documents were followed and that the measurement systems performed in accordance with the specified criteria.

Following data verification and validation, you should perform data quality assessment (DQA). DQA is the scientific and statistical evaluation of data to determine if the data are of the right type, quality, and quantity to support their intended purpose. You can find detailed guidance on DQA in EPA's *Guidance for Data Quality Assessment, EPA QA/G-9* (USEPA 1998c).

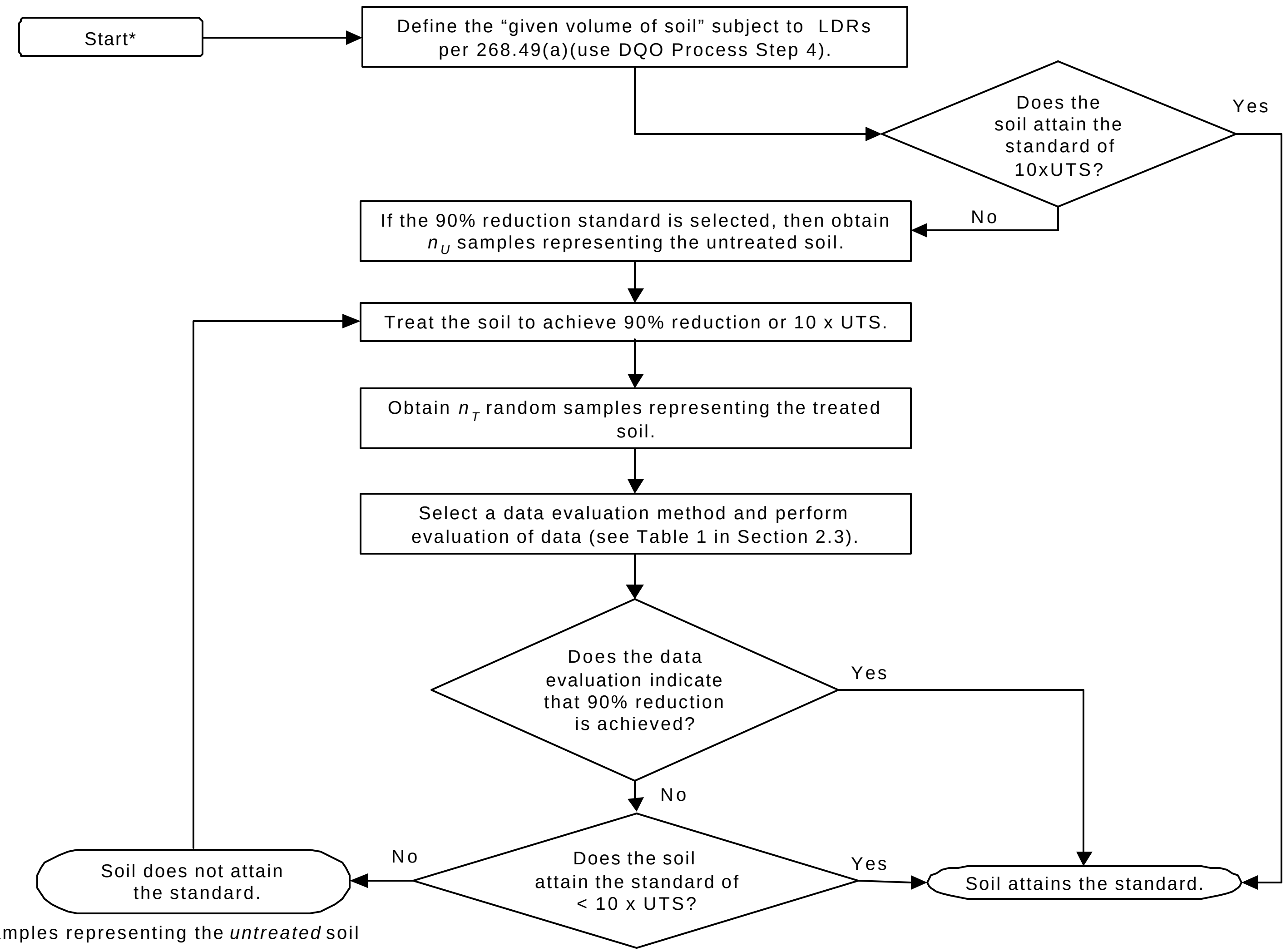
As one of the final activities in the DQA process, you should evaluate the data to determine whether or not you have attained the alternative treatment standards. You can select the appropriate method for data evaluation based on the type of treatment standard being used and other site-specific conditions (such as the volume of soil subject to the treatment standards and the physical characteristics of the soil).

Figure 2 provides a generalized flow diagram indicating the decision-making process for determining attainment of the alternative soil treatment standards.

Table 1 provides an overview of the various data evaluation methods available for determining attainment of the alternative soil treatment standards along with their appropriate conditions for use, advantages, and limitations. Note that the statistical methods included here are provided as guidance only. In those cases where you require additional information or more advanced statistical methods, we suggest you seek assistance from a statistician.

Section 2.3.1 describes a simple nonstatistical method that can be used when only a small volume of soil is in question or when relatively small individual "batches" of soil are subject to treatment. Section 2.3.2 describes methods that can be used to evaluate attainment of the UTS or 10 x UTS. Section 2.3.3 describes statistical methods that can be used to evaluate attainment of the 90-percent reduction standard.

Figure 2. Flow Chart for Determining Attainment of the Alternative Soil Treatment Standards



n_U = number of samples representing the *untreated* soil

n_T = number of samples representing the *treated* soil

* Use of the chart assumes the generator or treater has elected to use the alternative soil treatment standards and has not obtained a site-specific variance under 40 CFR 268.44(h).

Table 1. Summary of Data Evaluation Methods

Data Evaluation Method	***Type of Standard***		***Guidance Section No.***	***Appropriate Conditions for Use***	***Advantages***	***Limitations***
	90% Reduction	*10 x UTS*				
Nonstatistical Method	**T**	**T**	2.3.1	• Useful when sampling and measurement error can be minimized, and the volume of soil is relatively small • Useful when only a rough estimate of the constituent concentration is required	• Simple • Easy to use and understand • Low-cost	• Only provides a "point estimate" of the constituent concentration • Does not provide information about variability • Does not quantify the uncertainty associated with the estimate
Simple Exceedance Rule	**V**	**T**	2.3.2	• Analytical quantitation limit must be less than the treatment standard.	• Simple, easy to use and understand • Easy to enforce • Data set can include nondetects.	• Requires a large number of samples to provide high confidence that the standard is achieved
Tolerance Limit	**V**	**T**	2.3.2	• Most useful when the analytical quantitation limit is well below the treatment standard and sampling and measurement error are minimal • Data must exhibit an approximately normal distribution.	• A small number of samples can be used (we recommend at least *four* random samples). • Relatively easy to calculate	• The calculated limit will be very sensitive to the size of the standard deviation relative to the mean.
Nonparametric Test of Location	**T**	**V**	2.3.3.1	• Useful if there are no extreme values in the data sets	• Quick • Simple • Easy to use • Does not require the assumption that the data exhibit a normal distribution. • Can be used with data sets that include "nondetects"	• Provides less statistical "power" than Welch's t-Test or the Wilcoxon Rank-Sum test (i.e., the test may indicate that 90-percent reduction has not been achieved, when in fact it has)
Welch's t-Test	**T**	**V**	2.3.3.2	• Data must exhibit an approximately normal distribution.	• Provides more statistical "power" than the test of location if the underlying assumptions for the test are satisfied	• Cannot be used when a large percentage (>20%) of the data are reported as nondetect • Requires more statistical calculations than other methods (e.g., calculation of the mean, variance, and degrees of freedom)
Wilcoxon Rank-Sum Test	**T**	**V**	2.3.3.3	• Useful when the underlying distribution of the data is unknown or cannot be readily identified • Useful when a significant percentage (>20%) of the data are reported as nondetect	• Easy to compute and understand • Can be used with data sets that include "nondetects"	• Provides less statistical "power" than Welch's t-Test if the data follow a normal distribution or are approximately symmetrical

T = appropriate for use.
V = not appropriate for use.

2.3.1 What Simple Nonstatistical Method Can I Use to Evaluate Attainment of the Soil Treatment Standards?

As part of the planning process, the planning team must define the volume of soil that needs to be characterized for the purpose of evaluating attainment of the alternative soil treatment standards. If the "given volume" (as specified at 40 CFR 268.49(d)) is relatively small and the sampling and measurement error can be minimized [8], then a single representative sample (within the meaning of a representative sample given at 40 CFR 260.10) may be adequate to *estimate* the concentration in the volume of soil, and use of a statistical method to determine attainment of soil treatment standards may not be necessary or appropriate.

As a practical matter, the volume of soil characterized using this nonstatistical method could be defined operationally, such as: (1) the volume of soil that will fit in a 55-gallon drum, (2) some reasonably small volume that could be excavated by a backhoe during remedial activities (such as a 10 ft-by-10 ft-by 2 ft block of soil), or (3) small volumes of soil that are considered "batches" in a batch treatment process.

This approach can be used to evaluate attainment of either the 90-percent reduction standard or the standard of 10 x UTS. If the 90-percent reduction standard is used, then a representative sample must be obtained and analyzed *before* treatment of the given volume and a second representative sample obtained from the same unit of soil and analyzed *after* treatment. Only those two data points would be used to determine 90-percent reduction. Using this nonstatistical approach, the decision rule to determine compliance with the 90-percent reduction standard is simple: the concentration (C) of the constituent of concern in the sample of the treated soil must be less than or equal to 1/10 of the concentration found in the sample of the untreated soil.

$$C_{treated} \leq 0.1\left(C_{untreated}\right)$$

One of the key underlying assumptions of this approach is that a single soil sample can provide an adequate estimate of the concentration within a given volume of soil. If the soil is heterogeneous, then a single soil sample (such as a core a few centimeters in diameter) may not provide a good estimate of the mean concentration within the given volume of soil.

The nonstatistical procedure for evaluating attainment of the 90-percent reduction standard is performed as follows:

Step 1. Define a small "given volume" of soil to be characterized and treated (see DQO process Step 4).

[8] Sampling error can be minimized by using an optimal sample mass, obtaining the correct shape and orientation of individual samples (known as the sample "support"), and by using sampling devices and sub-sampling procedures that will minimize biases. For detailed guidance on controlling error in sampling, see Mason (1992) and Myers (1997).

Step 2. Obtain a representative sample from the given volume and submit the sample for laboratory analysis.

Step 3. After treatment of the given volume of soil, obtain another sample from the same given volume using the same sampling and analysis procedures used in Step 2.

Step 4. If the concentration in the sample from the *treated* soil is less than or equal to the 1/10th of the concentration in the sample of the *untreated* soil (or less than 10 x UTS), then you can conclude that the alternative soil treatment standard has been attained for that volume of soil. Otherwise, you cannot conclude that the treatment standard has been attained.

If 10 x UTS is the selected standard, then the decision rule is simplified even further: the sample analysis result(s) (from one or more grab samples representing the given volume of soil) must be less than 10 x UTS.

Hypothetical Example: Using the Nonstatistical Method to Evaluate Attainment of the 90-Percent Reduction Standard

A wood preserving facility is closing a tank that contained spent formulations from a wood preserving process (F035). Upon removal of the tank, the operator discovered a small patch of soil contaminated with F035. The operator excavated the soil and placed it into a 55-gallon drum. Because the excavated soil contains a listed hazardous waste, Land Disposal Restrictions under RCRA apply. The applicable standard is for "nonwastewaters" and can be found in the table at 40 CFR 268.40. The facility operator decides to apply the alternative treatment standards for contaminated soil (10 x UTS or 90-percent reduction). Because the volume of soil subject to LDRs is small, the operator decides to use the "small volume" approach to determine attainment of the 90-percent reduction standard:

Step 1. The "given volume" of soil is the volume of soil in the drum.

