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Standard Guide for ~~Determination of Representative Sediment Background Concentrations~~Developing Representative Background Concentrations at Sediment Sites—Data Evaluation and Development Methodologies[1]

This standard is issued under the fixed designation E3242; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide describes data visualization, statistical, forensic chemistry and geochemical methodologies (including case studies) used in the evaluation of candidate background data sets; this evaluation leads to the development of representative background data sets for the sediment site. Statistical methodologies can then be applied to the representative background data sets to develop background threshold values (BTVs) that are measures of the upper limit of representative sediment background concentrations for the sediment site. In addition, representative background data sets and sediment site data sets can be compared using two-sample statistical tests to determine if there are statistically significant differences (at a specified confidence level) between the two data sets (such as, the median or mean values of the two data sets are significantly different).

1.1.1 This guide is intended to inform, complement, and support, but not supersede the guidelines established by local, state, tribal, federal, or international agencies.

1.2 Technically defensible representative sediment background concentrations are critical for several purposes (**1**).[2] These include sediment site delineation, establishing remedial goals and cleanup levels, remedy selection, assessment of risks posed by representative background concentrations, and establishing appropriate post-remedial monitoring plans.

1.3 The overarching framework for the development of representative sediment background concentrations at sediment sites is presented in Guide E3382. Guide E3240 provides a general discussion of how conceptual site model (CSM) development fits into the risk-based corrective action framework for contaminated sediment sites, while Guide E3382 provides a detailed discussion of the elements of a sediment site CSM that need to be considered when developing representative sediment background concentrations. Guide E3344 describes how to select an appropriate background reference area(s) from which to collect sediment samples for laboratory analysis. Guide E3164 describes the sampling methodologies to obtain sediment samples in the field (whether from the sediment site or background reference area[s]), while Guide E3163 discusses appropriate laboratory methodologies for the chemical analysis of potential contaminants of concern (PCOCs) in the sediment samples. Relevant content contained in Guides E3344 and E3382 is summarized herein, but the individual guides should be consulted for more detailed coverage of these topics.

1.4 This guide focuses on the approach for ~~determination~~ the development of representative sediment background concentrations

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[2] The boldface numbers in parentheses refer to the list of references at the end of this standard.

used for remedial actions performed under various regulatory programs, including the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Although many of the references cited in this guide are CERCLA oriented, the guide is applicable to remedial actions performed under local, state, tribal, federal, and international cleanup programs. However, the guide does not describe requirements for each jurisdiction. The requirements for the regulatory entity under which the cleanup is being performed should be reviewed to confirm compliance.

1.5 This guide ~~provides a framework, including specific statistical and geochemical considerations, as well as case studies, demonstrating the approach to determine representative sediment background concentrations. This guide is intended to inform, complement, and support, but not supersede, local, state, federal, or international regulations.~~is designed to apply to contaminated sediment sites where sediment data have been collected and are readily available. Additionally, this guide assumes that risk assessments have been performed, so that the contaminants of concern (COCs) that exceed risk-based thresholds have been identified.

~~1.2.1 This guide does not address methods and means of data collection (Guide E3163, Guide E3164.)~~

~~1.2.2 This guide is designed to apply to contaminated sediment sites where sediment data have been collected and are readily available. Additionally, this guide assumes that risk assessments have been performed, so that the contaminants/chemicals of interest that exceed risk-based thresholds have been identified.~~

1.5.1 Furthermore, this guide presumes that the identified risk-based thresholds ~~identified~~ are low enough to pose corrective action implementation challenges, ~~and/or~~or the site is subject to recontamination from uncontrolled ongoing anthropogenic ~~and/or natural sources that are not controlled. In both~~or natural sources, or both. In all cases, representative sediment background concentrations will be useful for determining the extent of corrective remedial actions (when used as remedial ~~goals),~~ goals or cleanup levels), evaluating risks posed by representative background concentrations, and establishing appropriate post-remedial monitoring plans.

1.6 *Units*—The values stated in SI or CGS units are to be regarded as standard. No other units of measurement are included in this standard.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D6312 Guide for Developing Appropriate Statistical Approaches for Groundwater Detection Monitoring Programs at Waste Disposal Facilities

D7048 Guide for Applying Statistical Methods for Assessment and Corrective Action Environmental Monitoring Programs

D7659 Guide for Strategies for Surface Sampling of Metals and Metalloids for Worker Protection

D7720 Guide for Statistically Evaluating Measurand Alarm Limits when Using Oil Analysis to Monitor Equipment and Oil for Fitness and Contamination

E178 Practice for Dealing With Outlying Observations

E456 Terminology Relating to Quality and Statistics

E1689 Guide for Developing Conceptual Site Models for Contaminated Sites

E3163 Guide for Selection and Application of Analytical Methods and Procedures Used during Sediment Corrective Action

E3164 Guide for Contaminated Sediment Site Risk-Based Corrective Action – Baseline, Remedy Implementation and Post-Remedy Monitoring Programs

E3240 Guide for Risk-Based Corrective Action for Contaminated Sediment Sites

E3248 Guide for NAPL Mobility and Migration in Sediment – Conceptual Models for Emplacement and Advection

E3344 Guide for Developing Representative Sediment Background Concentrations at Sediment Sites—Selection of Background Reference Areas

E3382 Guide for Developing Representative Background Concentrations at Sediment Sites — Framework Overview, Including Conceptual Site Model Considerations

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3. Terminology

3.1 *Definitions:*

3.1.1 *anthropogenic background, n*—~~natural and~~ human-made substances present in the environment ~~as a result of~~ due to human activities, not specifically related to ~~the site release in question.~~current or historical site-related releases ~~(or1)~~ activities. **E3344**

