APPENDIX A

GLOSSARY OF TERMS*

Accuracy - A measure of the closeness of an individual measurement or the average of a number of measurements to the true value. Accuracy includes a combination of random error (*precision*) and systematic error (bias) components that are due to sampling and analytical operations. EPA recommends using the terms "precision" and "bias," rather than the term "accuracy," to convey the information usually associated with accuracy. Pitard (1993) indicates that a sample is accurate when the absolute value of the bias is smaller than an acceptable standard of accuracy.

Action Level - The numerical value that causes the decision maker to choose one of the alternative actions (for example, compliance or noncompliance). It may be a regulatory threshold standard, such as the maximum contaminant level for drinking water, a risk-based concentration level, a technological limitation, or a reference-based standard (ASTM D 5792-95).

Alternative Hypothesis - See *Hypothesis*.

Assessment - The evaluation process used to measure the performance or effectiveness of a system and its elements. As used here, assessment is an all-inclusive term used to denote any of the following: *audit*, performance evaluation (PE), management systems review (MSR), peer review, inspection, or surveillance.

Audit (quality) - A systematic and independent examination to determine whether quality activities and related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve objectives.

Audit of Data Quality - A qualitative and quantitative evaluation of the documentation and procedures associated with environmental measurements to verify that the resulting data are of acceptable quality.

Baseline Condition - A tentative assumption to be proven either true or false. When *hypothesis* testing is applied to a site *assessment* decision, the data are used to choose between a presumed baseline condition of the environment and an alternative condition. The baseline condition is retained until overwhelming evidence indicates that the baseline condition is false. This is often called the *null hypothesis* in statistical tests.

Bias - The systematic or persistent distortion of a measured value from its true value (this can occur during sampling design, the sampling process, or laboratory analysis).

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* The definitions in this appendix are from USEPA 1998a, 2000b, 2000e, and 2001b, unless otherwise noted. Some definitions were modified based on comments received from technical reviewers during development of this document. These definitions do not constitute the Agency's official use of the terms for regulatory purposes and should not be construed to alter or supplant other terms in use.

Note: Terms in *italics* also are defined in this glossary.

Blank - A sample that is intended to contain none of the analytes of interest and is subjected to the usual analytical or measurement process to establish a zero baseline or background value. Sometimes used to adjust or correct routine analytical results. A blank is used to detect contamination during sample handling preparation and/or analysis (see also *Rinsate*, *Method Blank*, *Trip Blank*, and *Field Blank*).

Boundaries - The spatial and temporal limits and practical constraints under which environmental data are collected. Boundaries specify the area or volume (spatial boundary) and the time period (temporal boundary) to which the decision will apply. Samples are then collected within these boundaries.

Calibration - Comparison of a measurement standard, instrument, or item with a standard or instrument of higher *accuracy* to detect and quantify inaccuracies and to report or eliminate those inaccuracies by adjustments. Calibration also is used to quantify instrument measurements of a given concentration in a given sample.

Calibration Drift - The deviation in instrument response from a reference value over a period of time before recalibration.

Chain of Custody - An unbroken trail of accountability that ensures the physical security of samples, data, and records.

Characteristic - Any property or attribute of a datum, item, process, or service that is distinct, describable, and/or measurable.

Coefficient of Variation (CV) - A dimensionless quantity used to measure the spread of data relative to the size of the numbers. For a normal distribution, the coefficient of variation is given by $s / \bar{x}$. Also known as the *relative standard deviation (RSD)*.

Colocated Samples - Two or more portions collected as close as possible at the same point in time and space so as to be considered identical. If obtained in the field, these samples also are known as “field replicates.”

Comparability - A measure of the confidence with which one data set or method can be compared to another.

Completeness - A measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under correct, normal conditions.

Component - An easily identified item such as a large crystal, an agglomerate, rod, container, block, glove, piece of wood, or concrete (ASTM D 5956-96). An elementary part or a constituent that can be separated and quantified by analysis (Pitard 1993).

Composite Sample - A physical combination of two or more samples (ASTM D 6233-98). A sample collected across a temporal or spatial range that typically consists of a set of discrete samples (or "individual" samples) that are combined or "composited." Area-wide or long-term compositing should not be confused with localized compositing in which a sample of the desired support is created from many small increments taken at a single location. Four types of composite samples are listed below:

1. Time Composite - a sample comprising a varying number of discrete samples collected at equal time intervals during the compositing period. The time composite sample is typically used to sample waste water or streams.

2. Flow Proportioned Composite (FPC) - a sample collected proportional to the flow during the compositing period by either a time-varying/constant volume (TVCV) or a time-constant/varying volume method (TCVV). The TVCV method typically is used with automatic samplers that are paced by a flow meter. The TCVV method is a manual method that individually proportions a series of discretely collected samples. The FPC is typically used when sampling waste water.

3. Areal Composite - sample composited from individual equal-size samles collected on an areal or horizontal cross-sectional basis. Each discrete sample is collected in an identical manner. Examples include sediment composites from quarter-point sampling of streams and soil samples from within grids.

4. Vertical Composite - a sample composited from individual equal samples collected from a vertical cross section. Each discrete sample is collected in an identical manner. Examples include vertical profiles of soil/sediment columns, lakes, and estuaries (USEPA 1996c).

Confidence Level - The probability, usually expressed as a percent, that a confidence interval will contain the *parameter* of interest (ASTM D 5792-95). Also known as the confidence coefficient.