Step 2. The operator obtains a soil core representing the full thickness of the soil in the drum and submits this sample for laboratory analysis. The concentrations of the hazardous constituents are as follows:

Hazardous Constituent	UTS for Non-wastewaters (ppm TCLP) (from the UTS Table at § 268.48)	10 x UTS (ppm TCLP)	Conc. In Sample Obtained From Untreated Soil (ppm TCLP)	Target Treatment Level For 90% Reduction (ppm TCLP)
Arsenic	5.0	50	420	42*
Chromium	0.6	6.0	120	12

* Compliance also may be demonstrated by achieving 10 x UTS, or 50 ppm.

Step 3. After treatment of the soil, the treatment facility obtains another sample using the same sampling and analysis procedures used in Step 2. The concentrations of hazardous constituents are as follows:

Arsenic (TCLP):	48 ppm
Chromium (TCLP):	10 ppm

Step 4. The concentration of arsenic in the treated soil is not less than the target treatment level for 90-percent reduction; however, it is less than 10 x UTS. Therefore, the alternative treatment standard is attained for arsenic. The concentration of chromium in the treated soil is less than the target treatment level for 90-percent reduction. Therefore, the alternative treatment standard also is attained for chromium.

2.3.2 What Methods Can I Use to Determine Attainment of the UTS or 10 x UTS?

The concentration level treatment standards established for compliance with RCRA Land Disposal Restrictions, such as the universal treatment standards (UTS), represent concentration levels that should never be exceeded. To comply with the UTS (or to comply with the alternative of 10 x UTS for hazardous soils), no portion of the waste may exceed the standard. If testing results show that "hot spots" remain, this is evidence that the treatment was not effective and there is noncompliance with the LDR treatment requirements (see 63 FR 28567, May 26, 1998). You should consider the amount of variability in the treated soil to ensure compliance with the UTS or 10 x UTS. Statistical variability is "built in" to the LDR treatment standards (USEPA 1991c), and it is expected that the *mean* will be well below the standard for all portions of the waste to be below the standard (see Figure 3).

To determine attainment of a concentration level LDR treatment standard such as the UTS (or 10 x UTS), conduct waste-testing in accordance with your WAP and determine whether or not any sample analysis result exceeds the standard. If any sample analysis results exceed the standard, then you must conclude that the standard is not met. (Note that samples of the *untreated* soil are not required to determine attainment of the UTS or 10 x UTS). Though simple in practice, this **simple exceedance rule** has a potential limitation: a large number

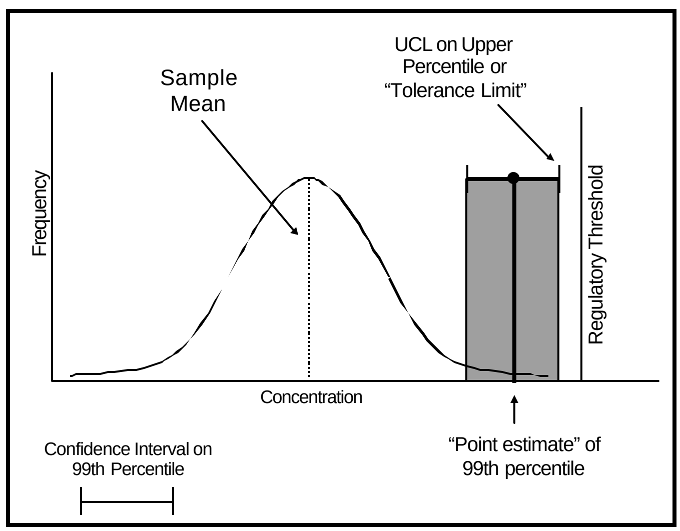


Figure 3. To comply with the alternative soil treatment standard of 10 x UTS, the mean concentration must be well below the standard for all portions of the soil to be at or below the treatment standard.

of samples are required to have a high degree of confidence that little or no portion of the waste exceeds the standard.[9]

The LDR regulations do not require hazardous waste generators or treaters to conduct statistical sampling, however, some waste handlers may wish to evaluate their sample analysis data statistically to quantify the level of "comfort" they can have in concluding that a standard has been met. This could be done by testing whether a high *percentile* (such as the 99th percentile) or proportion of the soil (that is, all possible soil samples of a given sample "support") comply with the standard. An upper percentile serves as a reasonable approximation of the *maximum* concentration found in any portion of the waste. This approach is consistent with the manner in which the LDR concentration level treatment standards are calculated — each standard is calculated as the 99th percentile of the data obtained from a properly operating waste treatment process (USEPA 1988, 1991c).

The 99th percentile can be estimated from a set of samples drawn from the waste or soil by using an *upper confidence limit for a percentile*. You can use an upper confidence limit on a percentile to determine attainment of the standard as follows:

- If the upper confidence limit on the percentile is less than or equal to the applicable LDR standard (such as the UTS or 10 x UTS), then the waste can be judged in compliance with the standard (see Figure 3), *as long as no individual sample values exceed the standard*.

- If the upper confidence limit on the percentile exceeds the standard (but *all* sample values are less than or equal to the standard), then the waste still could be judged in compliance with the standard. However, you would not have the specified level of confidence that the specified proportion (e.g., 0.99) of the waste complies with the standard.

Methods for testing a percentile against a fixed standard are fairly simple and are described in several USEPA guidance documents (for example, see Chapter 7 in USEPA 1989, and USEPA 1992) and statistical references (e.g., Hahn and Meeker 1991, and Guttman 1970).

2.3.3 What Statistical Methods Can I Use to Determine Attainment of the Alternative Soil Treatment Standard of 90-Percent Reduction?

Statistical methods can be used to determine if a given volume of soil has been treated such that there is a 90-percent reduction from the initial concentration of hazardous constituents. This involves use of a statistical test selected from a category of tests known as "two-sample" tests. The statistical tests are called two-sample tests because they involve two *sets* of samples, one drawn independently from the *untreated* soil and another drawn independently from the *treated* soil, so that a comparison can be made between the "before" and "after"

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[9] The exceedance rule has statistical properties. The statistical performance $(1-a)$ can be determined for given number of samples, n (all less than or equal to the standard), by $(1-a) = 1-p^n$ where p equals the proportion (e.g., 0.99) of the waste that must have concentrations less than or equal to the standard.

conditions of the soil.[10] That is, the generator will test the soil *before* treatment and again *after* treatment, then perform the statistical test to determine if 90-percent reduction has been attained. For all of the statistical tests presented in this guidance, it is necessary that the samples be obtained using a random or systematic sampling plan.

We present two "tiers" of statistical tests for determining attainment of the 90-percent reduction standard. Under the first tier, we present a "quick and simple" method that does not require statistical calculations or assumptions about the distributional form of the data (see Section 2.3.3.1). The test is known as the **Nonparametric Test of Location**. The test is quick and easy to use and may be preferred by users of this guidance who have little or no training in statistics. The test does not require the assumption of normally distributed data. One limitation of the test is that it lacks statistical "power" – that is, compared with other statistical methods (described below) the test is less likely to show that 90-percent reduction has been attained.

The statistical tests in the second tier are more powerful but require more calculations. If both sets of data (i.e., the data representing the untreated soil and the data representing the treated soil) exhibit an approximately normal distribution or can be transformed to a normal distribution, then **Welch's t-Test** can be used (see Section 2.3.3.2). Welch's t-Test does not require the same number of samples in each group of data and does not require that the variances of the two groups of data be equal. If the distributions of the two groups of data are unknown or cannot be readily identified as normal or lognormal, a non-parametric alternative to Welch's test should be used. The **Wilcoxon Rank Sum** test is recommended for use where the underlying distribution of the data is unknown and cannot be readily identified, or when a significant percentage (e.g., 20 to 90%) of the combined data set are reported as "nondetects" (see Section 2.3.3.3).

Checking Data for Normality:

The assumption of normality is very important, as it is the basis for many statistical tests. While the assumption of a normal distribution (i.e., a "mound-shaped" frequency distribution) is convenient for statistical testing purposes, it is not always appropriate. For example, sometimes data are highly skewed (such as with a lognormal distribution in which the natural logarithms of the data exhibit a normal distribution), or they may have no specific shape at all. If the assumption of normality is not satisfied, then you should consider using an alternative nonparametric test (see list of tests in Table 1).

You can check data sets for normality by using graphical methods, such as histograms, box and whisker plots, and normal probability plots, or by using numerical tests such as Filliben's Statistic or the Shapiro-Wilk test. We recommend the Shapiro-Wilk test as a superior method for testing normality of the data. The specific method for implementing the Shapiro-Wilk Test is described in Gilbert (1987) and can be performed with EPA's DataQUEST free software (USEPA 1997) or other commercially available statistical software. EPA's *Guidance for Data Quality Assessment, EPA QA/G-9* (USEPA 1998c) also describes methods you can use to check data for normality.

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[10] The statistical methods for determining 90-percent reduction described in this guidance involve the use of independent samples obtained from the untreated and treated soil. These tests should not be confused with a set of statistical tests that deal with analyzing "paired" data.

2.3.3.1 A "Quick and Simple" Statistical Method for Determining 90-Percent Reduction

To test whether the treatment process has resulted in 90-percent reduction from the initial concentration in the untreated soil, the quick and simple statistical method described here can be used. All that is required to perform the test is knowing the number of samples representing the soil before treatment, the number of samples representing the soil after treatment, identification of the smallest observation in the "before" treatment data set, and use of a lookup table. The method described below is a modification of the nonparametric test of location (Rosenbaum 1954). Also, note that the presence of one or more extreme values within the data sets could further reduce the power of the test (i.e., if there is a value in the untreated soil data set that is much *lower* than the bulk of the other values, and/or there is a value in the treated soil data set that is much *higher* than the bulk of the other values in the data set, then the test will have reduced statistical power).

The procedure for performing the nonparametric test of location is as follows:

Step 1. Count the number of samples $\left(n_U\right)$ used to characterize the *untreated* soil, and count the number of samples $\left(n_T\right)$ used to characterize the *treated* soil.

Step 2. Use Table B-1 (found in Appendix B - Statistical Tables) (for 90% confidence) or Table B-2 (for 95% confidence) to obtain the critical value corresponding to n_U and n_T.

Step 3. Identify the smallest value in the set of samples obtained from the *untreated* soil and divide the value by 10.

Step 4. Count the number of samples (*s*) from the *treated* soil that are less than or equal to the value obtained in Step 3. If *s* is greater than or equal to the critical value from the table, then you can conclude that 90-percent reduction has been attained. If *s* is less than the value in the table, then you cannot conclude that 90-percent reduction has been achieved. If the "quick and simple" test fails to show that 90-percent reduction has been achieved, then consider evaluating the data using a more powerful statistical method such as Welch's t-Test (Section 2.3.3.2) or the Wilcoxon Rank Sum test (Section 2.3.3.3).

Hypothetical Example: Using the "Quick and Simple" Nonparametric Statistical Test to Evaluate Attainment of the 90-Percent Reduction Standard

Using data obtained from a site characterization, the site operator delineates a volume of hazardous soil known to have contaminant concentrations greater than 10 x UTS within the defined volume (Figure 4). To determine attainment of the 90-percent reduction standard, the operator obtains eight random samples from the volume of untreated soil (note that the samples also could be obtained from a pile of soil that is the complete excavation of the block). The volume of soil is then treated using an *ex situ* soil washing technology.

After treatment, a new set of seven samples is obtained and analyzed. The analytical results are as follows (in ppm):

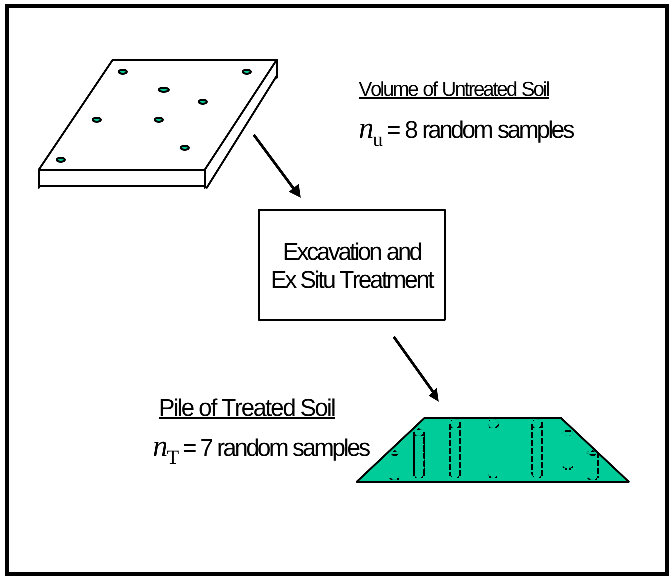

Figure 4. Sample collection strategy for measuring attainment of 90-percent reduction.