3.1.1.1 *Discussion*—

The definition of "anthropogenic background" varies with jurisdiction. In some jurisdictions, the regulator defines anthropogenic background as having both human-made and naturally occurring components. **(2)**

3.1.2 ~~*arithmetic mean,*~~ *background (aka "reference"), n*—a ~~measure of central tendency that is the sum of observed values in the sample divided by the sample size.~~term applied to substances, conditions, or locations that are similar to those found at a sediment site but not influenced by current or historical releases or activities from the sediment site; these are usually a combination of naturally occurring (consistently present in the environment but not influenced by human activity) and anthropogenic (influenced by human activity but not related to specific current or historical releases or activities at the sediment site) components. **E3382**

3.1.3 *candidate background data set, n*—a raw (that is, unprocessed) background data set obtained either by the collection of data from a background reference area(s), or by the extraction of background data from the sediment site data set, or a combination of both. **E3382**

3.1.3.1 *Discussion*—

The candidate background data set must first be evaluated using the steps described in this guide to obtain a representative background data set.

3.1.4 *contaminant of concern (COC), n*—substances identified as posing a risk based on a tiered risk assessment and that may warrant corrective action. **E3382**

3.1.4.1 *Discussion*—

Typically, all potential contaminants of concern (PCOCs) identified for a sediment site are evaluated in the risk assessment process. PCOCs that have sediment concentrations greater than risk-based thresholds identified in the risk assessment process are defined as COCs. Thus, the COCs identified for a sediment site are a subset of the PCOCs identified for that site.

3.1.5 *distribution, n*—*as used in statistics*, a set of all the various values that individual observations may ~~acquire~~have and the frequency of their occurrence in the sample or population. **D7720**

~~3.1.4 *false negative error, n*—also known as "Type II" error. For the purposes of this guide, in site versus background comparisons, the error that occurs when the statistical procedure does not indicate concentrations above background, when such concentrations are present.~~

~~3.1.5 *false outlier, n*—measurements that are very large or small relative to the rest of the data, but represent true extreme values of a distribution and indicate more variability in the population than was expected. **(2)**~~

~~3.1.6 *false positive error, n*—also known as "Type I" error. For the purposes of this guide, in site versus background comparisons, the error that occurs when the statistical procedure indicates concentrations above background, when such concentrations are not present.~~

3.1.6 *high nondetect, n*—a nondetect concentration with a highly elevated detection limit; for example, a concentration that resides in the upper decile of the analyte's distribution (that is, a detection limit above the 90th percentile of the data set). **E3382**

3.1.7 *median, n*—~~in statistics, the value~~the 50th ~~below which 50 % of a sample or population falls.~~percentile in a population or sample. **E456**

3.1.8 *nonparametric, adj*—a term referring to a statistical technique in which the distribution of the constituent in the population is unknown and is not restricted to be of a specified ~~form (Guide~~ form.~~D7048).~~ **D7048**

3.1.9 *outlier, n*—see *outlying observation*.

3.1.10 *outlying observation, n*—an extreme observation in either direction that appears to deviate markedly in value from other members of the sample in which it ~~appears (Practice~~ appears.~~E178~~). **E178**

3.1.11 *parametric, adj*—a term referring to a statistical technique in which the distribution of the constituent in the population is assumed to be ~~known (Guide~~ known.~~D7048~~) **D7048**

~~3.1.13 *probability plot, n*—a plot of ascending observations in a sample, versus their corresponding cumulative probabilities, based on a specified distribution function.~~

3.1.12 *representative background concentrations, n*—~~a~~ chemical ~~concentration that is~~concentrations that are inclusive of naturally occurring sources and anthropogenic ~~sources,~~sources similar to those present at a ~~site,~~ sediment site but not related to ~~site releases and site-related activities (Guide~~ current or historical site releases or activities.~~E3164~~). **E3382**

3.1.13 ~~*sample,*~~ *representative background data set, n*—~~in statistics, a group of observations taken from a population that serve to provide information that may be~~a background data set obtained by evaluating candidate background data using the steps described in Guide E3242~~used as a basis for making a decision concerning the population.~~ . **E3382**

3.1.13.1 *Discussion*—

The evaluation determines if there are any data points in the candidate background data set that are not representative of sediment site background conditions. These data points are then removed from the candidate background data set (using technically justifiable rationale) to obtain a representative background data set. Typically, this data set can be used to develop a BTV, which is a measure of the upper limit of representative background concentrations; it is this BTV that is often used as a representative background concentration.

~~3.1.16 *sample size, n*—in statistics, the number of observations or measurements in the sample.~~

3.1.14 *sediment(s), n*—a matrix of pore water and particles including gravel, sand, silt, clay and other natural and anthropogenic substances that have settled at the bottom of a tidal or nontidal body of ~~water (Guide~~ water.~~E3163~~). **E3163**

3.1.15 ~~*significance,*~~ *sediment site, n*—~~in statistical hypothesis testing, the probability of the test rejecting the null hypothesis, when the null hypothesis is actually true.~~the area(s) defined by the likely physical distribution of COC(s) from a source area and the adjacent areas required to implement the corrective action. A site could be an entire water body or a defined portion of a water body. **E3240**

~~3.1.19 *tolerable error rate, n*—the specified maximum acceptable error rate set by the decision maker.~~

~~3.1.20 *true outlier, n*—measurements that are very large or small relative to the rest of the data, but are a result of transcription errors, data coding errors, or measurement system problems. (2)~~

~~3.1.21 *upper confidence limit (UCL), n*—an upper limit of an estimated value, such as the mean, that has a specified probability of including the true value, with a specified confidence level.~~

~~3.1.22 *upper percentile, n*—the value below which a specified percentage of observed values falls.~~

~~3.1.23 *upper prediction limit (UPL), n*—the value below which a specified number of future independent measurements will fall, with a specified confidence level.~~

3.1.16 *upper tolerance limit (UTL), n*—the ~~value below which a specified percentage of observed values falls, with a specified confidence level.~~upper confidence limit (with specified confidence level) for a percentile of a distribution. **D7659**

3.1.16.1 *Discussion*—

The UTL is the value below which a specified fraction of the population will be found, with a specified level of confidence. For example, the 95/95 UTL is a value for which one would have 95 % confidence that 95 % of the population is below the UTL.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *arithmetic mean, n*—a measure of central tendency that is the sum of observed values in the sample divided by the sample size.