Confidence Limits - Upper and/or lower limit(s) within which the true value of a parameter is likely to be contained with a stated probability or confidence (ASTM D 6233-98).

Conformance - An affirmative indication or judgment that a product or service has met the requirements of the relevant specifications, contract, or regulation. Also the state of meeting the requirements.

Consensus Standard - A standard established by a group representing a cross section of a particular industry or trade, or a part thereof.

Control Sample - A quality control sample introduced into a process to monitor the performance of the system (from Chapter One, SW-846).

Data Collection Design - A design that specifies the configuration of the environmental monitoring effort to satisfy the *data quality objectives*. It includes: the types of samples or monitoring information to be collected; where, when, and under what conditions they should be collected; what variables are to be measured; and the quality assurance/quality control (QA/QC) components that ensure acceptable sampling design error and measurement error to meet the *decision error* rates specified in the DQOs. The data collection design is the principal part of the quality assurance project plan (QAPP).

Data of Known Quality - Data that have the qualitative and quantitative components associated with their derivation documented appropriately for their intended use, and when such documentation is verifiable and defensible.

Data Quality Assessment (DQA) Process - A statistical and scientific evaluation of the data set to assess the validity and performance of the data collection design and statistical test and to establish whether a data set is adequate for its intended use.

Data Quality Indicators (DQIs) - The quantitative statistics and qualitative descriptors that are used to interpret the degree of acceptability or utility of data to the user. The principal data quality indicators are *bias*, *precision*, *accuracy* (precision and bias are preferred terms), *comparability*, *completeness*, and *representativeness*.

Data Quality Objectives (DQOs) - Qualitative and quantitative statements derived from the DQO Process that clarify study technical and quality objectives, define the appropriate type of data, and specify tolerable levels of potential *decision error*s that will be used as the basis for establishing the quality and quantity of data needed to support decisions.

Data Quality Objectives (DQO) Process - A systematic strategic planning tool based on the scientific method that identifies and defines the type, quality, and quantity of data needed to satisfy a specified use. The key elements of the process include:

- concisely defining the problem
- identifying the decision to be made
- identifying the key inputs to that decision
- defining the *boundaries* of the study
- developing the decision rule
- specifying tolerable limits on potential *decision errors*
- selecting the most resource efficient data collection design.

Data Reduction - The process of transforming the number of data items by arithmetic or statistical calculations, standard curves, and concentration factors, and collating them into a more useful and understandable form. Data reduction generally results in a reduced data set and an associated loss of detail.

Data Usability - The process of ensuring or determining whether the quality of the data produced meets the intended use of the data.

Data Validation - See *Validation*.

Debris - Under 40 CFR 268.2(g) (Land Disposal Restrictions regulations) debris includes “solid material exceeding a 60 mm particle size that is intended for disposal and that is a manufactured object; or plant or animal matter; or natural geologic material.” 268.2(g) also identifies materials that are not debris. In general, debris includes materials of either a large particle size or variation in the items present. When the constituent items are more than 2 or 3 inches in size or are of different compositions, *representative* sampling becomes more difficult.

Decision Error - An error made when drawing an inference from data in the context of *hypothesis* testing such that variability or *bias* in the data mislead the decision maker to draw a conclusion that is inconsistent with the true or actual state of the population under study. See also *False Negative Decision Error*, and *False Positive Decision Error*.

Decision Performance Curve - A graphical representation of the quality of a decision process. In statistical terms it is known as a power curve or function (or a reverse power curve depending on the hypotheses being tested).

Decision Performance Goal Diagram (DPGD) - A graphical representation of the tolerable risks of *decision errors*. It is used in conjunction with the decision performance curve.

Decision Unit - A volume or mass of material (such as waste or soil) about which a decision will be made.

Defensible - The ability to withstand any reasonable challenge related to the veracity, integrity, or quality of the logical, technical, or scientific approach taken in a decision-making process.

Design - Specifications, drawings, design criteria, and performance requirements. Also, the result of deliberate planning, analysis, mathematical manipulations, and design processes (such as experimental design and sampling design).

Detection Limit - A measure of the capability of an analytical method to distinguish samples that do not contain a specific analyte from samples that contain low concentrations of the analyte. The lowest concentration or amount of the target analyte that can be determined to be different from zero by a single measurement at a stated level of probability. Detection limits are analyte- and matrix-specific and may be laboratory-dependent.

Discrete Sample - A sample that represents a single location or short time interval. A discrete sample can be composed of more than one increment. The term has the same meaning as "individual sample."

Distribution - A probability function (density function, mass function, or distribution function) used to describe a set of observations (*statistical sample*) or a population from which the observations are generated.

Duplicate Samples - Two samples taken from and *representative* of the same population and carried through all steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess the *variance* of the total method, including sampling and analysis. See also *Colocated Sample* and *Field Duplicate Samples*.

Dynamic Work Plan - A work plan that allows the project team to make decisions in the field about how subsequent site activities will progress (for example, by use field analytical methods that provide near real-time sample analysis results). Dynamic work plans provide the strategy for how dynamic field activities will take place. As such, they document a flexible, adaptive sampling and analytical strategy. (Adopted from EPA Superfund web site at http://www.epa.gov/superfund/programs/dfa/dynwork.htm).

Environmental Conditions - The description of a physical medium (e.g., air, water, soil, sediment) or a biological system expressed in terms of its physical, chemical, radiological, or biological characteristics.

Environmental Data - Any measurements or information that describe environmental processes, location, or conditions; ecological or health effects and consequences; or the performance of environmental technology. For EPA, environmental data include information collected directly from measurements, produced from models, and compiled from other sources, such as data bases or the scientific literature.