Untreated Soil (ppm): 1200, 800, 400, 540, 370, 260, 230, 200

Treated Soil (ppm): 25, 18, 15, 14, 12, 8, 6

Use the "quick and simple" nonparametric method to determine if the treatment process has attained the 90-percent reduction standard:

Step 1. The number of samples (n_U) used to characterize the *untreated* soil is 8. The number of samples (n_T) used to characterize the *treated* soil is 7.

Step 2. Using Table B-1 (for 90% confidence) found in Appendix B, we obtain a critical value of 3 corresponding to n_U = 8 and n_T = 7.

Step 3. The smallest value in the set of samples obtained from the *untreated* soil is 200 ppm. 200 divided by 10 equals 20.

Step 4. There are 6 samples from the *treated* soil that are less than or equal to 20. Because 6 is greater than or equal to 3 (the critical value from the table), then you can conclude with 90% confidence that 90-percent reduction has been attained.

2.3.3.2 Welch's t-Test

If both sets of data (i.e., the data representing the untreated soil and the data representing the treated soil) exhibit an approximately normal distribution or can be transformed to a normal distribution, then Welch's t-Test can be used. Welch's t-Test does not require the same number of samples in each group of data and does not require that the variances of the two groups of data are equal. If the distributions of the two groups of data are unknown or cannot be readily identified as normal or lognormal, or a large percentage of the data (e.g., 20 to 90%) is reported as "nondetect", then the nonparametric Wilcoxon Rank-Sum test should be used instead (see Section 2.3.3.3).

Procedure

Using a simple random or systematic sampling design, obtain a set of samples representing the untreated soil known to have contamination with concentrations greater than 10 x UTS. After treatment of the soil, obtain a new set of samples representing the same mass of soil.

Multiply each datum from the untreated soil (U_i) by 0.1 such that each is reduced by 90 percent of its original value. The 90-percent reduced data will serve as the reference data set ("*ref*"). If 90-percent reduction has been attained, then the mean concentration in the treated soil should be the same as the mean concentration in the reference data set or shifted to the left of the mean of the reference data set.

Step 1: Calculate the sample mean $\bar{x}_T$ and the sample variance s_T^2 for the "Treated" soil. Calculate the sample mean $\bar{x}_{ref}$ and the sample variance s_{ref}^2 for the reference data set. The number of samples representing the untreated and treated soil do not need to be the same.

Step 2: Calculate Welch's t-Statistic as follows:

$$t = \left(\bar{x}_T - \bar{x}_{ref}\right) \Big/ \sqrt{\frac{s_T^2}{n_T} + \frac{s_{ref}^2}{n_{ref}}} \qquad \textbf{Equation 1}$$

Step 3: Calculate the approximate degrees of freedom as follows:

$$df = \left[\frac{s_T^2}{n_T} + \frac{s_{ref}^2}{n_{ref}}\right]^2 \Bigg/ \left[\frac{\left(s_T^2/n_T\right)^2}{n_T - 1} + \frac{\left(s_{ref}^2/n_{ref}\right)^2}{n_{ref} - 1}\right] \qquad \textbf{Equation 2}$$

Round df to the nearest integer.

Step 4: Use Table B-3 in Appendix B to find the critical value t_{1-a} such that 100 $(1-a)$% of the t-distribution for the nearest degrees of freedom (df).

Step 5: If $t \leq -t_{1-a}$, then conclude that 90 percent reduction has been attained. If, however, $t > -t_{1-a}$, then you cannot conclude that 90-percent reduction has been attained.

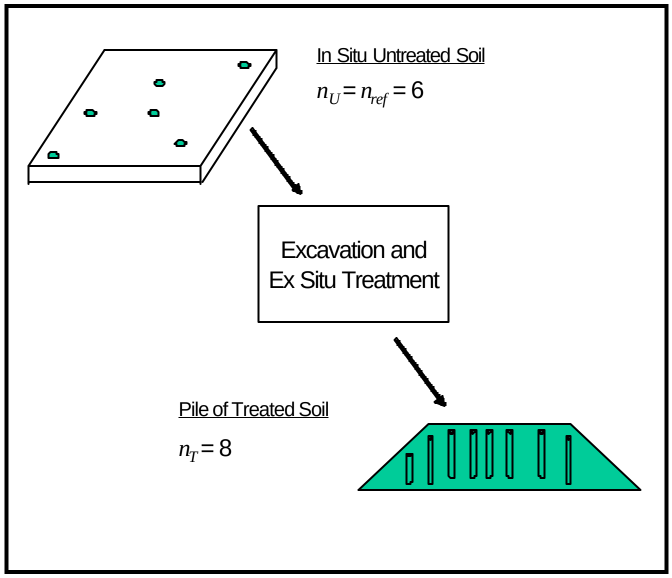

Figure 5. Sample collection strategy for measuring attainment of 90-percent reduction using Welch's t-Test.

Hypothetical Example: Using Welch's t-Test to Evaluate Attainment of the 90-Percent Reduction Standard

Using data obtained from a site characterization, the site operator delineates a unit of hazardous soil known to have contaminant concentrations greater than 10 x UTS within the defined volume (Figure 5). To determine the mean and the variance of the concentration of the constituent of concern, the operator obtains six random samples from the unit of untreated soil (note that the samples also could be obtained from a pile of soil that is the complete excavation of the unit). The unit of soil is then treated using an *ex situ* soil washing technology.

After treatment, a new set of eight random samples is obtained and analyzed. The sample analysis results are as follows:

Untreated Soil (ppm) (U_i): 400, 540, 260, 160, 370, 80

Reference (ppm), 0.1 (U_i): 40, 54, 26, 16, 37, 8

Treated Soil (ppm) (T_i): 25, 12, 18, 8, 14, 6, 15, 21

Calculate Welch's t statistic to determine if the treatment process has attained the 90-percent reduction standard:

Step 1: Calculate the sample mean and the variance for the treated soil and the reference data set.

	Treated Soil	***Reference Data***
Number of Samples	$n_T = 8$	$n_{ref} = 6$
Sample Mean	$\bar{x}_T = 14.9$	$\bar{x}_{ref} = 30.2$
Sample Variance	$s_T^2 = 40.7$	$s_{ref}^2 = 284.3$

Step 2: Calculate Welch's t statistic as follows:

$$t = \left(\bar{x}_T - \bar{x}_{ref}\right) \Big/ \sqrt{\frac{s_T^2}{n_T} + \frac{s_{ref}^2}{n_{ref}}}$$

$$= \left(14.9 - 30.2\right) \Big/ \sqrt{\frac{40.7}{8} + \frac{284.3}{6}} = -2.11$$

Step 3: Calculate the approximate degrees of freedom as follows:

$$df = \left[\frac{s_T^2}{n_T} + \frac{s_{ref}^2}{n_{ref}}\right]^2 \Bigg/ \left[\frac{\left(s_T^2/n_T\right)^2}{n_T - 1} + \frac{\left(s_{ref}^2/n_{ref}\right)^2}{n_{ref} - 1}\right]$$

$$= \left[\frac{40.7}{8} + \frac{284.3}{6}\right]^2 \Bigg/ \left[\frac{\left(40.7/8\right)^2}{8 - 1} + \frac{\left(284.3/6\right)^2}{6 - 1}\right] = 6.1$$

Rounding df down to the nearest integer, we get 6.

Step 4: Using Table B-3 in Appendix B, we find the 90% critical value $-t_{1-a}$ for 6 degrees of freedom is -1.440.

Step 5: Welch's t-Statistic (-2.11) is less than the critical value of -1.440 therefore we can conclude, with 90-percent confidence, that the 90 percent reduction soil treatment standard has been attained for the given volume of soil.

2.3.3.3 Wilcoxon Rank-Sum Test

The Wilcoxon Rank Sum test is recommended for use where the underlying distribution of the data is unknown and cannot be readily identified or when a significant percentage (e.g., between 20 and 90%) of the combined data sets are reported as "nondetects." The assumptions for the

Wilcoxon Rank Sum test include the following: (1) both sets of samples are random samples from their respective populations, (2) in addition to independence within each sample, there must be mutual independence between the two samples (i.e., there can not be spatial correlation between observations and the samples must not be "paired"), and (3) the measurement scale is at least ordinal (i.e., you can rank the sample values from highest to lowest). In addition, it is assumed that the two populations are identical in shape (variance), however, the test is relatively robust with respect to violations of the equal variance assumption -– that is, the test is approximately correct even when the variances of the two populations differ.

Procedure

Let n_T represent the number of samples obtained from the "Treated" soil. Let n_U represent the number of samples obtained from the "Untreated" soil. Multiply each datum from the untreated soil by 0.1 such that each is reduced by 90 percent of its original value. The 90-percent reduced data, n_{ref}, will serve as the reference data set. If 90-percent reduction has been attained, then the concentrations in the treated soil should tend to be the same as or less than the concentrations in the reference data set.

Step 1: Combine all of the reference data (i.e., the untreated data reduced by 90-percent) and the treated soil data into a single data set. Sort and rank the combined values from smallest to largest, assigning the rank of 1 to the smallest result, the rank of 2 to the next smallest result, and so on. Keep track of which samples belong to the reference population and the treated population. If two or more measurements are the same, assign all of them a rank equal to the average of the ranks they occupy.

Step 2: Calculate R as the sum of the ranks of the data from the treated soil, then calculate

$$W = R - \frac{n_T(n_T + 1)}{2}$$ **Equation 3**

Step 3: Use Table B-4 in Appendix B to find the critical value w_a for the appropriate values of n_T, n_{ref}, and a. If $W < w_a$, reject the null hypothesis and conclude that 90-percent reduction is attained (i.e., conclude that the concentrations in the treated soil tend to be the same as or less than the concentration found in the reference soil data set). Otherwise, you cannot conclude that 90-percent reduction was attained.

Hypothetical Example: Using the Wilcoxon Rank Sum Test to Evaluate Attainment of the 90-Percent Reduction Standard

Using data obtained from a site characterization, the site operator delineates a unit of soil known to have contaminant concentrations no less that 10 x UTS within the defined volume (Figure 6). The operator obtains $n_U = n_{ref} = 8$ random samples from the unit of untreated soil (note that the samples also could be obtained from a pile of soil that is the complete excavation of the unit of soil). The unit of soil is then treated using an *ex situ* soil washing technology.

After treatment, a new set of $n_T = 7$ samples is obtained from the treated soil and analyzed. A table of the data is created denoting data representing the untreated soil, the reference data, and the treated soil.

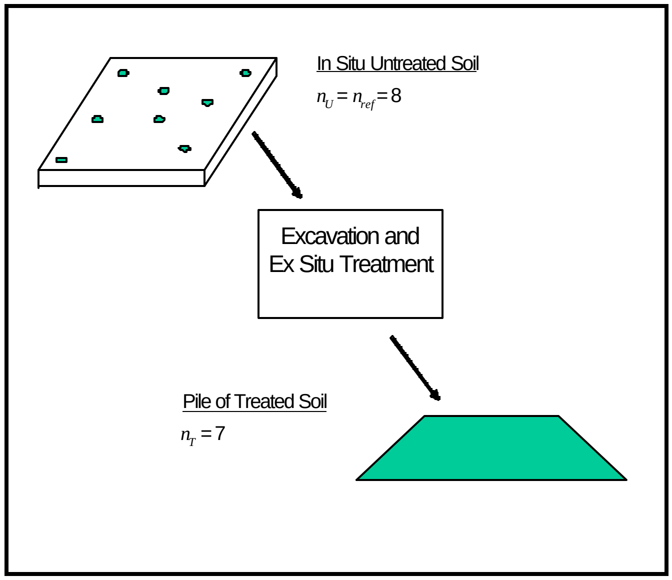

Figure 6. Sample collection strategy for measuring attainment of 90-percent reduction using the Wilcoxon Rank Sum test.