3.2.2 *background reference areas, n*—~~for the purposes of this guide,~~ sediment areas that have similar physical, chemical, geological, biological, and land-use characteristics as the site being ~~investigated,~~investigated but are not affected by current or historical site-related releases ~~and/or~~or activities.

3.2.3 *background threshold value (BTV), n*—~~for the purposes of this guide,~~ a measure of the upper limit of representative background concentrations.

3.2.4 *cleanup level, n*—~~for the purposes of this guide, the~~ the prescribed average or point sediment concentration of a chemical that shall not be exceeded at the remediated site.

3.2.5 *conceptual site model (CSM), n*—~~for the purposes of this guide, the~~ the integrated representation of the physical and environmental context, the complete and potentially complete exposure pathways and the potential fate and transport of potential contaminants of concern at a site.

3.2.5.1 *Discussion*—

The CSM should include both the current understanding of the site and an understanding of the potential future conditions and uses for the site. It provides a method to conduct the exposure pathway evaluation, inventory the exposure pathways evaluated, and determine the status of the exposure pathways as incomplete, potentially complete, or complete.

3.2.6 *false negative error, n—in statistical tests*, also known as "Type II" error.

3.2.6.1 *Discussion*—

For the purposes of this guide, in site versus background comparisons, the error that occurs when the statistical procedure does not indicate concentrations above background, when such concentrations are present.

3.2.7 *false outlier, n*—measurements that are very large or small relative to the rest of the data but represent true extreme values of a distribution and indicate more variability in the population than was expected. **(3)**

3.2.8 *false positive error, n—in statistical tests*, also known as "Type I" error.

3.2.8.1 *Discussion*—

For the purposes of this guide, in site versus background comparisons, the error that occurs when the statistical procedure indicates concentrations above background, when such concentrations are not present.

3.2.9 *population, n*—~~*for the purposes of this guide,*~~ *as used in statistics*, a comprehensive set of values consisting of all possible observations or measurements of a certain phenomenon from which a sample is to be drawn.

3.2.10 *potential contaminant of concern (PCOC), n*—~~for the purposes of this guide,~~ a contaminant whose sediment concentrations at the site may exceed applicable screening levels; this includes chemicals of potential environmental concern (COPECs) and chemicals of potential concern (COPCs).

3.2.11 *probability plot, n*—a plot of ascending observations in a sample, versus their corresponding cumulative probabilities, based on a specified distribution function.

3.2.12 *reference element, n*—~~for the purposes of this guide,~~ a major element that represents the mineral to which a trace element may be adsorbed.

3.2.13 *sample, n—as used in statistics*, a group of observations taken from a population that serve to provide information that may be used as a basis for making a decision concerning the population.

3.2.14 *sample size, n—as used in statistics*, the number of observations or measurements in the sample.

3.2.15 *significance level, n—as used in statistical hypothesis testing*, the probability of rejecting a null hypothesis when it is true.

3.2.15.1 *Discussion*—

Also known as “alpha” (α), it is selected prior to performing a statistical test. The significance level is commonly set to 0.05, but should be determined on a site-specific basis; consultation with a statistician to choose the optimal significance level may be warranted.

3.2.16 *tolerable error rate, n*—the specified maximum acceptable error rate set by the decision maker.

3.2.17 *trace element, n*—~~for the purposes of this guide,~~ an element defined as generally being present at less than 0.1 weight percent in the sediment sample; its natural concentrations are typically one or more orders of magnitude lower than those of the reference elements.

3.2.18 *true outlier, n*—measurements that are very large or small relative to the rest of the data, but are a result of transcription errors, data-coding errors, or measurement system problems; or it is not representative of the investigated data population as confirmed by other lines of evidence.

3.2.19 *upper confidence limit (UCL), n*—an upper limit of an estimated value, such as the mean, which has a specified probability of including the true value, with a specified confidence level.

3.2.20 *upper percentile, n*—the value below which a specified percentage of observed values falls.

3.2.21 *upper prediction limit (UPL), n*—the value below which a specified number of future independent measurements will fall, with a specified confidence level.

4. Significance and Use

4.1 *Intended Use:*

4.1.1 This guide may be used by various parties involved in sediment corrective action programs, including regulatory agencies, project sponsors, environmental consultants, toxicologists, risk assessors, site remediation professionals, environmental contractors, and other stakeholders.

4.2 *Importance of the CSM:*

4.2.1 The CSM should be continuously updated and refined to describe the physical properties, chemical composition and occurrence, biologic features, and environmental conditions of the sediment corrective action project (Guide E1689).

4.3 *Reference Material:*

4.3.1 This guide should be used in conjunction with other ASTM guides listed in 2.1 (especially Guides E3344 and E3382); this guide should also be used in conjunction with the material in the References at the end of this guide (including **1**). Utilizing these reference materials will direct the user in developing representative background concentrations for a sediment site.