Environmental Monitoring - The process of measuring or collecting environmental data for evaluating a change in the environment (e.g., ground-water monitoring).

Environmental Processes - Manufactured or natural processes that produce discharges to or that impact the ambient environment.

Equipment Blank - See *Rinsate*.

Estimate - A characteristic from the sample from which inferences about population *parameters* can be made.

Evaluation - See *validation*.

Evidentiary Records - Records identified as part of litigation and subject to restricted access, custody, use, and disposal.

False Negative (False Acceptance) Decision Error (β) - A false negative decision error occurs when the decision maker does not reject the null *hypothesis* when the null hypothesis actually is false. In statistical terminology, a false negative decision error also is called a Type II error. The measure of the size of the error is expressed as a probability, usually referred to as "beta" (β). This probability also is called the complement of power (where "power" is expressed as $(1-\beta)$).

False Positive (False Rejection) Decision Error (α) - A false positive decision error occurs when a decision maker rejects the null *hypothesis* when the null hypothesis is true. In statistical terminology, a false positive decision error also is called a Type I error. The measure of the size of the error is expressed as a probability, usually referred to as "alpha" (α), the "level of significance," or "size of the critical region."

Field Blank - A *blank* used to provide information about contaminants that may be introduced during sample collection, storage, and transport. The clean sample is carried to the sampling site, exposed to sampling conditions, returned to the laboratory, and treated as an environmental sample.

Field Duplicates - Independent samples that are collected as close as possible to the same point in space and time. Two separate samples are taken from the same source, stored in separate containers, and analyzed independently. These duplicates are useful in documenting the *precision* of the sampling process (from Chapter One, SW-846, July 1992).

Field (matrix) Spike - A sample prepared at the sampling point (i.e., in the field) by adding a known mass of the target analyte to a specified amount of the sample. Field matrix spikes are used, for example, to determine the effect of the sample preservation, shipment, storage, matrix, and preparation on analyte recovery efficiency (the analytical *bias*).

Field Split Samples - Two or more *representative* portions taken from the same sample and usually submitted for analysis to different laboratories to estimate interlaboratory *precision*.

Fundamental Error - The fundamental error results when discrete units of the material to be sampled have different compositions with respect to the property of interest. The error is referred to as "fundamental" because it is an incompressible minimum sampling error that depends on the mass, composition, shape, fragment size distribution, and liberation factor of the material and is not affected by homogenization or mixing. The fundamental error is the only error that remains when the sampling operation is "perfect," i.e., when all parts of the sample are obtained in a probabilistic manner and each part is independent. The fundamental error is never zero (unless the population is completely homogeneous or the entire population is submitted for exhaustive analysis) and it never "cancels out." It can be reduced by taking larger physical samples and by using particle-size reduction steps in preparing the analytical sample.

Geostatistics - A branch of statistics, originating in the mining industry and greatly developed in the 1950s, that assesses the spatial correlation among samples and incorporates this information into the estimates of population *parameters*.

Goodness-of-Fit Test - In general, the level of agreement between an observed set of values and a set wholly or partly derived from a model of the data.

Grab Sample - A one-time sample taken from any part of the waste (62 FR 91, page 26047, May 12, 1997).

Graded Approach - The process of basing the level of application of managerial controls applied to an item or work according to the intended use of the results and the degree of confidence needed in the quality of the results. (See also *Data Quality Objectives Process*.)

Gray Region - A range of values of the population *parameter* of interest (such as mean contaminant concentration) within which the consequences of making a *decision error* are relatively minor. The gray region is bounded on one side by the *action level*. The width of the gray region is denoted by Δ in this guidance.

Guidance - A suggested practice that is not mandatory, but rather intended as an aid or example in complying with a standard or requirement.

Guideline - A suggested practice that is nonmandatory in programs intended to comply with a standard.

Hazardous Waste - Any waste material that satisfies the definition of "hazardous waste" as given in 40 CFR Part 261, "Identification and Listing of Hazardous Waste."

Heterogeneity - The condition of the population under which items of the population are not identical with respect to the *parameter* of interest (ASTM D 6233-98). (See Section 6.2.1).

Holding Time - The period of time a sample may be stored prior to its required analysis. While exceeding the holding time does not necessarily negate the veracity of analytical results, it causes the qualifying or “flagging” of any data not meeting all of the specified acceptance criteria.

Homogeneity - The condition of the population under which all items of the population are identical with respect to the *parameter* of interest (ASTM D 6233-98). The condition of a population or lot in which the elements of that population or lot are identical; it is an inaccessible limit and depends on the “scale” of the elements.

Hot Spots - Strata that contain high concentrations of the *characteristic* of interest and are relatively small in size when compared with the total size of the materials being sampled (ASTM D 6009-96).

Hypothesis - A tentative assumption made to draw out and test its logical or empirical consequences. In hypothesis testing, the hypothesis is labeled "null" (for the baseline condition) or "alternative," depending on the decision maker's concerns for making a *decision error*. The baseline condition is retained until overwhelming evidence indicates that the baseline condition is false. See also *baseline condition*.

Identification Error - The misidentification of an analyte. In this error type, the contaminant of concern is unidentified and the measured concentration is incorrectly assigned to another contaminant.

Increment - A group of particles extracted from a batch of material in a single operation of the sampling device. It is important to make a distinction between an increment and a sample that is obtained by the reunion of several increments (from Pitard 1989).