Calculate the Wilcoxon Rank-Sum Test to determine if the treatment process has attained the 90 percent reduction standard:

Treated Soil (ppm) (T_i): 17, 23, 26, 5, 13, 13, 12

Untreated Soil (ppm) (U_i): 160, 200, 50, 40, 80, 100, 70, 30

Reference (ppm), 0.1 (U_i): 16, 20, 5, 4, 8, 10, 7, 3

Step 1: Combine the data for the *treated* soil and the data from the *reference* data set and sort and rank the values (the treated soil data are denoted by *):

Data:	3	4	5	5*	7	8	10	12*	13*	13*	16	17*	20	23*	26*
Rank:	1	2	3.5	3.5*	5	6	7	8*	9.5*	9.5*	11	12*	13	14*	15*

Note that the data occupying ranks 3 and 4 are “ties” (both value are 5). Therefore, we assign both values a rank equal to the average of the ranks they occupy (i.e., (3+4)/2=3.5). The same situation occurs at ranks 9 and 10 and both values are assigned a rank equal to the average of 9 + 10 (i.e., (9+10)/2=9.5).

Step 2: Calculate R as the sum of the ranks of the data from the treated soil:

R = 3.5 + 8 + 9.5 + 9.5 + 12 + 14 + 15 = 71.5

Then calculate W :

$$W = R - \frac{n_T(n_T + 1)}{2} = 71.5 - \frac{7(7+1)}{2} = 43.5$$

Step 3: Using Table 4 in Appendix B, the critical value $(w_{0.10})$ is found to be 17.

Because 43.5 > 17, do not reject the null hypothesis. In other words, we *cannot* conclude with 90-percent confidence that 90-percent reduction has been attained.

3. WHAT ARE THE NOTIFICATION, CERTIFICATION, AND RECORDKEEPING REQUIREMENTS FOR CONTAMINATED SOILS?

Contaminated soil subject to the land disposal restrictions must comply with the same recordkeeping requirements as other wastes subject to LDR. The generator of a hazardous soil must comply with the applicable provisions of 40 CFR 268.7(a). This would include a certification statement sent with the initial waste shipment and retained in the generator's files. The statement must certify that the soil [does/does not] contain a listed hazardous waste and [does/does not] exhibit a hazardous characteristic. Note that certifications accompanying waste shipments need only be provided for hazardous soils shipped off site. For hazardous soils remaining on site, this certification is not required.

Once a characteristic soil is treated to remove its hazardous characteristic, it no longer must be disposed in a hazardous waste (Subtitle C) land disposal unit. However, it could require further treatment if the soils were prohibited from land disposal at the point of generation and the underlying hazardous constituents remain present at concentrations greater than 10 x UTS after treatment to remove the characteristic. Special notification requirements for treated characteristic wastes (found at 40 CFR 268.9(d)) allow generators to send a one-time notice to the EPA region or their state agency instead of the Subtitle D disposal facility. This notification must be placed in the generator's files and include the following information:

- the name and address of the receiving facility; and
- a description of the waste including hazardous waste codes, treatability groups and subcategories, and any underlying hazardous constituents

The generator also must prepare a certification statement in accordance with § 268.7(b)(5) to accompany the notification. Both the certification and notification statements must be updated if there are any changes to the waste or receiving facility. Such changes must be submitted to the appropriate EPA region or state agency on an annual basis.

Facilities should also be able to demonstrate how the alternative soil treatment standards have been met. As a result, you should keep records documenting the following:

- The rationale for arriving at a manageable list of monitoring constituents for the hazardous soil to be treated,
- The rationale for sampling protocols or methodology for collecting representative samples of hazardous constituents of concern in the contaminated soil (e.g., QAPP, sampling plan, and spatial analyses to delineate volumes of soil with constituent concentrations greater than 10 x UTS soils),
- The methodology for determining attainment of the standard of 90-percent reduction or 10 x UTS, and
- Treatment data used to verify attainment of 90-percent reduction or 10 x UTS.

References

Note: Due to the dynamic nature of the Internet, the location and content of web sites given in this document may change over time. If you find a broken link to an EPA document, use the search engine at http://www.epa.gov/ to find the document. Links to web sites outside the U.S. EPA web site are listed for the convenience of the user, and the U.S. EPA does not exercise any editorial control over the information you may find at these external web sites.

ASTM D 4220-95. 1995. *Standard Practices for Preserving and Transporting Soil Samples*. West Conshohocken, PA. http://www.astm.org

ASTM D 6311-98. 1998a. *Standard Guide for Generation of Environmental Data Related to Waste Management Activities: Selection and Optimization of Sampling Design*. West Conshohocken, PA.

ASTM D 4547-98. 1998b. *Standard Guide for Sampling Waste and Soils for Volatile Organics*. West Conshohocken, PA.

ASTM D 6169-98. 1998c. *Standard Guide for Selection of Soil and Rock Sampling Devices Used With Drill Rigs for Environmental Investigations*. West Conshohocken, PA.

ASTM D 6418-99. 1999. *Standard Practice for Using the Disposable EnCore™ Sampler for Sampling and Storing Soil for Volatile Organic Analysis*. West Conshohocken, PA.

Davidson, J.R., Jr. 1995. *ELIPGRID-PC: Hot Spot Probability Calculations*. Battelle/Pacific Northwest National Laboratory, Richland, WA. Software and documentation available at http://terrassa.pnl.gov:2080/DQO/software/elipgrid.html

Gilbert, R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring*. New York: Van Nostrand Reinhold.

Guttman, I. 1970. *Statistical Tolerance Regions: Classical and Bayesian*. London: Charles Griffin & Co.

Hahn, G.J. and W.Q. Meeker. 1991. *Statistical Intervals: A Guide for Practitioners*. New York: John Wiley & Sons, Inc.

Isaaks, E.H. and R.M. Srivastava. 1989. *An Introduction to Applied Geostatistics*. New York: Oxford University Press.

Journel, A.G. 1988. "Non-parametric Geostatistics for Risk and Additional Sampling Assessment." *Principles of Environmental Sampling*. L.H. Keith, ed. Washington, DC: American Chemical Society.

Mason, B.J. 1992. *Preparation of Soil Sampling Protocols: Sampling Techniques and Strategies*. EPA/600/R-92/128. NTIS PB 92-220532. U.S. Environmental Protection Agency, Office of Research and Development. Las Vegas, NV.

http://www.epa.gov:80/swerust1/cat/mason.pdf

Myers, J.C. 1997. *Geostatistical Error Management: Quantifying Uncertainty for Environmental Sampling and Mapping.* New York: Van Nostrand Reinhold.

Rosenbaum, S. 1954. Tables for a nonparametric test of location. Annals of Mathematical Statistics. 25:146–150.

US Army Corp of Engineers (USACE). 1997. *Engineering and Design - Practical Aspects of Applying Geostatistics at Hazardous, Toxic, and Radioactive Waste Sites.* Publication Number ETL 1110-1-175. http://www.usace.army.mil/usace-docs/eng-tech-ltrs/etl1110-1-175/toc.html

USEPA. 1988. *Methodology for Developing Best Demonstrated Available (BDAT) Treatment Standards*. EPA/530-SW-89-017L. Treatment Technology Section, Office of Solid Waste. Washington, DC.

USEPA. 1989. *Methods for Evaluating the Attainment of Cleanup Standards, Volume 1: Soils and Solid Media.* EPA 230/02-89-042. NTIS PB89-234959. Statistical Policy Branch, Office of Policy, Planning, and Evaluation. Washington, DC. http://www.epa.gov/swertio1/download/stats/vol1soils.pdf

USEPA. 1991a. *GEO-EAS 1.2.1 User's Guide*. EPA/600/8-91/008. Environmental Monitoring Systems Laboratory, Las Vegas, NV.

USEPA. 1991b. *Description and Sampling of Contaminated Soils–A Field Pocket Guide*. EPA/625/12-91/002. Center for Environmental Research Information. Cincinnati, OH.

USEPA. 1991c. *Final Best Demonstrated Available Technology (BDAT) Background Document for Quality Assurance/Quality Control Procedures and Methodology*. NTIS PB95-230926. Office of Solid Waste. Washington, DC.

USEPA. 1992. *Methods for Evaluating the Attainment of Cleanup Standards*. *Volume 2: Ground Water*. EPA 230-R-92-14. Office of Policy, Planning, and Evaluation. Washington, DC. http://www.epa.gov/swertio1/download/stats/vol2gw.pdf

USEPA. 1994a. *Guidance for the Data Quality Objectives Process, EPA QA/G-4* (Revised, August 2000). EPA/600/R-96/055. Office of Environmental Information. Quality Staff. Washington, DC. http://www.epa.gov/quality1/qa_docs.html

USEPA. 1994b. *Waste Analysis at Facilities That Generate, Treat, Store, and Dispose of Hazardous Wastes, a Guidance Manual.* OSWER 9938.4-03. http://www.epa.gov/epaoswer/hazwaste/ldr/guidance.htm Office of Solid Waste and Emergency Response. Washington, DC.

USEPA. 1996. *Determination of Background Concentrations of Inorganics in Soils and Sediment at Hazardous Waste Sites*. EPA/540/S-96/500. Office of Research and Development and Office of Solid Waste and Emergency Response http://www.epa.gov/nerlesd1/pdf/engin.pdf

USEPA. 1997. *Data Quality Assessment Statistical Toolbox (DataQUEST)*, *EPA QA/G-9D*. User's Guide and Software. http://www.epa.gov/quality/dqa.html. EPA/600/R-96/085. Office of Research and Development. Las Vegas.

USEPA. 1998a. *Management of Remediation Waste Under RCRA*. EPA/530-F-98-026. Office of Solid Waste and Emergency Response (5305W). Washington, DC. http://www.epa.gov/epaoswer/hazwaste/ca/resource/guidance.htm#Remediation Waste

USEPA. 1998b. *EPA Guidance For Quality Assurance Project Plans, EPA QA/G-5*. EPA/600/R-98/018. Office of Research and Development, Washington, DC. http://www.epa.gov/quality/qa_docs.html

USEPA. 1998c. *Guidance for Data Quality Assessment, EPA QA/G-9* (QA00 Update, revised July 2000). EPA/600/R-96/084. Final. Office of Environmental Information, Quality Staff. Washington, DC. http://www.epa.gov/quality/qa_docs.html

USEPA. 1998d. "Phase IV Land Disposal Restrictions Rule – Clarification of Effective Dates." Memorandum from Elizabeth A. Cotsworth, Acting Director Office of Solid Waste, to RCRA Senior Policy Advisors, Regions I - X. October 19, 1998. http://www.epa.gov/epaoswer/hazwaste/ldr/ldrmetal/memos/effectiv.pdf

USEPA. 2000a. *Data Quality Objectives Process for Hazardous Waste Site Investigations EPA QA/G-4HW Final*. EPA/600/R-00/007. Office of Environmental Information. January 2000. http://www.epa.gov/quality1/qa_docs.html

USEPA. 2000b. *Guidance for Choosing a Sampling Design for Environmental Data Collection, Use in the Development of a Quality Assurance Project Plan. EPA QA/G-5S.* Quality Staff, Office of Environmental Information. Washington, D.C. Peer Review Draft. August 2000. http://www.epa.gov/quality1/qa_docs.html

APPENDIX A:
“MANAGEMENT OF REMEDIATION WASTE UNDER RCRA”

October 14, 1998

MEMORANDUM

SUBJECT: Management of Remediation Waste Under RCRA

TO: RCRA/CERCLA Senior Policy Managers
Regional Counsels

FROM: Timothy Fields, Jr., Acting Assistant Administrator for
Solid Waste and Emergency Response ***/signed/***

Steven A. Herman, Assistant Administrator for
Enforcement and Compliance Assurance ***/signed/***

Rapid clean up of RCRA corrective action facilities and Superfund sites is one of the Agency's highest priorities. In this context, we often receive questions about management of remediation waste under the Resource Conservation and Recovery Act (RCRA). To assist you in successfully implementing RCRA requirements for remediation waste, this memorandum consolidates existing guidance on the RCRA regulations and policies that most often affect remediation waste management. We encourage you to work with the regulations, policies and approaches outlined in this memorandum to achieve our cleanup goals as quickly and efficiently as possible.