4.4 *Flexible Site-Specific Implementation:*

4.4.1 This guide provides a systematic, but flexible, framework to accommodate variations in approaches by regulatory agencies and by the user based on project objectives, site complexity, unique site features, regulatory requirements, newly developed guidance, newly published scientific research, changes in regulatory criteria, advances in scientific knowledge and technical capability, and unforeseen circumstances.

4.5 ~~*Related ASTM Standards:*~~ *Regulatory Frameworks:* ~~This guide is related to Guide E3164, which addresses corrective action monitoring before, during, and after sediment remediation activities; as well as Guide E3163, concerning sediment analytical techniques used during sediment programs.~~

4.5.1 This guide is intended to be applicable to a broad range of local, state, tribal, federal, or international jurisdictions, each with its own unique regulatory framework. As such, this guide does not provide a detailed discussion of the requirements or guidance associated with any of these regulatory frameworks, nor is it intended to supplant applicable regulations and guidance. The user of this guide will need to be aware of the regulatory requirements and guidance in the jurisdiction where the work is being

performed.

4.6 *Systematic Project Planning and Scoping Process:*

4.6.1 When applying this guide, the user should undertake a systematic project planning and scoping process to collect information to assist in making site-specific, user-defined decisions for a particular project, including assembling an experienced team of project professionals. These practitioners should have the appropriate expertise to scope, plan, and execute a sediment data acquisition and analysis program. This team may include, but is not limited to, project sponsors, environmental consultants, toxicologists, site remediation professionals, analytical chemists, geochemists, and statisticians.

4.7 *Use of Representative Background to Set a Boundary:* ~~Representative background concentrations for sediments can be used to delineate a sediment corrective action, establishing the boundary of the sediment corrective action by distinguishing site-related impacts from representative background concentrations.~~

4.7.1 Representative background concentrations for sediments can be used to delineate a sediment corrective action, establishing the boundary of the sediment corrective action area by distinguishing site-related impacts from representative background concentrations. This application requires the development of a BTV for the representative background data set.

4.8 *Use of Representative Background to Establish Cleanup Levels:* ~~Representative background concentrations for sediments can also be used to establish cleanup levels for use in sediment corrective actions. In cases where risk-based sediment cleanup levels are below representative background concentrations, background concentrations are typically used as the cleanup level. This ensures that the cleanup levels are sustainable. Any recontamination from ongoing sources will eventually result in surface sediment concentrations greater than the risk-based cleanup level, but the surface sediment should still meet a cleanup level based on representative background concentrations, even after recontamination.~~

4.8.1 Representative background concentrations for sediments can be used to establish cleanup levels for use in sediment corrective actions. In cases where risk-based sediment cleanup levels are below representative background concentrations, background concentrations are typically used as the cleanup level (**4**). This ensures that the cleanup levels are sustainable. Any recontamination from ongoing sources will eventually result in surface sediment concentrations greater than the risk-based cleanup level, but the surface sediment should still meet a cleanup level based on representative background concentrations, even following recontamination.

4.9 *Use of Representative Background in Risk Assessments:* ~~Representative background concentrations can be used in the risk assessment process (including human and ecological risk assessments) to understand risks posed by background levels of contaminants to human health and the environment, and the incremental risks posed by site-related releases and/or activities that result in sediment concentrations that exceed representative background concentrations. Conversely, they can be used to estimate the risk reduction for various contaminants, if sediment is remediated from existing PCOC concentrations to lower values (that is, representative background concentrations).~~

4.9.1 Representative background concentrations can be used in the risk assessment process (including human and ecological risk assessments) to understand risks posed by background levels of contaminants to human health and the environment, and the incremental risks posed by site-related releases or activities (or both) that result in sediment concentrations that exceed representative background concentrations. Conversely, they can be used to estimate the risk reduction for various contaminants, if sediment is remediated from existing COC concentrations to lower values (that is, representative background concentrations).

4.10 *Use of Representative Background in ~~Long-Term~~Post-Remedy Monitoring Programs:* ~~Long-term monitoring programs can also use representative background concentrations in sediment, either as a corrective action target or to understand how post-corrective action concentrations compare to sources not attributable to site releases and/or activities. Typically, source control actions taken to ensure that site-related releases are controlled and will not re-contaminate the post-corrective action sediments must be developed based on an understanding of ongoing contributions from representative background. Ongoing sources not related to site-related releases and/or activities (that may or may not be subject to source control actions) must be considered in this evaluation.~~

4.10.1 Post-remedy monitoring programs can also use representative background sediment concentrations either as a corrective action target or to understand how post-remedy concentrations compare to the sources not attributable to current or historical site releases or activities. Typically, source control actions taken to ensure that site-related releases are controlled and will not re-contaminate the post-corrective action sediments must be developed based on an understanding of ongoing contributions from

representative background. Ongoing sources unrelated to current or historical site-related releases or activities (that may or may not be subject to source control actions) must be considered in this evaluation.

4.11 ~~*Importance of the CSM:*~~ *Other Considerations:* ~~The users of this guide are encouraged to continuously update and refine the CSM used to describe the physical properties, chemical composition and occurrence, biologic features, and environmental conditions of the sediment corrective action project (Guide E1689).~~

4.11.1 This guide does not cover all components of a program to develop representative sediment background concentrations.

4.11.2 The overarching process to develop representative background concentrations (including CSM considerations) is not covered in detail in this guide but is discussed in more depth in Guide E3382.

4.11.3 The selection of a background reference area(s) for the sediment site is not covered in detail in this guide but is extensively described in Guide E3344.

4.11.4 Sediment sampling and laboratory analyses are not covered in this guide. Guides E3163 and E3164 contain extensive information concerning sediment sampling and laboratory analyses.