Individual Sample - See *Discrete Sample*.

Inspection - The examination or measurement of an item or activity to verify *conformance* to specific requirements.

Internal Standard - A standard added to a test portion of a sample in a known amount and carried through the entire determination procedure as a reference for calibrating and assessing the *precision* and *bias* of the applied analytical method.

Item - An all-inclusive term used in place of the following: appurtenance, facility, sample, assembly, *component*, equipment, material, module, part, product, structure, subassembly, subsystem, system, unit, documented concepts, or data.

Laboratory Split Samples - Two or more *representative* portions taken from the same sample for laboratory analysis. Often analyzed by different laboratories to estimate the interlaboratory *precision* or variability and the data *comparability*.

Limit of Quantitation - The minimum concentration of an analyte or category of analytes in a specific matrix that can be identified and quantified above the method detection limit and within specified limits of *precision* and *bias* during routine analytical operating conditions.

Limits on Decision Errors - The tolerable maximum decision error probabilities established by the decision maker. Potential economic, health, ecological, political, and social consequences of decision errors should be considered when setting the limits.

Matrix Spike - A sample prepared by adding a known mass of a target analyte to a specified amount of sample matrix for which an independent estimate of the target analyte concentration is available. Spiked samples are used, for example, to determine the effect of the matrix on a method's recovery efficiency.

Mean (arithmetic) ($\bar{x}$) **-** The sum of all the values of a set of measurements divided by the number of values in the set; a measure of central tendency.

Mean Square Error (MSE) - A statistical term equivalent to the *variance* added to the square of the *bias*. An overall measure of the representativeness of a sample.

Measurement Error - The difference between the true or actual state and that which is reported from measurements.

Median - The middle value for an ordered set of n values. Represented by the central value when n is odd or by the average of the two most central values when n is even. The median is the 50th percentile.

Medium - A substance (e.g., air, water, soil) that serves as a carrier of the analytes of interest.

Method - A body of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, quantification) systematically presented in the order in which they are to be executed.

Method Blank - A *blank* prepared to represent the sample matrix as closely as possible and analyzed exactly like the *calibration* standards, samples, and QC samples. Results of method blanks provide an estimate of the within-batch variability of the blank response and an indication of *bias* introduced by the analytical procedure.

Natural Variability - The variability that is inherent or natural to the media, objects, or subjects being studied.

Nonparametric - A term describing statistical methods that do not assume a particular population probability distribution, and are therefore valid for data from any population with any probability distribution, which can remain unknown (Conover 1999).

Null Hypothesis - See *Hypothesis*.

Observation - (1) An *assessment* conclusion that identifies a condition (either positive or negative) that does not represent a significant impact on an item or activity. An observation may identify a condition that has not yet caused a degradation of quality. (2) A datum.

Outlier - An observation that is shown to have a low probability of belonging to a specified data population.

Parameter - A quantity, usually unknown, such as a mean or a standard deviation characterizing a population. Commonly misused for "variable," "*characteristic*," or "property."

Participant - When used in the context of environmental programs, an organization, group, or individual that takes part in the planning and design process and provides special knowledge or skills to enable the planning and design process to meet its objective.

Percent Relative Standard Deviation (%RSD) **-** The quantity, 100(RSD)%.

Percentile - The specific value of a distribution that divides the distribution such that *p* percent of the distribution is equal to or below that value. For example, if we say "the 95th percentile is X," then it means that 95 percent of the values in the *statistical sample* are less than or equal to X.

Planning Team - The group of people that will carry out the DQO Process. Members include the decision maker (senior manager), representatives of other data users, senior program and technical staff, someone with statistical expertise, and a QA/QC advisor (such as a QA Manager).

Population -The total collection of objects, media, or people to be studied and from which a sample is to be drawn. The totality of items or units under consideration (ASTM D 5956-96).

Precision - A measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions, expressed generally in terms of the sample standard deviation. See also the definition for *precision* in Chapter One, SW-846.

Probabilistic Sample - See *statistical sample*.

Process - A set of interrelated resources and activities that transforms inputs into outputs. Examples of processes include analysis, design, data collection, operation, fabrication, and calculation.

Qualified Data - Any data that have been modified or adjusted as part of statistical or mathematical evaluation, data *validation*, or data verification operations.

Quality - The totality of features and characteristics of a product (including data) or service that bears on its ability to meet the stated or implied needs and expectations of the user (i.e., fitness for use).

Quality Assurance (QA) - An integrated system of management activities involving planning, implementation, *assessment*, reporting, and quality improvement to ensure that a process, item, or service is of the type and quality needed and expected by the client.

Quality Assurance Manager - The individual designated as the principal manager within the organization having management oversight and responsibilities for planning, coordinating, and assessing the effectiveness of the quality system for the organization.

Quality Assurance Project Plan (QAPP) - A formal document describing, in comprehensive detail, the necessary QA, QC, and other technical activities that must be implemented to ensure that the results of the work performed will satisfy the stated performance criteria.

Quality Control (QC) - The overall system of technical activities that measures the attributes and performance (quality characteristics) of a process, item, or service against defined standards to verify that they meet the stated requirements established by the customer. Operational techniques and activities that are used to fulfill requirements for quality. The system of activities and checks used to ensure that measurement systems are maintained within prescribed limits, providing protection against “out-of-control” conditions and ensuring the results are of acceptable quality.