Note that not all remediation wastes are subject to RCRA Subtitle C hazardous waste requirements. As with any other solid waste, remediation wastes are subject to RCRA Subtitle C only if they are listed or identified hazardous waste. Environmental media are subject to RCRA Subtitle C only if they contain listed hazardous waste, or exhibit a characteristic of hazardous waste. These distinctions are discussed more completely below.

The information in this memo is divided into three categories: information on regulations and policies that apply to all remediation waste; information on regulations and policies that apply only to contaminated media; and, information on regulations and policies that apply only to contaminated debris. Most of the references cited in this memo are available over the Internet. The Federal Register notices published after 1994 are available at www.access.gpo.gov/nara; the guidance memos and other EPA documents are available at www.epa.gov/correctiveaction. Federal Register notices and other documents are also available through the RCRA/CERCLA hotline: in Washington D.C., call (703) 412-9810; outside Washington D.C., call (800) 424-9346; and hearing impaired call (800) 553-7672. The hotline's hours are Monday - Friday, excluding

Federal holidays, 8:00 - 5:00, eastern standard time. Many EPA guidance memos and other documents may also be obtained through the RCRA/CERCLA hotline fax-back system. To obtain a list of documents available over the fax-back system, and fax-back system code numbers, call the RCRA/CERCLA hotline at the numbers listed above.

I hope this information will assist you as you continue to make protective, inclusive, and efficient cleanup decisions. If you have additional questions or require more information, please contact Robert Hall or Greg Madden, of our staffs, on (703) 308-8484 or (202) 564-4229 respectively.

Regulations and Policies that Apply to All Remediation Wastes

Area of Contamination Policy. In what is typically referred to as the area of contamination (AOC) policy, EPA interprets RCRA to allow certain discrete areas of generally dispersed contamination to be considered RCRA units (usually landfills). Because an AOC is equated to a RCRA land-based unit, consolidation and *in situ* treatment of hazardous waste within the AOC do not create a new point of hazardous waste generation for purposes of RCRA. This interpretation allows wastes to be consolidated or treated *in situ* within an AOC without triggering land disposal restrictions or minimum technology requirements. The AOC interpretation may be applied to any hazardous remediation waste (including non-media wastes) that is in or on the land. Note that the AOC policy only covers consolidation and other in situ waste management techniques carried out within an AOC. For *ex situ* waste management or transfer of wastes from one area of contamination to another, see discussion of corrective action management units, below.

The AOC policy was first articulated in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). See 53 FR 51444 for detailed discussion in proposed NCP preamble; 55 FR 8758-8760, March 8, 1990 for final NCP preamble discussion. See also, most recent EPA guidance, March 13, 1996 EPA memo, “Use of the Area of Contamination Concept During RCRA Cleanups.”

Corrective Action Management Units (CAMUs). The corrective action management unit rule created a new type of RCRA unit – a Corrective Action Management Unit or CAMU -- specifically intended for treatment, storage and disposal of hazardous remediation waste. Under the CAMU rule, EPA and authorized states may develop and impose site-specific design, operating, closure and post-closure requirements for CAMUs in lieu of MTRs for land-based units. Although there is a strong preference for use of CAMUs to facilitate treatment, remediation waste placed in approved CAMUs does not have to meet LDR treatment standards.

The main differences between CAMUs and the AOC policy (discussed above) are that, when a CAMU is used, waste may be treated *ex situ* and then placed in a CAMU, CAMUs may be located in uncontaminated areas at a facility, and wastes may be consolidated into CAMUs from areas that are not contiguously contaminated. None of these activities are allowed under the AOC policy, which, as discussed above, covers only consolidation and *in situ* management techniques carried out within an AOC.

CAMUs must be approved by EPA or an authorized state and designated in a permit or corrective action order. In certain circumstances, EPA and states (including states that are not authorized for the CAMU regulations) may use other mechanisms to approve CAMUs. See, 58 FR 8677, February 16, 1993; appropriate use of RCRA Section 7003 orders and comparable state orders is discussed below and in an EPA guidance memo from J. Winston Porter to EPA Regional Administrators, "RCRA Permit Requirements for State Superfund Actions," November 16, 1987, OSWER Directive 9522.00-2. In addition, as appropriate, CAMUs may be approved by EPA as an applicable or relevant and appropriate requirement during a CERCLA cleanup using a record of decision or by an authorized state during a state cleanup using a CERCLA-like authority and a similar state document. See, e.g., 58 FR 8679, February 16, 1993. An opportunity for the public to review and comment on tentative CAMU approvals is required by the regulations when CAMUs are approved using permitting procedures and as a matter of EPA policy when CAMUs are approved using orders. EPA recommends that, whenever possible, remediation project managers combine this public participation with other public involvement activities that are typically part of remediation. For example, public notice of tentative approval of a CAMU could be combined with public notice of a proposed plan under CERCLA.

The CAMU rule is currently subject to litigation; however, the suit has been stayed pending promulgation of the final HWIR-Media regulations. Although EPA proposed to withdraw CAMUs as part of the HWIR-Media proposal, the Agency now intends to retain the CAMU rule. The Agency encourages approval of CAMUs when they are appropriate given the site-specific conditions.

The CAMU regulations are at 40 CFR 264.552, promulgated February 16, 1993 (58 FR 8658). The differences between CAMUs and AOCs are discussed in more detail in the March 13, 1996 EPA guidance memo, "Use of the Area of Contamination Concept During RCRA Cleanups."

Corrective Action Temporary Units (TUs). Temporary units, like corrective action management units, are RCRA units established specifically for management of hazardous remediation waste. The regulations for temporary units (TUs) were promulgated at the same time as the regulations for corrective action management units. The CAMU regulations established land-based units for treatment, storage and disposal of remediation waste; the TU regulations established non-land based units for treatment and storage of hazardous remediation waste. Under the TU regulations, EPA and authorized states may modify existing MTR design, operating and closure standards for temporary tank and container units used to treat and store hazardous remediation waste. Temporary units may operate for one year, with an opportunity for a one year extension.

Like CAMUs, temporary units must be approved by EPA or an authorized state and designated in a permit or corrective action order. In certain circumstances, EPA and states (including states that are not authorized for the TU regulations) may use other mechanisms to approve TUs. See, 58 FR 8677, February 16, 1993; appropriate use of RCRA Section 7003 orders and comparable state orders is discussed below and in an EPA guidance memo from J. Winston Porter to EPA Regional Administrators, "RCRA Permit Requirements for State Superfund Actions," November 16, 1987, OSWER Directive 9522.00-2. In addition, as appropriate, TUs may be approved by EPA as an applicable or relevant and appropriate requirement during a CERCLA cleanup using a record of decision or by an authorized state during a state cleanup using a CERCLA-like authority and a similar state document. Placement of waste in tanks or containers, including temporary units, is not considered land disposal. Therefore, waste does not have to be treated to meet LDR treatment standards prior to being placed in a TU. Of course, LDRs must be met if hazardous remediation wastes are eventually land disposed, for example, after they are removed from the TU; however, if treatment in a TU results in constituent concentrations that comply with applicable land disposal restriction treatment standards, no further treatment prior to land disposal is required as a condition of the LDRs.

An opportunity for the public to review and comment on tentative TU approvals is required by the regulations when TUs are approved using permitting procedures and as a matter of EPA policy when TUs are approved using orders. As with CAMUs, EPA recommends that whenever possible, remediation project managers combine this public participation with other public involvement activities that are typically part of remediation. For example, public notice of tentative approval of a temporary unit could be combined with public notice of a proposed plan under CERCLA.

The TU regulations are at 40 CFR 264.553, promulgated February 16, 1993 (58 FR 8658).

Determination Of When Contamination is Caused by Listed Hazardous Waste. Where a facility owner/operator makes a good faith effort to determine if a material is a listed hazardous waste but cannot make such a determination because documentation regarding a source of contamination, contaminant, or waste is unavailable or inconclusive, EPA has stated that one may assume the source, contaminant or waste is not listed hazardous waste and, therefore, provided the material in question does not exhibit a characteristic of hazardous waste, RCRA requirements do not apply. This approach was first articulated in the Proposed NCP preamble which notes that it is often necessary to know the source of a waste (or contaminant) to determine whether a waste is a listed hazardous waste under RCRA[1] and also notes that, "at many CERCLA sites no information exists on the source of the wastes." The proposed NCP preamble goes on to recommend that the lead agency use available site information such as manifests, storage records and vouchers in an effort to ascertain the sources of wastes or contaminants, but that when this documentation is not available or inconclusive the lead agency may assume that the wastes (or contaminants) are not listed RCRA hazardous wastes. This approach was confirmed in the final NCP preamble. See, 53 FR 51444, December 21, 1988 for proposed NCP preamble discussion; 55 FR 8758, March 13, 1990 for final NCP preamble discussion.

This approach was also discussed in the HWIR-Media proposal preamble, 61 FR 18805, April 29, 1996, where it was expanded to also cover dates of waste disposal – i.e., if, after a good faith effort to determine dates of disposal a facility owner/operator is unable to make such a determination because documentation of dates of disposal is unavailable or inconclusive, one may

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[1] Listing determinations are often particularly difficult in the remedial context because the listings are generally identified by the sources of the hazardous wastes rather than the concentrations of various hazardous constituents; therefore, analytical testing alone, without information on a waste's source, will not generally produce information that will conclusively indicate whether a given waste is a listed hazardous waste.

assume disposal occurred prior to the effective date of applicable land disposal restrictions. This is important because, if hazardous waste was originally disposed of before the effective dates of applicable land disposal restrictions and media contaminated by the waste are determined not to contain hazardous waste when first generated (i.e., removed from the land, or area of contamination), the media are not subject to RCRA requirements, including LDRs. See the discussion of the contained-in policy, below.

Site Specific LDR Treatment Variances. The regulations for site-specific LDR treatment variances allow EPA and authorized states to establish a site-specific LDR treatment standard on a case-by-case basis when a nationally applicable treatment standard is unachieveable or inappropriate. Public notice and a reasonable opportunity for public comment must be provided before granting or denying a site-specific LDR treatment variance. EPA recommends that remediation project managers combine this public involvement with other public involvement activities that are typically part of remediation. Regulations governing site-specific LDR treatment variances are at 40 CFR 268.44(h), promulgated August 17, 1988 (53 FR 31199) and clarified December 5, 1997 (62 FR 64504). The most recent EPA guidance on site-specific LDR treatment variances, which includes information on establishing alternative LDR treatment standards, is in the January 8, 1997 guidance memo, "Use of Site-Specific Land Disposal Restriction Treatability Variances Under 40 CFR 268.44(h) During Cleanups."

In 1996, EPA revised its policy on state authorization for site-specific LDR treatment variances and began encouraging states to become authorized to approve variances. See, HWIR-Media proposal, 61 FR 18828 (April 29, 1996).

On May 26, 1998, EPA promulgated additional site-specific land disposal restriction treatment variance opportunities specific to hazardous contaminated soil. These opportunities are discussed below.

Treatability Studies Exemption. The term "treatability study"as defined at 40 CFR 260.10 refers to a study in which a hazardous waste is subjected to a treatment process to determine: (1) whether the waste is amenable to the treatment process; (2) what pretreatment (if any) is required; (3) the optimal process conditions needed to achieve the desired treatment; (4) the efficiency of a treatment process for a specific waste or wastes; or, (5) the characteristics and volumes of residuals from a particular treatment process. Under regulations at 40 CFR 261.4(e) and (f), hazardous wastes managed during a treatability study are exempt from many RCRA Subtitle C requirements. The regulations limit the amount of waste that may be managed under an exempt treatability study to, generally, 1000 kg of hazardous waste or 1 kg of acutely hazardous waste per study. For contaminated environmental media, the volume limit is, generally, 10,000 kilograms of media that contain non-acutely hazardous waste and 2,500 kilograms of media that contain acutely hazardous waste per study. There are also limits on the types and lengths of studies that may be conducted under the exemption and record keeping and reporting requirements. Regulations governing treatability studies are at 40 CFR 261.4(e) and (f), associated preamble discussions at 52 FR 27290 (July 19, 1988) and 59 FR 8362 (February 18, 1994).