4.11.5 Data quality objectives are not covered in this guide. Data quality objectives are described in (**5**).

4.11.6 Background study design considerations are not covered in this guide but are described in other references, including Guides E3163 and E3164, as well as (**6, 7**).

4.11.7 Geospatial analysis considerations are not thoroughly discussed in this guidance but are discussed in more depth relative to environmental evaluations in (**8**), which focuses on quality assurance concerns relative to geospatial analyses.

4.11.8 In this guide, only the concentrations of COCs are considered to be in scope. Residual background radioactivity is out of scope.

4.12 ~~*Reference Material:*~~ *Structure and Components of This Guide:* ~~This guide should be used in conjunction with other reference material (refer to Section 2 and References at the end of this guide) to direct the user in developing and implementing sediment corrective action programs.~~

4.12.1 The user of this guide should review the overall structure and components of this guide before proceeding with use, including:

Section 1	Scope
Section 2	Referenced Documents
Section 3	Terminology
Section 4	Significance and Use
Section 5	Overview of Representative Background Concentration Development Process
Section 6	Development of Candidate Background Data Sets
Section 7	Evaluation of Candidate Background Data Sets to Obtain Representative Background Data Sets
Section 8	Data Visualization
Section 9	Evaluation of High Nondetect Data Points
Section 10	Evaluation of Outlying Data Points
Section 11	Forensic Chemistry Evaluation of Organic Contaminants
Section 12	Geochemical Evaluation of Metals
Section 13	Methodology Application to Develop a Representative Background Data Set from a Candidate Background Data Set
Section 14	Development of Representative Background Concentrations
Section 15	Comparison of Sediment Site and Representative Background Data Sets Using Statistical Two-Sample Testing
Section 16	Keywords
Appendix X1	Organic and Inorganic Chemistry Overview
Appendix X2	Illustrative Case Studies from One Example Sediment Site
Appendix X3	Summaries for Outlier Testing and Two-Sample Statistical Testing
References	

4.9 *Flexible Site-Specific Implementation:* This guide provides a systematic, but flexible, framework to accommodate variations in approaches by regulatory agencies and by the user based on project objectives, site complexity, unique site features, regulatory requirements, newly developed guidance, newly published scientific research, changes in regulatory criteria, advances in scientific knowledge and technical capability, and unforeseen circumstances.

4.10 *Systematic Project Planning and Scoping Process:* When applying this guide, the user should undertake a systematic project planning and scoping process to collect information to assist in making site-specific, user-defined decisions for a particular project, including assembling an experienced team of project professionals (that is, experienced practitioners familiar with current sediment site characterization and remediation techniques, as well as geochemistry, and statistics). These practitioners should have the appropriate expertise to scope, plan, and execute a sediment data acquisition and analysis program. This team may include, but is not limited to, project sponsors, environmental consultants, toxicologists, site remediation professionals, analytical chemists, geochemists, and statisticians.

5. Importance Overview of Representative Background Concentration Development Process

5.1 At many sediment sites, multiple sources may contribute to the nature and extent of contamination. The largest contribution of contamination at sediment sites is typically attributed to site releases and/or activities. However, contamination can also result from natural and ongoing anthropogenic sources not related to site releases and/or activities. Discharges from combined sewer overflows (CSOs), industrial outfalls, surface runoff, and/or storm sewer systems (municipal and private) are examples of ongoing anthropogenic sources that may be unrelated to site releases and/or activities.

5.1 The off-site contamination not associated with site releases and/or activities is considered a component of representative background concentrations and will continue to be a source of contamination to the site, unless all transport pathways are eliminated. A primary objective of determining representative background concentrations is to account for any background chemical input (both natural and anthropogenic) that is expected to continue migrating onto the site. It is recognized that one of the important principles for management of contaminated sediment sites is the control of sources of contamination, to the greatest extent practicable, prior to the initiation of corrective actions at the subject site (for example, see (**3**, **4**)). However, it is rarely practicable to control all background sources.*Importance of Representative Background:*

5.1.1 Multiple sources may contribute to the nature and extent of contamination at sediment sites. The largest contribution of contamination at sediment sites is typically attributed to current or historical site releases or activities. However, contamination can also result from natural or ongoing anthropogenic sources (or both) not related to current or historical site releases or activities. Discharges from combined sewer overflows (CSOs), industrial outfalls, and storm sewer systems (municipal and private) or surface runoff are examples of ongoing anthropogenic sources that may be unrelated to current or historical site releases or activities.

5.1.2 The off-site contamination not associated with current or historical site releases or activities is considered a component of representative background concentrations and will continue to be a source of contamination to the sediment site unless all transport pathways are eliminated. A primary objective of determining representative background concentrations is to account for any background chemical input (both natural and anthropogenic) that is expected to continue migrating onto the sediment site after the completion of corrective actions. One of the important principles for management of contaminated sediment sites is the control of sources of contamination, to the greatest extent practicable, prior to the initiation of corrective actions at the subject site (**4**, **9**). However, it is rarely practicable to control all background sources.

5.1.3 Technically defensible representative background concentrations are those that accurately reflect chemical inputs to a sediment site from natural and ongoing anthropogenic sources unrelated to current or historical site releases or activities. In addition to informing or establishing technically defensible cleanup levels, representative background concentrations can assist in determining site boundaries, identifying COCs, establishing and optimizing realistic post-remedy monitoring plans, and assessing the performance of corrective actions.