Quality Control (QC) Sample - An uncontaminated sample matrix spiked with known amounts of analytes from a source independent of the *calibration* standards. Generally used to establish intralaboratory or analyst-specific *precision* and *bias* or to assess the performance of all or a portion of the measurement system.

Quality Management - That aspect of the overall management system of the organization that determines and implements the quality policy. Quality management includes strategic planning, allocation of resources, and other systematic activities (e.g., planning, implementation, and *assessment*) pertaining to the quality system.

Quality Management Plan - A formal document that describes the quality system in terms of the organization’s structure, the functional responsibilities of management and staff, the lines of authority, and the required interfaces for those planning, implementing, and assessing all activities conducted.

Quality System - A structured and documented management system describing the policies, objectives, principles, organizational authority, responsibilities, accountability, and implementation plan of an organization for ensuring quality in its work processes, products (items), and services. The quality system provides the framework for planning, implementing, and assessing work performed by the organization and for carrying out required QA and QC.

Random Error - The chance variation encountered in all measurement work, characterized by the random occurrence of deviations from the mean value.

Range - The numerical difference between the minimum and maximum of a set of values.

Relative Standard Deviation - See *Coefficient of Variation*.

Remediation - The process of reducing the concentration of a contaminant (or contaminants) in air, water, or soil media to a level that poses an acceptable risk to human health.

Repeatability - The degree of agreement between independent test results produced by the same analyst using the same test method and equipment on random aliquots of the same sample within a short time period; that is, within-rum precision of a method or set of measurements.

Reporting Limit - The lowest concentration or amount of the target analyte required to be reported from a data collection project. Reporting limits are generally greater than detection limits and usually are not associated with a probability level.

Representative Sample - RCRA regulations define a representative sample as “a sample of a universe or whole (e.g., waste pile, lagoon, ground water) which can be expected to exhibit the average properties of the universe or whole" (40 CFR § 260.10).

Representativeness - A measure of the degree to which data accurately and precisely represent a *characteristic* of a population, parameter variations at a sampling point, a process condition, or an environmental condition.

Reproducible - The condition under which there is no statistically significant difference in the results of measurements of the same sample made at different laboratories.

Reproducibility - The degree of agreement between independent test results produced by the same method or set of measurements for very similar, but not identical, conditions (e.g., at different times, by different technicians, using different glassware, laboratories, or samples); that is, the between-run precision of a method or set of measurements.

Requirement - A formal statement of a need and the expected manner in which it is to be met.

Rinsate (Equipment Rinsate) - A sample of analyte-free medium (such as HPLC-grade water for organics or reagent-grade deionized or distilled water for inorganics) which has been used to rinse the sampling equipment. It is collected after completion of decontamination and prior to sampling. This *blank* is useful in documenting the adequate decontamination of sampling equipment (modified from Chapter One, SW-846).

Sample - A portion of material that is taken from a larger quantity for the purpose of estimating the properties or the composition of the larger quantity (ASTM D 6233-98).

Sample Support - See *Support*.

Sampling - The process of obtaining *representative* samples and/or measurements of a population or subset of a population.

Sampling Design Error - The error due to observing only a limited number of the total possible values that make up the population being studied. It should be distinguished from: errors due to imperfect selection; *bias* in response; and errors of observation, measurement, or recording, etc.

Scientific Method - The principles and processes regarded as necessary for scientific investigation, including rules for concept or *hypothesis* formulation, conduct of experiments, and validation of hypotheses by analysis of observations.

Sensitivity - The capability of a method or instrument to discriminate between measurement responses representing different levels of a variable of interest (i.e., the slope of the calibration).

Set of Samples - More than one individual sample.

Split Samples - Two or more *representative* portions taken from one sample and often analyzed by different analysts or laboratories as a type of QC sample used to assess analytical variability and *comparability*.

Standard Deviation - A measure of the dispersion or imprecision of a sample or population distribution expressed as the positive square root of the *variance* and that has the same unit of measurement as the mean. See *variance*.

Standard Operating Procedure (SOP) - A written document that details the method for an operation, analysis, or action with thoroughly prescribed techniques and steps and that is officially approved (usually by the quality assurance officer) as the method for performing certain routine or repetitive tasks.

Statistic - A function of the sample measurements; e.g., the sample mean or standard deviation. A statistic usually, but not necessarily, serves as an estimate of a population *parameter*. A summary value calculated from a sample of observations.

Statistical Sample - A set of samples or measurements selected by probabilistic means (i.e., by using some form of randomness). Also known as a *probabilistic sample*.

Statistical Test - Any statistical method that is used to determine the acceptance or rejection of a hyothesis.

Stratum - A subgroup of a population separated in space or time, or both, from the remainder of the population and being internally consistent with respect to a target constituent or property of interest and different from adjacent portions of the population (ASTM D 5956-96).

Subsample - A portion of material taken from a larger quantity for the purpose of estimating properties or the composition of the whole sample (ASTM D 4547-98).

Support - The physical volume or mass, orientation, and shape of a sample, subsample, or decision unit.

Surrogate Spike or Analyte - A pure substance with properties that mimic the analyte of interest. It is unlikely to be found in environmental samples and is added to them to establish that the analytical method has been performed properly.

Technical Review - A documented critical review of work that has been performed within the state of the art. The review is accomplished by one or more qualified reviewers who are independent of those who performed the work, but are collectively equivalent in technical expertise to those who performed the original work. The review is an indepth analysis and evaluation of documents, activities, material, data, or items that require technical verification or *validation* for applicability, correctness, adequacy, *completeness*, and assurance that established requirements are satisfied.