Exemption for Ninety Day Accumulation. Management of hazardous waste in tanks, containers, drip pads and containment buildings does not constitute land disposal. In addition, EPA has provided an exemption for generators of hazardous waste which allows them to accumulate (i.e., treat or store) hazardous waste at the site of generation in tanks, containers, drip pads or containment buildings for up to ninety days without RCRA interim status or a RCRA permit. Accumulation units must meet applicable design, operating, closure and post-closure standards. Because putting hazardous waste in a tank, container, drip pad or containment building is not considered land disposal, LDR treatment standards do not have to be met before putting waste in such units. LDRs must be met if hazardous wastes are eventually land disposed, for example, after they are removed from the accumulation unit; however, if treatment in an accumulation unit results in constituent concentrations that comply with applicable land disposal restriction treatment standards, no further treatment prior to land disposal is required as a condition of the LDRs. The exemption for ninety-day accumulation is found in regulations at 40 CFR 262.34; associated preamble discussion is at 51 FR at 10168 (March 24, 1986).

Permit Waivers. Under CERCLA Section 121(e), no Federal, state or local permit is required for on-site CERCLA response actions. EPA has interpreted CERCLA Section 121(e) to waive the requirement to obtain a permit and associated administrative and procedural requirements of permits, but not the substantive requirements that would be applied through permits.[2]

In addition, on a case-by-case basis, where there may be an imminent and substantial endangerment to human health or the environment, EPA has broad authority to require corrective action and other appropriate activities under RCRA Section 7003. Under RCRA Section 7003, EPA has the ability to waive both the requirement to obtain a permit and the substantive requirements that would be imposed through permits. When EPA uses RCRA Section 7003, however, the Agency seldom uses RCRA Section 7003 to waive substantive requirements. In rare situations where substantive requirements are waived, the Agency would impose alternative requirements (e.g, waste treatment or storage requirements) as necessary to ensure protection of human health and the environment. EPA may issue RCRA Section 7003 orders at, among other sites, facilities that have been issued RCRA permits and facilities that are authorized to operate under RCRA interim status. In discussing the use of 7003 orders, where other permit authorities are available to abate potential endangerments, EPA generally encourages use of those other permit authorities (e.g., 3005(c)(3) omnibus permitting authority) rather than RCRA Section 7003. Similarly, if RCRA Section 3008(h) or RCRA Section 3013 authority is available, EPA generally encourages use of these authorities rather than RCRA Section 7003. If permit authorities or non-RCRA Section 7003 enforcement authorities are inadequate, cannot be used to address the potential endangerment in a timely manner, or are otherwise inappropriate for the potential endangerment at issue, use of RCRA Section 7003 should be considered. See, "Guidance on the Use of Section 7003 of RCRA," U.S. EPA, Office of Enforcement and Compliance Assurance, October 1997.

In 1987, EPA issued guidance indicating that RCRA-authorized states with state waiver authorities comparable to CERCLA 121(e) or RCRA Section 7003 could use those state waiver authorities to waive RCRA requirements as long as the state did so in a manner no less stringent than that allowed under the corresponding Federal authorities. These waivers are most often

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[2] Note that, under certain circumstances, substantive requirements may be waived using CERCLA. See the ARAR waiver provisions at 40 CFR 300.430(f)(1)(ii)(C).

used, as are the Federal waivers, to obviate the need to obtain a RCRA permit, rather than to eliminate substantive requirements. See, EPA guidance memo from J. Winston Porter to EPA Regional Administrators, “RCRA Permit Requirements for State Superfund Actions,” November 16, 1987, OSWER Directive 9522.00-2.

Exemption from 40 CFR Part 264 Requirements for People Engaged in the Immediate Phase of a Spill Response. Regulations at 40 CFR 264.1(g)(8) provide that people engaged in treatment or containment activities are not subject to the requirements of 40 CFR part 264 if the activities are carried out during immediate response to: (1) a discharge of hazardous waste; (2) an imminent and substantial threat of a discharge of hazardous waste; (3) a discharge of a materials which, when discharged, becomes a hazardous waste; or, (4) an immediate threat to human health, public safety, property or the environment from the known or suspected presence of military munitions, other explosive material, or an explosive device. This means that, during the immediate phase of a spill response, hazardous waste management activities do not require hazardous waste permits (or interim status) and hazardous waste management units used during immediate response actions are not subject to RCRA design, operating, closure or post-closure requirements.

Of course, if hazardous waste treatment activities or other hazardous waste management activities continue after the immediate phase of a spill response is over, all applicable hazardous waste management and permitting requirements would apply. In addition, if spills occur at a facility that is already regulated under 40 CFR part 264, the facility owner/operator must continue to comply with all applicable requirements of 40 CFR Part 264 Subparts C (preparedness and prevention) and D (contingency plan and emergency procedures). See regulations at 40 CFR 260.1(g) and associated preamble discussion at 45 FR 76626 (November 19, 1980). See also, Sept. 29, 1986 memo from J. Winston Porter (EPA Assistant Administrator) to Fred Hansen interpreting the 40 CFR 264.1(g) regulations.

Changes During Interim Status to Comply with Corrective Action Requirements. Under regulations at 40 CFR 270.72(a)(5), an owner or operator of an interim status facility may make changes to provide for treatment, storage and disposal of remediation wastes in accordance with an interim status corrective action order issued by EPA under RCRA Section 3008(h) or other Federal authority, by an authorized state under comparable state authority, or by a court in a judicial action brought by EPA or an authorized state. These changes are limited to treatment, storage and disposal of remediation waste managed as a result of corrective action for releases at the facility in question; however, they are exempt from the reconstruction ban under 40 CFR 270.72(b). Under this provision, for example, EPA could approve a corrective action management unit for treatment of remediation waste using a 3008(h) order (or an authorized state could approve a CAMU using a similar state authority), even if that unit would otherwise amount to “reconstruction.” Of course, units added at interim status facilities in accordance with this provision must meet all applicable unit requirements; for example, in the case of a CAMU, the CAMU requirements apply. See, regulations at 40 CFR 270.72(a)(5) promulgated March 7, 1989 and associated preamble discussion at 54 FR 9599.

Emergency Permits. In the event of an imminent and substantial endangerment to human health or the environment, EPA, or an authorized state, may issue a temporary emergency permit for treatment, storage or disposal of hazardous waste. Emergency permits may allow treatment, storage or disposal of hazardous waste at a non-permitted facility or at a permitted facility for waste not covered by the permit. Emergency permits may be oral or written. (If oral, they must be followed within five days by a written emergency permit.) Emergency permits must specify the hazardous wastes to be received and managed and the manner and location of their treatment, storage and disposal. Emergency permits may apply for up to ninety days, but may be terminated at any point if EPA, or an authorized state, determines that termination is appropriate to protect human health or the environment. Emergency permits must be accompanied by a public notice that meets the requirements of 40 CFR 124.10(b), including the name and address of the office approving the emergency permit, the name and location of the hazardous waste treatment, storage or disposal facility, a brief description of the wastes involved, the actions authorized and the reason for the authorization, and the duration of the emergency permit.

Emergency permits are exempt from all other requirements of 40 CFR part 270 and part 124; however, to the extent possible and not inconsistent with the emergency situation, they must incorporate all otherwise applicable requirements of 40 CFR part 270 and parts 264 and 266.

See, regulations at 40 CFR 270.61, originally promulgated as 40 CFR 122.27 on May 19, 1987 (45 FR 33326). EPA has also written a number of letters interpreting the emergency permit regulations, see, for example, November 3, 1992 letter to Mark Hansen, Environmental Products and Services Inc., from Sylvia Lowrance, Director Office of Solid Waste (available in the RCRA Permit Policy Compendium).

Temporary Authorizations at Permitted Facilities. Under regulations at 40 CFR 270.42(e), EPA, or an authorized state, may temporarily authorize a permittee for an activity that would be the subject of a class two or three permit modification in order to, among other things, facilitate timely implementation of closure or corrective action activities. Activities approved using a temporary authorization must comply with applicable requirements of 40 CFR part 264. Temporary authorizations are limited to 180 days, with an opportunity for an extension of 180 additional days. To obtain an extension of a temporary authorization, a permittee must have requested a class two or three permit modification for the activity covered in the temporary authorization. Public notification of temporary authorizations is accomplished by the permittee sending a notice about the temporary authorization to all persons on the facility mailing list and to appropriate state and local governments. See regulations at 40 CFR 270.42, promulgated on September 28, 1988, and associated preamble at 53 FR 37919.

Regulations and Policies that Apply to Contaminated Environmental Media Only

Contained-in policy. Contaminated environmental media, of itself, is not hazardous waste and, generally, is not subject to regulation under RCRA. Contaminated environmental media can become subject to regulation under RCRA if they “contain” hazardous waste. As discussed more fully below, EPA generally considers contaminated environmental media to contain hazardous waste: (1) when they exhibit a characteristic of hazardous waste; or, (2) when they are contaminated with concentrations of hazardous constituents from listed hazardous waste that are above health-based levels.

If contaminated environmental media contain hazardous waste, they are subject to all applicable RCRA requirements until they no longer contain hazardous waste. EPA considers contaminated environmental media to no longer contain hazardous waste: (1) when they no longer exhibit a characteristic of hazardous waste; and (2) when concentrations of hazardous constituents from listed hazardous wastes are below health-based levels. Generally, contaminated environmental media that do not (or no longer) contain hazardous waste are not subject to any RCRA requirements; however, as discussed below, in some circumstances, contaminated environmental media that contained hazardous waste when first generated (i.e., first removed from the land, or area of contamination) remain subject to LDR treatment requirements even after they "no longer contain" hazardous waste.

The determination that any given volume of contaminated media does not contain hazardous waste is called a "contained-in determination." In the case of media that exhibit a characteristic of hazardous waste, the media are considered to "contain" hazardous waste for as long as they exhibit a characteristic. Once the characteristic is eliminated (e.g., through treatment), the media are no longer considered to "contain" hazardous waste. Since this determination can be made through relatively straightforward analytical testing, no formal "contained-in" determination by EPA or an authorized state is required. Just like determinations about whether waste has been adequately decharacterized, generators of contaminated media may make independent determinations as to whether the media exhibit a characteristic of hazardous waste. In the case of media that are contaminated by listed hazardous waste, current EPA guidance recommends that contained-in determinations be made based on direct exposure using a reasonable maximum exposure scenario and that conservative, health-based, standards be used to develop the site-specific health-based levels of hazardous constituents below which contaminated environmental media would be considered to no longer contain hazardous waste. Since this determination involves development of site-specific health-based levels, the approval of EPA or an authorized state is required.

In certain circumstances the, RCRA land disposal restrictions will continue to apply to contaminated media that has been determined not to contain hazardous waste. This is the case when contaminated media contain hazardous waste when they are first generated (i.e., removed from the land, or area of contamination) and are subsequently determined to no longer contain hazardous waste (e.g., after treatment), but still contain hazardous constituents at concentrations above land disposal restriction treatment standards. It is also the case when media are contaminated as a result of disposal of untreated (or insufficiently treated) listed hazardous waste after the effective date of an applicable LDR treatment requirement. Of course, if no land disposal will occur (e.g., the media will be legitimately recycled) the LDR treatment standards do not apply. In addition, contaminated environmental media determined not to contain any waste (i.e., it is just media, it does not contain solid or hazardous waste) would not be subject to any RCRA Subtitle C requirements, including the LDRs, regardless of the time of the "contained-in" determination.