5.1.4 In the absence of representative background concentrations, risk-based cleanup levels may be inappropriately used at sediment sites where representative background concentrations are actually greater than the risk-based cleanup levels. Similarly, if the representative background concentrations have been erroneously developed (for example, by the inappropriate exclusion of some outlier data points [false outliers]; refer to Section 10), inappropriately low cleanup levels could be used in the corrective action evaluation process. Under both circumstances, surface sediments at sediment sites will eventually return to representative background concentrations at some time after corrective actions are completed and cleanup levels will be exceeded. Due to exceedances of the inappropriately low cleanup levels, the corrective actions would be perceived as failures.

5.1.5 Attempting to implement corrective actions to achieve concentrations less than representative background is not sustainable over the long-term and can require considerable expenditures that serve no environmental or public health purpose (Guide E3382). The process described in Guide E3382 is intended to help promote a scientifically sound approach for developing representative background concentrations, leading to corrective action decisions that avoid costly perceived corrective action failures at sediment sites. The topics covered in this guide are a critical component of the process outlined in Guide E3382 and include developing candidate background data sets; data visualization of candidate background data sets; evaluation of candidate background data sets to develop representative background data sets using statistical, forensic chemistry and geochemical methodologies; the development of various measures of representative background concentrations for applications at sediment sites using representative background data sets; and the application of two-sample statistical tests to compare representative background and sediment site data sets.

5.2 ~~Technically defensible representative background concentrations are those that accurately reflect chemical inputs to a site from natural and ongoing anthropogenic sources unrelated to site releases and/or activities. In addition to informing or establishing cleanup levels, representative background concentrations can assist in determining site boundaries, identifying PCOCs, establishing and optimizing realistic long-term monitoring plans, and assessing the performance of corrective actions.~~*Overview of Process to Develop Representative Background Concentrations in Sediment:*

5.2.1 Application of background guidance for soil and groundwater at upland sites may not be appropriate at sediment sites. Sediment sites have many different characteristics that are not present at upland sites (Guide E3248), including physical characteristics, geochemical characteristics, biological characteristics, and different contaminant emplacement and transport mechanisms.

5.2.2 This guide and its associated guides (Guides E3163, E3164, E3240, E3344, and E3382) have been developed (in part) to fill a gap due to the absence of existing guidance from various regulatory agencies for the development of representative background concentrations for contaminated sediment sites.

5.2.3 Fig. 1 presents the overall framework to develop the BTV, which is a measure of the upper limit of representative background concentrations at a sediment site; this process is presented in detail in Guide E3382. As a first step, a thorough understanding of the sediment site is necessary before developing the BTV. This can be accomplished by developing a sediment site CSM (refer to Guides E3240 and E3382). As part of this CSM, the sediment site PCOCs must be identified.

5.2.4 Once the preliminary sediment site CSM has been developed, a suitable background reference area (or areas) can be identified for sampling (that is, the second step in Fig. 1); the methodology used to do this is presented in detail in Guide E3344.

5.2.5 Candidate background data sets are typically obtained in two ways: *(1)* collecting sediment samples from background reference areas that have characteristics as similar as possible to that of the sediment site (see Guide E3344 for a detailed discussion on the selection of the background reference area), or *(2)* extracting candidate background data sets from the sediment site data from portions of the site that have been unaffected by current or historical site releases or activities (see Appendix X2 and Ref. (**7**) for a detailed discussion of background data extraction from the sediment site data set). Additionally, under certain circumstances data sets from *(1)* and *(2)* can be combined to develop a single candidate background data set. Section 6 describes the collection of sediment samples from background reference areas and extraction of background data sets from the sediment site data to develop candidate background data sets.

5.2.6 Once a candidate background data set is developed, Sections 6 – 14 describe the process used to evaluate these data sets to develop representative background data sets for the site and then develop BTVs for these representative background data sets (see Section 7 for further details on the evaluation process).

~~5.4 In the absence of representative background concentrations, risk-based cleanup levels may be used inappropriately at sites where representative background concentrations are actually greater than the risk-based cleanup levels. Similarly, if the representative background concentrations have been erroneously calculated (for example, by the inappropriate exclusion of some outlier data points [false outliers], refer to Section 11), inappropriately low cleanup goals could be used in the corrective action evaluation process. Under both circumstances, sites will eventually return to representative background concentrations after corrective actions are completed and cleanup goals will be exceeded. Due to exceedances of the inappropriately low cleanup goals, the corrective actions would be perceived as failures.~~

~~5.5 Attempting to implement corrective actions to achieve concentrations less than representative background is not sustainable~~