Total Study Error - The combination of sampling design error and measurement error.

Traceability - The ability to trace the history, application, or location of an entity by means of recorded identifications. In a *calibration* sense, traceability relates measuring equipment to national or international standards, primary standards, basic physical constants or properties, or reference materials. In a data collection sense, it relates calculations and data generated throughout the project back to the requirements for the project's quality.

Trip Blank - A clean sample of a matrix that is taken to the sampling site and transported to the laboratory for analysis without having been exposed to sampling procedures. A trip blank is used to document contamination attributable to shipping and field handling procedures. This type of *blank* is useful in documenting contamination of volatile organics samples.

True - Being in accord with the actual state of affairs.

Type I Error (α) - A Type I error occurs when a decision maker rejects the null *hypothesis* when it is actually true. See also *False Positive Decision Error*.

Type II Error (β) - A Type II error occurs when the decision maker fails to reject the null *hypothesis* when it is actually false. See also *False Negative Decision Error*.

User - When used in the context of environmental programs, an organization, group, or individual that utilizes the results or products from environmental programs. A user also may be the client for whom the results or products were collected or created.

Vadose Zone - In soil, the unsaturated zone, limited above by the ground surface and below by the saturated zone.

Validation - Confirmation by examination and provision of objective evidence that the particular requirements for a specific intended use are fulfilled. In design and development, *validation* concerns the process of examining a product or result to determine *conformance* to user needs.

Variable - The attribute of the environment that is indeterminant. A quantity which may take any one of a specified set of values.

Variance - A measure of the variability or dispersion in (1) a population (population variance, σ^2), or (2) a sample or set of subsamples (sample variance, s^2). The variance is the second moment of a frequency distribution taken about the arithmetic mean as the origin. For a normal distribution, it is the sum of the squared deviations of the (population or sample) member observation about the (population or sample) mean divided by the degrees of freedom (N for σ^2 , or $n-1$ for s^2).

Verification - Confirmation by examination and provision of objective evidence that specified requirements have been fulfilled. In design and development, verification concerns the process of examining a result of a given activity to determine *conformance* to the stated requirements for that activity.

APPENDIX B

SUMMARY OF RCRA REGULATORY DRIVERS FOR CONDUCTING WASTE SAMPLING AND ANALYSIS

Through RCRA, Congress provided EPA with the framework to develop regulatory programs for the management of solid and hazardous waste. The provisions of RCRA Subtitle C establish the criteria for identifying hazardous waste and managing it from its point of generation to ultimate disposal. EPA's regulations set out in 40 CFR Parts 260 to 279 are the primary reference for information on the hazardous waste program. These regulations include provisions for waste sampling and testing and environmental monitoring. Some of these RCRA regulations require sampling and analysis, while others do not specify requirements and allow sampling and analysis to be performed at the discretion of the waste handler or as specified in individual facility permits.

Table B-1 provides a comprehensive listing of the regulatory citations, the applicable RCRA standards, requirements for demonstrating attainment or compliance with the standards, and relevant USEPA guidance documents. The table is divided into three major sections addressing regulations for (1) hazardous waste identification, (2) land disposal restrictions, and (3) other programs. The table is meant to be used as a general reference guide. Consult the latest 40 CFR, related *Federal Register* notices, and EPA's World Wide Web site (www.epa.gov) for new or revised regulations and further clarification and definitive articulation of requirements. In addition, because some states have requirements that differ from EPA regulations and guidance, we recommend that you consult with a representative from your State if your State is authorized to implement the regulation.

Table B-1. Summary of Waste Analysis Drivers for Major RCRA Regulatory Program Areas

40 CFR Citation and Description	***Applicable Standards***	***Requirements for Demonstrating Attainment of or Compliance With the Standards***	***Relevant USEPA Guidance***
Waste Analysis Drivers for the Hazardous Waste Identification Program			
§261.3(a)(2)(v) - Used oil rebuttable presumption (see also Part 279, Subpart B and the Part 279 standards for generators, transporters, processors, re-refiners, and burners.)	Used oil that contains more than 1,000 parts per million (ppm) of total halogens is presumed to have been mixed with a regulated halogenated hazardous waste (e.g., spent halogenated solvents), and is therefore subject to applicable hazardous waste regulations. The rebuttable presumption does not apply to metalworking oils and oils from refrigeration units, under some circumstances.	A person may rebut this presumption by demonstrating, through analysis or other documentation, that the used oil has not been mixed with halogenated hazardous waste. One way of doing this is to show that the used oil does not contain significant concentrations of halogenated hazardous constituents (50 FR 49176; November 29, 1985). If the presumption is successfully rebutted, then the used oil will be subject to the used oil management standards instead of the hazardous waste regulations.	*Hazardous Waste Management System; Identification and Listing of Hazardous Waste; Recycled Used Oil Management Standards*, 57 FR 41566; September 10, 1992 *Part 279 Requirements: Used Oil Management Standards*, EPA530-H-98-001
§261.3(c)(2)(ii)(C) - Generic exclusion levels for K061, K062, and F006 nonwastewater HTMR residues	To be excluded from the definition of hazardous waste, residues must meet the generic exclusion levels specified at §261.3(c)(2)(ii)(C)(*1*) and exhibit no characteristics of hazardous waste.	Testing requirements must be incorporated in a facility's waste analysis plan or a generator's self-implementing waste analysis plan. At a minimum, composite samples of residues must be collected and analyzed quarterly and/or when the process or operation generating the waste changes. Claimant has the burden of proving by clear and convincing evidence that the material meets all of the exclusion requirements.	*Waste Analysis at Facilities That Generate, Treat, Store, and Dispose of Hazardous Wastes, a Guidance Manual*, EPA530-R-94-024 (USEPA 1994a)