The contained-in policy was first articulated in a November 13, 1986 EPA memorandum, "RCRA Regulatory Status of Contaminated Groundwater." It has been updated many times in Federal Register preambles, EPA memos and correspondence, see, e.g., 53 FR 31138, 31142, 31148 (Aug. 17, 1988), 57 FR 21450, 21453 (May 20, 1992), and detailed discussion in HWIR-Media proposal preamble, 61 FR 18795 (April 29, 1996). A detailed discussion of the continuing requirement that some soils which have been determined to no longer contain hazardous waste (but still contain solid waste) comply with land disposal treatment standards can be found in the

HWIR-Media proposal preamble, 61 FR 18804; the September 15, 1996 letter from Michael Shapiro (EPA OSW Director) to Peter C. Wright (Monsanto Company); and the preamble to the LDR Phase IV rule, 63 FR 28617 (May 26, 1998).

Note that the contained-in policy applies only to environmental media (soil, ground water, surface water and sediments) and debris. The contained-in policy for environmental media has not been codified. As discussed below, the contained-in policy for hazardous debris was codified in 1992.

RCRA Section 3020(b) Exemption for Reinjection of Contaminated Ground Water. Under RCRA Section 3020(a), disposal of hazardous waste into or above a formation that contains an underground source of drinking water is generally prohibited. RCRA Section 3020(b) provides an exception for underground injection carried out in connection with certain remediation activities. Under RCRA Section 3020(b), injection of contaminated ground water back into the aquifer from which it was withdrawn is allowed if: (1) such injection is conducted as part of a response action under Section 104 or 106 of CERCLA or a RCRA corrective action intended to clean up such contamination; (2) the contaminated ground water is treated to substantially reduce hazardous constituents prior to reinjection; and, (3) the response action or corrective action will, on completion, be sufficient to protect human health and the environment. Approval of reinjection under RCRA Section 3020(b) can be included in approval of other cleanup activities, for example, as part of approval of a RCRA Statement of Basis or CERCLA Record of Decision. See, RCRA Section 3020(b), established as part of the 1984 HSWA amendments. See also, OSWER Directive 9234.1-06, “Applicable of Land Disposal Restrictions to RCRA and CERCLA Ground Water Treatment Reinjection Superfund Management Review: Recommendation No. 26,” November 27, 1989.

LDR Treatment Standards for Contaminated Soils. On May 26, 1998, EPA promulgated land disposal restriction treatment standards specific to contaminated soils.[3] These treatment standards require that contaminated soils which will be land disposed be treated to reduce concentrations of hazardous constituents by 90 percent or meet hazardous constituent concentrations that are ten times the universal treatment standards (UTS), whichever is greater. (This is typically referred to as 90% capped by 10xUTS.) For contaminated soil that exhibits a characteristic of ignitable, reactive or corrosive hazardous waste, treatment must also eliminate the hazardous characteristic.

The soil treatment standards apply to all underlying hazardous constituents[4] reasonably expected to be present in any given volume of contaminated soil when such constituents are found at initial concentrations greater than ten times the UTS. For soil that exhibits a characteristic of toxic, ignitable, reactive or corrosive hazardous waste, treatment is also required for: (1) in the case of the toxicity characteristic, the characteristic constituent; and, (2) in the case of ignitability,

[3] This rule, which also addresses a number of non-soil issues, has been challenged by a number of parties. To date, the parties have filed non-binding statements of issues only; however, based on those statements, it appears that, with the exception of the requirement that PCBs be included as an underlying hazardous constituent which has been challenged for both soil and non-soil wastes, the soil treatment standards are not included in the challenges.

[4] Except fluoride, selenium, sulfides, vanadium and zinc.

reactivity or corrosivity, the characteristic property. Although treatment is required for each underlying hazardous constituent, it is not necessary to monitor soil for the entire list of underlying hazardous constituents. Generators of contaminated soil can reasonably apply knowledge of the likely contaminants present and use that knowledge to select appropriate underlying hazardous constituents, or classes of constituents, for monitoring. As with the LDR treatment standards for hazardous debris (discussed below), generators of contaminated soil may use either the applicable universal treatment standards for the contaminating hazardous waste or the soil treatment standards.

See, soil treatment standard regulations at 40 CFR 268.49, promulgated May 26, 1998 and associated preamble discussion at 63 FR 28602-28622.

Note that the soil treatment standards supersede the historic presumption that an LDR treatment variance is appropriate for contaminated soil. LDR treatment variances are still available for contaminated soil, provided the generator can show that an otherwise applicable treatment standard (i.e., the soil treatment standard) is unachieveable or inappropriate, as discussed above, or can show that a site-specific, risk-based treatment variance is proper, as discussed below.

Site-Specific, Risk-Based LDR Treatment Variance for Contaminated Soils. On May 26, 1998, EPA promulgated a new land disposal restriction treatment variance specific to contaminated soil. Under 40 CFR 268.44(h)(3), variances from otherwise applicable LDR treatment standards may be approved if it is determined that compliance with the treatment standards would result in treatment beyond the point at which short- and long-term threats to human health and the environment are minimized. This allows a site-specific, risk-based determination to supersede the technology-based LDR treatment standards under certain circumstances.

Alternative land disposal restriction treatment standards established through site specific, risk-based minimize threat variances should be within the range of values the Agency generally finds acceptable for risk-based cleanup levels. That is, for carcinogens, alternative treatment standards should ensure constituent concentrations that result in the total excess risk to an individual exposed over a lifetime generally falling within a range from 10^{-4} to 10^{-6}, using 10^{-6} as a point of departure and with a preference for achieving the more protective end of the risk range. For non-carcinogenic effects, alternative treatment standards should ensure constituent concentrations that an individual could be exposed to on a daily basis without appreciable risk of deleterious effect during a lifetime; in general, the hazard index should not exceed one (1). Constituent concentrations that achieve these levels should be calculated based on a reasonable maximum exposure scenario -- that is, based on an analysis of both the current and reasonable expected future land uses, with exposure parameters chosen based on a reasonable assessment of the maximum exposure that might occur; however, alternative LDR treatment standards may not be based on consideration of post-land disposal controls such as caps or other barriers.

See, regulations at 40 CFR 268.44(h)(4), promulgated May 26, 1998 and associated preamble discussion at 63 FR 28606-28608.

Regulations and Policies that Apply Only to Debris

LDR Treatment Standards for Contaminated Debris. In 1992, EPA established land disposal restriction treatment standards specific to hazardous contaminated debris. The debris-specific treatment standards established by these regulations are based on application of common extraction, destruction, and containment debris treatment technologies and are expressed as specific technologies rather than numeric criteria. As with the contaminated soil treatment standards discussed earlier, generators of hazardous contaminated debris may choose between meeting either the debris treatment standards or the numerical treatment standard promulgated for the contaminating hazardous waste. See, regulations at 40 CFR 268.45, promulgated August 18, 1992, and associated preamble discussion at 57 FR 37194 and 27221.

Interpretation that Debris Treated to the LDR Debris Treatment Standards Using Extraction or Destruction Technologies no Longer Contain Hazardous Waste. With the land disposal restriction treatment standards for hazardous contaminated debris, in 1992, EPA determined that hazardous debris treated to comply with the debris treatment standards using one of the identified extraction or destruction technologies would be considered no longer to contain hazardous waste and would, therefore, no longer be subject to regulation under RCRA, provided the debris do not exhibit any of the hazardous waste characteristics. This "contained-in determination" is automatic; no agency action is needed. Note that this automatic contained-in determination does not apply to debris treated to the debris treatment standards using one of the identified immobilization technologies. See, regulations at 40 CFR 261.3(f) and treatment standards at Table 1 of 40 CFR 268.45, promulgated August 18, 1992, and associated preamble discussion at 51 FR 37225.

cc: Barbara Simcoe, Association of State and Territorial Solid Waste Management Officials

APPENDIX B:
STATISTICAL TABLES

Table B-1: *10% Values For The Nonparametric Test of Location*

$n_U \setminus n_T$	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
1									9	10	11	12	13	14	15	16	17	18	19	19	20	21	22	23	24	25	26	27	28	28	29	30	31	32	33	34	35	36	37	37	38	39	40	41	42	43	44	45	46	46
2			3	4	5	6	6	7	8	8	9	10	10	11	12	12	13	14	15	15	16	17	17	18	19	19	20	21	21	22	23	23	24	25	25	26	27	28	28	29	30	30	31	32	32	33	34	34	35	36
3		2	3	4	4	5	5	6	6	7	7	8	9	9	10	10	11	11	12	12	13	13	14	14	15	15	16	17	17	18	18	19	19	20	20	21	21	22	22	23	24	24	25	25	26	26	27	27	28	28
4		2	3	3	4	4	5	5	5	6	6	7	7	8	8	9	9	9	10	10	11	11	12	12	13	13	13	14	14	15	15	16	16	16	17	17	18	18	19	19	20	20	20	21	21	22	22	23	23	23
5		2	3	3	3	4	4	4	5	5	6	6	6	7	7	7	8	8	9	9	9	10	10	10	11	11	12	12	12	13	13	13	14	14	14	15	15	16	16	16	17	17	17	18	18	19	19	19	20	20
6		2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8	8	8	9	9	9	10	10	10	11	11	11	11	12	12	12	13	13	13	14	14	14	15	15	15	16	16	16	17	17	17	18
7		2	2	3	3	3	3	4	4	4	5	5	5	5	6	6	6	7	7	7	7	8	8	8	9	9	9	9	10	10	10	11	11	11	11	12	12	12	13	13	13	13	14	14	14	14	15	15	15	16
8		2	2	2	3	3	3	4	4	4	4	5	5	5	5	6	6	6	6	7	7	7	7	8	8	8	8	9	9	9	9	10	10	10	10	11	11	11	11	12	12	12	12	13	13	13	13	14	14	14
9	1	2	2	2	3	3	3	3	4	4	4	4	4	5	5	5	5	6	6	6	6	7	7	7	7	7	8	8	8	8	9	9	9	9	9	10	10	10	10	11	11	11	11	12	12	12	12	12	13	13
10	1	2	2	2	2	3	3	3	3	4	4	4	4	4	5	5	5	5	5	6	6	6	6	7	7	7	7	7	8	8	8	8	8	9	9	9	9	9	10	10	10	10	10	11	11	11	11	11	12	12
11	1	2	2	2	2	3	3	3	3	3	4	4	4	4	4	5	5	5	5	5	6	6	6	6	6	6	7	7	7	7	7	8	8	8	8	8	9	9	9	9	9	10	10	10	10	10	10	11	11	11
12	1	2	2	2	2	2	3	3	3	3	3	4	4	4	4	4	5	5	5	5	5	5	6	6	6	6	6	6	7	7	7	7	7	8	8	8	8	8	8	9	9	9	9	9	9	10	10	10	10	10
13	1	2	2	2	2	2	3	3	3	3	3	3	4	4	4	4	4	4	5	5	5	5	5	5	6	6	6	6	6	6	7	7	7	7	7	7	8	8	8	8	8	8	9	9	9	9	9	9	10	10
14	1	2	2	2	2	2	3	3	3	3	3	3	3	4	4	4	4	4	4	5	5	5	5	5	5	5	6	6	6	6	6	6	7	7	7	7	7	7	7	8	8	8	8	8	8	9	9	9	9	9
15	1	2	2	2	2	2	2	3	3	3	3	3	3	3	4	4	4	4	4	4	5	5	5	5	5	5	5	6	6	6	6	6	6	6	7	7	7	7	7	7	7	8	8	8	8	8	8	8	9	9
16	1	2	2	2	2	2	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	6	6	6	6	6	6	6	7	7	7	7	7	7	7	7	8	8	8	8	8	8
17	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	7	7	7	7	7	7	7	7	8	8	8	8
18	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6	7	7	7	7	7	7	7	7	8
19	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6	7	7	7	7	7	7	7
20	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6	7	7	7	7	7
21	1	1	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6	6	7	7	7
22	1	1	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6	6	7
23	1	1	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6
24	1	1	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6
25	1	1	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6
26	1	1	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	6	6	6	6
27	1	1	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	6	6
28	1	1	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	6
29	1	1	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5
30	1	1	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5
31	1	1	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5
32	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5
33	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5
34	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5
35	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5
36	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5
37	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5
38	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
39	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
40	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
41	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4
42	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4
43	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4
44	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4
45	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4
46	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4
47	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4
48	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4
49	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4
50	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4