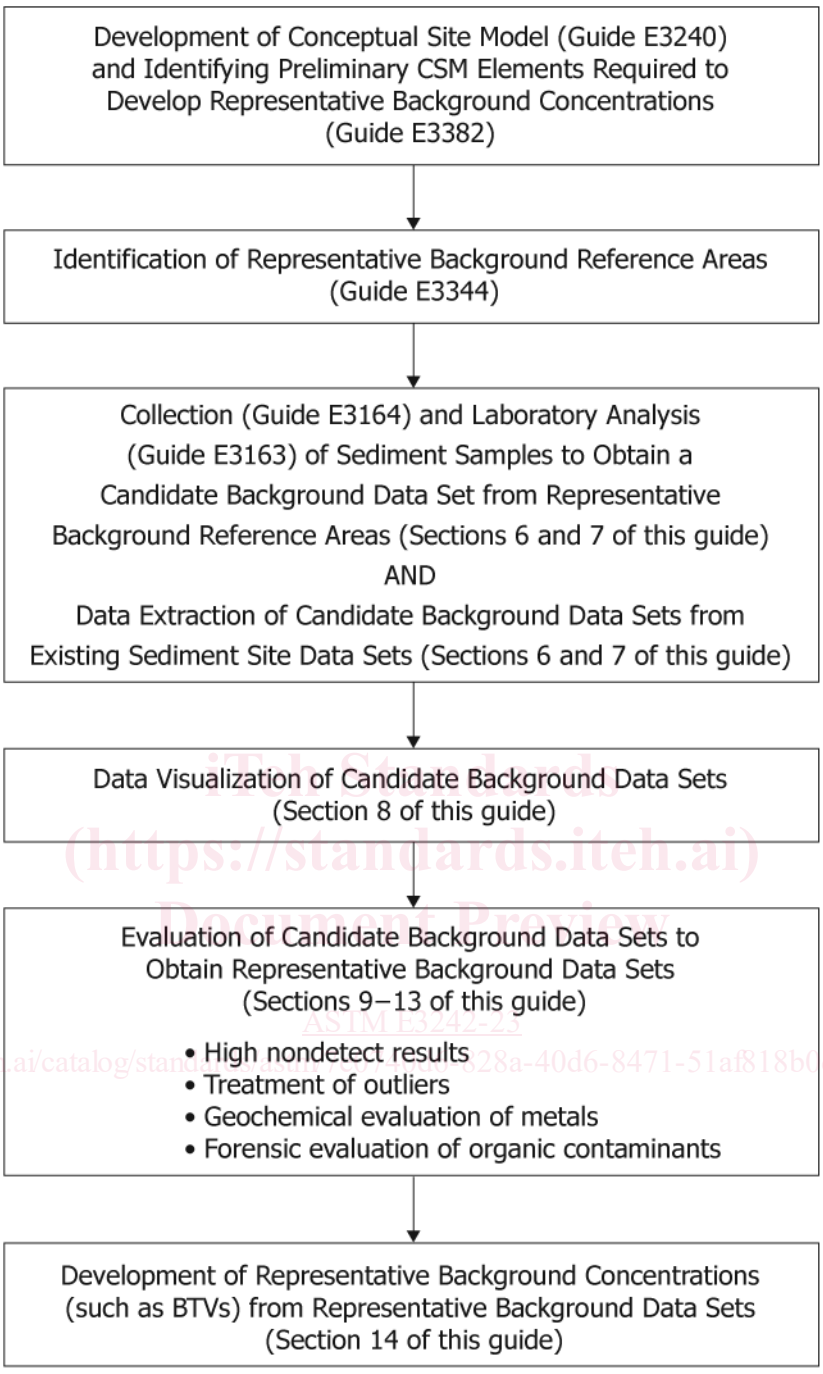

FIG. 1 ~~Overview of the Process~~Process to Develop Representative Sediment Background Concentrations (Modified from Guide E3382)

~~over the long-term and can require considerable expenditures that serve no environmental or public health purpose. The process described in this guide (refer to Section 6) is intended to help promote a scientifically sound approach for establishing representative background concentrations, leading to corrective action decisions that avoid costly perceived corrective action failures at sediment sites.~~

~~6. Overview of the Process~~

~~6.1 As shown in Fig. 1, to determine representative background concentrations, a thorough understanding of a site is necessary.~~

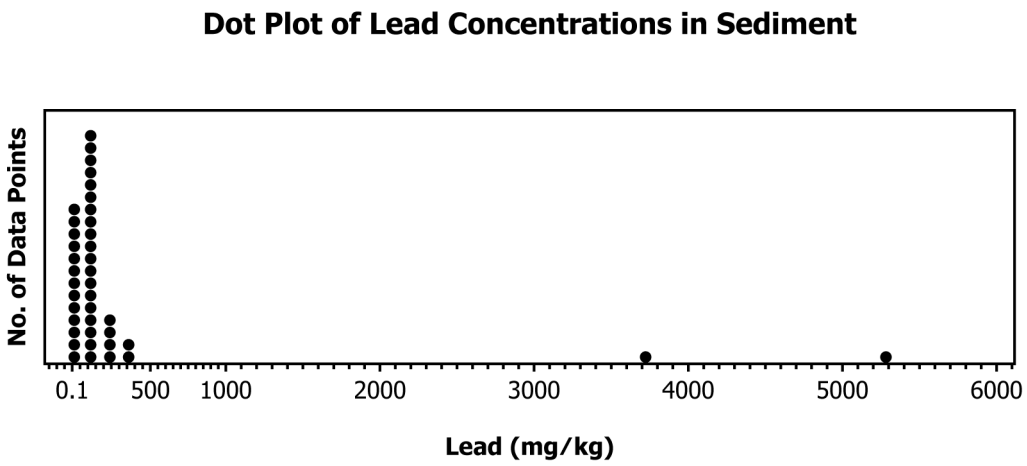

FIG. 2 Dot Plot of Lead Concentrations in a ~~Set of Sediment Samples~~Candidate Background Data Set

~~This can be accomplished by developing a CSM (see Guide E3164, Appendix X2) that informs the selection of the background reference area(s) where data collection will occur. Additionally, the site PCOCs must be identified.~~

~~6.2 Representative background concentrations are typically derived in two ways: *(1)* collecting sediment samples in background reference areas that have characteristics as similar as possible to that of the site (based on a preliminary CSM for the site), and/or *(2)* extracting representative background concentrations from the site data from portions of the site that have been unaffected by site releases and/or activities. Additionally, under certain circumstances *(1)* and *(2)* can be combined to derive representative background concentrations. Sections 8 and 9 provide additional information concerning the collection and extraction of representative background concentrations. Appendix X1 provides a simple case study illustrating the selection of representative background areas.~~

~~6.3 Once the preliminary CSM has been developed, background reference area(s) can be identified for sampling (refer to Section 8).~~