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40 CFR Citation and Description	***Applicable Standards***	***Requirements for Demonstrating Attainment of or Compliance With the Standards***	***Relevant USEPA Guidance***
Waste Analysis Drivers for the Hazardous Waste Identification Program (continued)			
§261.21- Characteristic of Ignitability	A solid waste exhibits the characteristic of ignitability if a representative sample of the waste is: (1) A liquid having a flashpoint of less than 140 degrees Fahrenheit (60 degrees Centigrade); (2) A non-liquid which causes fire through friction, absorption of moisture, or spontaneous chemical changes and, when ignited, burns so vigorously and persistently it creates a hazard; (3) An ignitable compressed gas; or (4) An oxidizer. (Aqueous solutions with alcohol content less than 24% are not regulated.)	If a representative sample of the waste exhibits the characteristic, then the waste exhibits the characteristic. Appendix I of 40 CFR Part 261 contains references to representative sampling methods; however a person may employ an alternative method without formally demonstrating equivalency. Also, for those methods specifically prescribed by regulation, the generator can petition the Agency for the use of an alternative method (see 40 CFR 260.21).	See Chapters Seven and Eight in *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, Updates I, II, IIA, IIB, III, and IIIA. SW-846*. (USEPA 1986a)
§261.22 - Characteristic of Corrosivity	A solid waste exhibits the characteristic of corrosivity if a representative sample of the waste is: (1) Aqueous, with a pH less than or equal to 2, or greater than or equal to 12.5; or (2) Liquid and corrodes steel at a rate greater than 6.35 mm per year when applying a National Association of Corrosion Engineers Standard Test Method.	If a representative sample of the waste exhibits the characteristic, then the waste exhibits the characteristic. Appendix I of 40 CFR Part 261 contains references to representative sampling methods; however a person may employ an alternative method without formally demonstrating equivalency. Also, for those methods specifically prescribed by regulation, the generator can petition the Agency for the use of an alternative method (see 40 CFR 260.21).	See Chapters Seven and Eight in *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, Updates I, II, IIA, IIB, III, and IIIA. SW-846*. (USEPA 1986a)

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40 CFR Citation and Description	*Applicable Standards*	*Requirements for Demonstrating Attainment of or Compliance With the Standards*	*Relevant USEPA Guidance*
Waste Analysis Drivers for the Hazardous Waste Identification Program (continued)			
§261.23 - Characteristic of Reactivity	A solid waste exhibits the characteristic of reactivity if a representative sample of the waste: (1) Is normally unstable and readily undergoes violent change; (2) Reacts violently with water; (3) Forms potentially explosive mixtures with water; (4) Generates toxic gases, vapors, or fumes when mixed with water; (5) Is a cyanide or sulfide-bearing waste which, when exposed to pH conditions between 2 and 12.5, can generate toxic gases, vapors, or fumes; (6) Is capable of detonation or explosion if subjected to a strong initiating source or if heated under confinement; (7) Is readily capable of detonation or explosive decomposition or reaction at standard temperature and pressure; or (8) Is a forbidden explosive as defined by DOT.	EPA relies on these narrative criterion to define reactive wastes. Waste handlers should use their knowledge to determine if a waste is sufficiently reactive to be regulated. Also, for those methods specifically prescribed by regulation, the generator can petition the Agency for the use of an alternative method (see 40 CFR 260.21).	EPA currently relies on narrative standards to define reactive wastes, and withdrew interim guidance related to sulfide and cyanide levels (see a Memorandum entitled, Withdrawal of Cyanide and Sulfide Reactivity Guidance" from David Bussard and Barnes Johnson to Diana Love, dated April 21, 1998).
§ 261.24 - Toxicity Characteristic	A solid waste exhibits the characteristic of toxicity if the extract of a representative sample of the waste contains any of the contaminants listed in Table 1 in 261.24, at or above the specified regulatory levels. The extract should be obtained through use of the Toxicity Characteristic Leaching Procedure (TCLP). If the waste contains less than .5 percent filterable solids, the waste itself, after filtering, is considered to be the extract.	Appendix I of 40 CFR Part 261 contains references to representative sampling methods; however, a person may employ an alternative method without formally demonstrating equivalency.	See Chapters Seven and Eight in *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, Updates I, II, IIA, IIB, III, and IIIA. SW-846*. (USEPA 1986a)

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40 CFR Citation and Description	***Applicable Standards***	***Requirements for Demonstrating Attainment of or Compliance With the Standards***	***Relevant USEPA Guidance***
Waste Analysis Drivers for the Hazardous Waste Identification Program (continued)			
§261.38(c)(8)(iii)(A) - Exclusion of Comparable Fuels from the Definition of Solid and Hazardous Waste	For each waste for which an exclusion is claimed, the generator of the hazardous waste must test for all of the constituents on Appendix VIII to part 261, except those that the generator determines, based on testing or knowledge, should not be present in the waste. The generator is required to document the basis for each determination that a constituent should not be present.	For waste to be eligible for exclusion, a generator must demonstrate that "each constituent of concern is not present in the waste above the specification level at the 95% upper confidence limit around the mean."	See the final rule from June 19,1998 (63 *FR* 33781) For further information on the comparable fuels exclusion, see the following web site: http://www.epa.gov/combustion/fastrack/
Part 261- Appendix I - Representative Sampling Methods	Provides sampling protocols for obtaining a representative sample.	For the purposes of Subpart C, a sample obtained using Appendix I sampling methods will be considered representative. The Appendix I methods, however, are not formally adopted (see comment at §261.20(c)).	*Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, Updates I, II, IIA, IIB, III, and IIIA. SW-846*. (USEPA 1986a) ASTM Standards