Table B-2: *5% Values For The Nonparametric Test of Location*

$n_U \setminus n_T$	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
1																				20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	39	40	41	42	43	44	45	46	47	48	49
2					5	6	7	8	9	9	10	11	12	13	13	14	15	16	16	17	18	19	20	20	21	22	23	23	24	25	26	26	27	28	29	30	30	31	32	33	33	34	35	36	37	37	38	39	40	40
3			3	4	5	5	6	7	7	8	9	9	10	11	11	12	12	13	14	14	15	16	16	17	18	18	19	19	20	21	21	22	23	23	24	24	25	26	26	27	28	28	29	30	30	31	31	32	33	33
4			3	4	4	5	5	6	6	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15	15	16	17	17	18	18	19	19	20	20	21	21	22	22	23	23	24	24	25	26	26	27	27	28	28
5		2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	9	10	10	11	11	12	12	13	13	14	14	14	15	15	16	16	17	17	18	18	18	19	19	20	20	21	21	22	22	23	23	23	24	24
6		2	3	3	4	4	4	5	5	6	6	6	7	7	8	8	8	9	9	10	10	10	11	11	12	12	12	13	13	14	14	14	15	15	16	16	16	17	17	18	18	18	19	19	20	20	20	21	21	21
7		2	3	3	3	4	4	5	5	5	6	6	6	7	7	7	8	8	8	9	9	9	10	10	11	11	11	12	12	12	13	13	13	14	14	14	15	15	15	16	16	16	17	17	18	18	18	19	19	19
8		2	3	3	3	4	4	4	5	5	5	6	6	6	6	7	7	7	8	8	8	9	9	9	10	10	10	11	11	11	12	12	12	12	13	13	13	14	14	14	15	15	15	16	16	16	17	17	17	17
9		2	2	3	3	3	4	4	4	5	5	5	5	6	6	6	7	7	7	7	8	8	8	9	9	9	9	10	10	10	11	11	11	11	12	12	12	13	13	13	13	14	14	14	15	15	15	15	16	16
10		2	2	3	3	3	4	4	4	4	5	5	5	5	6	6	6	6	7	7	7	8	8	8	8	9	9	9	9	10	10	10	10	11	11	11	11	12	12	12	12	13	13	13	14	14	14	14	15	15
11		2	2	3	3	3	3	4	4	4	4	5	5	5	5	6	6	6	6	7	7	7	7	8	8	8	8	9	9	9	9	9	10	10	10	10	11	11	11	11	12	12	12	12	13	13	13	13	14	14
12		2	2	3	3	3	3	3	4	4	4	4	5	5	5	5	6	6	6	6	6	7	7	7	7	8	8	8	8	8	9	9	9	9	10	10	10	10	10	11	11	11	11	12	12	12	12	12	13	13
13		2	2	2	3	3	3	3	4	4	4	4	4	5	5	5	5	6	6	6	6	6	7	7	7	7	7	8	8	8	8	8	9	9	9	9	9	10	10	10	10	11	11	11	11	11	12	12	12	12
14		2	2	2	3	3	3	3	3	4	4	4	4	4	5	5	5	5	5	6	6	6	6	6	7	7	7	7	7	8	8	8	8	8	9	9	9	9	9	10	10	10	10	10	11	11	11	11	11	12
15		2	2	2	3	3	3	3	3	4	4	4	4	4	4	5	5	5	5	5	6	6	6	6	6	7	7	7	7	7	7	8	8	8	8	8	9	9	9	9	9	9	10	10	10	10	10	11	11	11
16		2	2	2	2	3	3	3	3	3	4	4	4	4	4	5	5	5	5	5	5	6	6	6	6	6	6	7	7	7	7	7	7	8	8	8	8	8	9	9	9	9	9	9	10	10	10	10	10	10
17		2	2	2	2	3	3	3	3	3	4	4	4	4	4	4	5	5	5	5	5	5	6	6	6	6	6	6	7	7	7	7	7	7	8	8	8	8	8	8	8	9	9	9	9	9	9	10	10	10
18		2	2	2	2	3	3	3	3	3	3	4	4	4	4	4	4	5	5	5	5	5	5	5	6	6	6	6	6	6	7	7	7	7	7	7	8	8	8	8	8	8	8	9	9	9	9	9	9	10
19	1	2	2	2	2	3	3	3	3	3	3	3	4	4	4	4	4	4	5	5	5	5	5	5	5	6	6	6	6	6	6	7	7	7	7	7	7	7	8	8	8	8	8	8	8	9	9	9	9	9
20	1	2	2	2	2	2	3	3	3	3	3	3	4	4	4	4	4	4	4	5	5	5	5	5	5	5	6	6	6	6	6	6	6	7	7	7	7	7	7	7	8	8	8	8	8	8	8	9	9	9
21	1	2	2	2	2	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	7	7	7	7	7	7	7	8	8	8	8	8	8	8	9
22	1	2	2	2	2	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	7	7	7	7	7	7	7	7	8	8	8	8	8	8
23	1	2	2	2	2	2	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	7	7	7	7	7	7	7	7	8	8	8	8
24	1	2	2	2	2	2	2	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	7	7	7	7	7	7	7	7	7	8	8
25	1	2	2	2	2	2	2	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6	7	7	7	7	7	7	7	7	8
26	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6	7	7	7	7	7	7	7	7
27	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6	6	7	7	7	7	7	7
28	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6	7	7	7	7	7
29	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6	6	7	7	7
30	1	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6	6	7	7
31	1	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6	6	6
32	1	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6
33	1	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6
34	1	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6
35	1	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6
36	1	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	6	6	6	6	6
37	1	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	6	6	6
38	1	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	6	6
39	1	1	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	6
40	1	1	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5
41	1	1	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5
42	1	1	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5
43	1	1	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5
44	1	1	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5
45	1	1	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5
46	1	1	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5
47	1	1	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5
48	1	1	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5
49	1	1	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5
50	1	1	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5

Table B-3. *Critical Values of Student's t Distribution (One-Tailed)*

Degrees of Freedom	*1- "*				
	0.80	***0.85***	***0.90***	***0.95***	***0.99***
1	1.376	1.963	3.078	6.314	31.821
2	1.061	1.386	1.886	2.920	6.965
3	0.978	1.250	1.638	2.353	4.541
4	0.941	1.190	1.533	2.132	3.747
5	0.920	1.156	1.476	2.015	3.365
6	0.906	1.134	1.440	1.943	3.143
7	0.896	1.119	1.415	1.895	2.998
8	0.889	1.108	1.397	1.860	2.896
9	0.883	1.100	1.383	1.833	2.821
10	0.879	1.093	1.372	1.812	2.764
11	0.876	1.088	1.363	1.796	2.718
12	0.873	1.083	1.356	1.782	2.681
13	0.870	1.079	1.350	1.771	2.650
14	0.868	1.076	1.345	1.761	2.624
15	0.866	1.074	1.340	1.753	2.602
16	0.865	1.071	1.337	1.746	2.583
17	0.863	1.069	1.333	1.740	2.567
18	0.862	1.067	1.330	1.734	2.552
19	0.861	1.066	1.328	1.729	2.539
20	0.860	1.064	1.325	1.725	2.528
21	0.859	1.063	1.323	1.721	2.518
22	0.858	1.061	1.321	1.717	2.508
23	0.858	1.060	1.319	1.714	2.500
24	0.857	1.059	1.318	1.711	2.492
25	0.856	1.058	1.316	1.708	2.485
26	0.856	1.058	1.315	1.706	2.479
27	0.855	1.057	1.314	1.703	2.473
28	0.855	1.056	1.313	1.701	2.467
29	0.854	1.055	1.311	1.699	2.462
30	0.854	1.055	1.310	1.697	2.457
40	0.851	1.050	1.303	1.684	2.423
60	0.848	1.046	1.296	1.671	2.390
120	0.845	1.041	1.289	1.658	2.358
∞	0.842	1.036	1.282	1.645	2.326

Table B-4. *Critical Values For the Wilcoxon Rank Sum Test*

n_T	a	n_{ref}																		
		2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
2	0.05	0	0	0	1	1	1	2	2	2	2	3	3	4	4	4	4	5	5	5
	0.10	0	1	1	2	2	2	3	3	4	4	5	5	5	6	6	7	7	8	8
3	0.05	0	1	2	2	3	3	4	5	5	6	6	7	8	8	9	10	10	11	12
	0.10	1	2	2	3	4	5	6	6	7	8	9	10	11	11	12	13	14	15	16
4	0.05	0	1	2	3	4	5	6	7	8	9	10	11	12	13	15	16	17	18	19
	0.10	1	2	4	5	6	7	8	10	11	12	13	14	16	17	18	19	21	22	23
5	0.05	1	2	3	5	6	7	9	10	12	13	14	16	17	19	20	21	23	24	26
	0.10	2	3	5	6	8	9	11	13	14	16	18	19	21	23	24	26	28	29	31
6	0.05	1	3	4	6	8	9	11	13	15	17	18	20	22	24	26	27	29	31	33
	0.10	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	35	37	39
7	0.05	1	3	5	7	9	12	14	16	18	20	22	25	27	29	31	34	36	38	40
	0.10	2	5	7	9	12	14	17	19	22	24	27	29	32	34	37	39	42	44	47
8	0.05	2	4	6	9	11	14	16	19	21	24	27	29	32	34	37	40	42	45	48
	0.10	3	6	8	11	14	17	20	23	25	28	31	34	37	40	43	46	49	52	55
9	0.05	2	5	7	10	13	16	19	22	25	28	31	34	37	40	43	46	49	52	55
	0.10	3	6	10	13	16	19	23	26	29	32	36	39	42	46	49	53	56	59	63
10	0.05	2	5	8	12	15	18	21	25	28	32	35	38	42	45	49	52	56	59	63
	0.10	4	7	11	14	18	22	25	29	33	37	40	44	48	52	55	59	63	67	71
11	0.05	2	6	9	13	17	20	24	28	32	35	39	43	47	51	55	58	62	66	70
	0.10	4	8	12	16	20	24	28	32	37	41	45	49	53	58	62	66	70	74	79
12	0.05	3	6	10	14	18	22	27	31	35	39	43	48	52	56	61	65	69	73	78
	0.10	5	9	13	18	22	27	31	36	40	45	50	54	59	64	68	73	78	82	87
13	0.05	3	7	11	16	20	25	29	34	38	43	48	52	57	62	66	71	76	81	85
	0.10	5	10	14	19	24	29	34	39	44	49	54	59	64	69	75	80	85	90	95
14	0.05	4	8	12	17	22	27	32	37	42	47	52	57	62	67	72	78	83	88	93
	0.10	5	11	16	21	26	32	37	42	48	53	59	64	70	75	81	86	92	98	103
15	0.05	4	8	13	19	24	29	34	40	45	51	56	62	67	73	78	84	89	95	101
	0.10	6	11	17	23	28	34	40	46	52	58	64	69	75	81	87	93	99	105	111

Table B-4. *Critical Values For the Wilcoxon Rank Sum Test (continued)*

n_T	*a*	n_{ref}																		
		2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
16	0.05	4	9	15	20	26	31	37	43	49	55	61	66	72	78	84	90	96	102	108
	0.10	6	12	18	24	30	37	43	49	55	62	68	75	81	87	94	100	107	113	120
17	0.05	4	10	16	21	27	34	40	46	52	58	65	71	78	84	90	97	103	110	116
	0.10	7	13	19	26	32	39	46	53	59	66	73	80	86	93	100	107	114	121	128
18	0.05	5	10	17	23	29	36	42	49	56	62	69	76	83	89	96	103	110	117	124
	0.10	7	14	21	28	35	42	49	56	63	70	78	85	92	99	107	114	121	129	136
19	0.05	5	11	18	24	31	38	45	52	59	66	73	81	88	95	102	110	117	124	131
	0.10	8	15	22	29	37	44	52	59	67	74	82	90	98	105	113	121	129	136	144
20	0.05	5	12	19	26	33	40	48	55	63	70	78	85	93	101	108	116	124	131	139
	0.10	8	16	23	31	39	47	55	63	71	79	87	95	103	111	120	128	136	144	152