~~6.4 When analytical data are available—either by collecting new data or by extricating data from the existing site data set—data can be visualized with a variety of techniques. Section 10 describes several types of graphical methods that aid in statistical and geochemical evaluations of the data.~~

~~6.5 Evaluation of outliers is performed to identify statistical outlying observations in the candidate background data set, as further discussed in Section 11.~~

~~6.6 Chemical and geochemical processes that influence the concentrations of elements in sediment are also considered when identifying a representative background data set, evaluating statistical outliers, and comparing analyses of site versus background samples. The use of geochemical evaluation is discussed in Sections 7 and 12.~~

~~6.7 As described in Section 13, the identification of representative background data should include the screening of high-nondetect values, outlier testing, consideration of impacts from organic contaminants, and geochemical evaluation of metals concentrations.~~

~~6.8 As described in Section 14, once a technically sound background data set has been obtained, representative background concentration values can be calculated by a number of methods and applied for a variety of uses.~~

~~7. Chemical and Geochemical Considerations~~

~~7.1 Identifying representative sediment background concentrations, to include in a background data set, is typically an iterative process. The goal is to maximize the likelihood of obtaining a final data set that contains a wide range of representative background concentrations and that captures the natural and anthropogenic variance in the data set, without biasing the data by including "true outliers" (3.1.20 and 11.4), excluding "false outliers" (3.1.5 and 11.4), or including "high-nondetect" values (3.1.7 and 13.1.1) in the background data set. The resulting background data set is less likely to yield erroneous conclusions when used for statistical~~

and geochemical comparisons to site data. The analytes that are the focus of the background study should be understood and evaluated with respect to their source(s) and potential site-related impacts. The screening steps of 13.1 include consideration of geochemistry, as well as consideration of other characteristics of the candidate background samples, such as laboratory reporting limits and qualifiers.

7.2 Organic Compounds:

7.2.1 Background studies may focus on one or more groups of organic compounds that can be pervasive in the environment, typically at low concentrations. They include polycyclic aromatic hydrocarbons (PAHs) and polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/F), which can have both natural and anthropogenic sources; and pesticides and polychlorinated biphenyls (PCBs), which are solely from anthropogenic sources (**5**, **6**, **7**).

7.2.2 Different sources of PAHs have different proportions of individual PAH compounds. These proportions provide a signature, or "fingerprint," that can be used to examine the PAH data on a sample-by-sample basis. Selected PAH compound ratios (for example, fluoranthene/pyrene) reflect the thermal stability of related isomers, and they can be examined to distinguish pyrogenic and petrogenic sources, among other forensic uses (Appendix X2; also see Appendix A of (**8**)). Normalized ratios (for example, anthracene/[anthracene+phenanthrene]), visualized using double-ratio plots, can be a powerful technique for PAH data evaluation (**9**).

7.2.3 PAH, PCB, and PCDD/F data are well suited for evaluation using the "FALCON" fingerprinting approach described in (**10**). FALCON is a simple method that is suitable for limited data sets; more sophisticated (but more complicated) methods for exploratory data analysis of organic compounds can also be used. For example, multi-component mixtures are amenable to compositional analysis via a number of different multivariate data analysis techniques (**5**, **11**). All of these methods allow the investigator to identify samples that have ratios or fingerprints that differ from those of other samples and that might not represent ambient background conditions. For example, a background sediment sample that possesses relatively high PAH concentrations that also exhibits PAH ratios identical to those of the other background sediment samples may be part of the background population(s) and should be retained in the background data set. In contrast, if this sample exhibits distinctly different PAH ratios relative to those of the other background sediment samples, then it warrants further investigation and possible exclusion from the representative background data set.

7.3 Inorganics:

7.3.1 *Naturally Occurring Elements*—Background studies commonly focus on the concentrations of elements, due to their ubiquity in nature and the fact that naturally occurring concentrations often exceed risk-based screening values. Naturally occurring elements detected in sediment derive from parent material (commonly bedrock) that was chemically and physically weathered and then transported from other locations to a point of deposition. Climate and the composition of the parent material determine the minerals that form during sediment development. Some minerals, such as metal sulfides, can precipitate from the sediment pore water, and this contributes to the detected sediment concentrations.

7.3.1.1 Common reference elements in sediment include aluminum, calcium, iron, magnesium, and manganese. These elements are found at higher concentrations in sediments (often greater than 1 weight percent) and serve as potential reference elements during geochemical evaluations (Section 12). Trace elements are typically defined as being present at less than 0.1 weight percent, and their natural concentrations can be one or more orders of magnitude lower than those of the reference elements. The USEPA's Target Analyte List (TAL) of 23 metals includes most of the trace elements that may be of interest at most sediment sites: antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, silver, thallium, vanadium, and zinc. Molybdenum and tin are other trace elements that are not included in the USEPA's TAL, but are potential contaminants of concern at some sediment sites and may need to be analyzed.

7.3.2 *Anthropogenic Input of Elements*—Inorganic contaminants can have many different sources; see references such as (**5**, **12**). During a sediment background study, it is important to identify and exclude any samples that have been impacted by site releases and/or activities. For example, the addition of a trace element, such as zinc, from a contaminant source at a given location will result in an elevated trace-versus-reference element ratio in the sample relative to unimpacted samples. This is because the trace element was added to the sediment at that sample location but the reference element was not added (that is, the trace element concentration has increased while the reference element concentration is unchanged). Therefore, geochemical evaluation of all candidate background samples is recommended, to identify potentially impacted samples and flag them for removal, when appropriate. Section 12 provides an overview of the theory behind geochemical evaluation, and the case studies in Appendix X3 provide detailed examples of geochemical evaluation using a variety of sediment data sets.