Table B-1. Summary of Waste Analysis Drivers for Major RCRA Regulatory Program Areas

40 CFR Citation and Description	***Applicable Standards***	***Requirements for Demonstrating Attainment of or Compliance With the Standards***	***Relevant USEPA Guidance***
Waste Analysis Drivers for the Land Disposal Restriction Program			
§268.6(b)(1) - Petitions to Allow Land Disposal of a Waste Prohibited Under Subpart C of Part 268 (No-Migration Petition)	The demonstration must meet the following criteria: (1) All waste and environmental sampling, test, and analysis data must be accurate and reproducible to the extent that state-of-the-art techniques allow; (2) All sampling, testing, and estimation techniques for chemical and physical properties of the waste and all environmental parameters must have been approved by the EPA Administrator.	• Waste analysis requirements will be specific to the petition. • Sampling methods are specified in the facility's Waste Analysis Plan.	*Waste Analysis at Facilities That Generate, Treat, Store, and Dispose of Hazardous Wastes, a Guidance Manual*, EPA530-R-94-024 (USEPA 1994a) *Land Disposal Restrictions No Migration Variances; Proposed Rule.* Federal Register, August 11, 1992 (USEPA 1992)
§268.40 - Land Disposal Restriction (LDR) concentration-level standards	For total waste standards, all hazardous constituents in the waste or in the treatment residue must be at or below the values in the table at 268.40. For waste extract standards, the hazardous constituents in the extract of the waste or in the extract of the treatment residue must be at or below the values in the table at 268.40.	• Sampling methods are specified in the facility's Waste Analysis Plan. • Compliance with the standards for nonwastewater is measured by an analysis of grab samples. Compliance with wastewater standards is based on composite samples. No single sample may exceed the applicable standard.	*Waste Analysis at Facilities That Generate, Treat, Store, and Dispose of Hazardous Wastes, a Guidance Manual*, EPA530-R-94-024 (USEPA 1994a)

Table B-1. Summary of Waste Analysis Drivers for Major RCRA Regulatory Program Areas

40 CFR Citation and Description	***Applicable Standards***	***Requirements for Demonstrating Attainment of or Compliance With the Standards***	***Relevant USEPA Guidance***
Waste Analysis Drivers for the Land Disposal Restriction Program (continued)			
§268.44 - Land Disposal Restriction Treatability Variance	If you are a generator or treatment facility whose wastes cannot be treated to achieve the established treatment standards, or for which treatment standards are not appropriate, you may petition EPA for a variance from the treatment standard. A treatment variance does not exempt your wastes from treatment, but rather establishes an alternative LDR treatment standard.	The application must demonstrate that the treatment standard for the waste in question is either "unachievable" or "inappropriate."	Memorandum entitled "*Use of Site-Specific Land Disposal Restriction Treatability Variances Under 40 CFR 268.44(h) During Cleanups*" (Available from the RCRA Call Center or on EPA's web site at http://www.epa.gov/epaoswer/hazwaste/ldr/tv-rule/guidmem.txt Variance Assistance Document: Land Disposal Restrictions Treatability Variances & Determinations of Equivalent Treatment (available from the RCRA Call Center or on EPA's web site at http://www.epa.gov/epaoswer/hazwaste/ldr/guidance2.pdf
§268.49(c)(1) - Alternative LDR Treatment Standards for Contaminated Soil	All constituents subject to treatment must be treated as follows: (A) For non-metals, treatment must achieve 90 percent reduction in total constituent concentrations except where treatment results in concentrations less that 10 times the Universal Treatment Standard (UTS) at 268.48. (B) For metals, treatment must achieve 90 percent reduction in constituent concentrations as measured in TCLP leachate from the treated media or 90 percent reduction in total concentrations when a metal removal technology is used, except where treatment results in concentrations less that 10 times the UTS at 268.48.	Sampling methods are specified in the facility's Waste Analysis Plan.	*Guidance on Demonstrating Compliance With the Land Disposal Restrictions (LDR) Alternative Soil Treatment Standards* (USEPA 2002) *Waste Analysis at Facilities That Generate, Treat, Store, and Dispose of Hazardous Wastes, a Guidance Manual*, EPA530-R-94-024 (USEPA 1994a)

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40 CFR Citation and Description	***Applicable Standards***	***Requirements for Demonstrating Attainment of or Compliance With the Standards***	***Relevant USEPA Guidance***
Waste Analysis Drivers in Other RCRA Regulations			
§260.10 - Definitions	"Representative sample" means a sample of a universe or whole (e.g. waste pile, lagoon, ground water) which can be expected to exhibit the average properties of the universe or whole.	Representative samples may be required to measure compliance with various provisions within the RCRA regulations. See requirements specified in the applicable regulation or implementation guidance.	*Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, Updates I, II, IIA, IIB, III, and IIIA. SW-846*. (USEPA 1986a)
Part 260 - Subpart C - Rulemaking Petitions	In the section for petitions to amend Part 261 to "delist" a hazardous waste, the petitioner must demonstrate that the waste does not meet any of the criteria under which the waste was listed as a hazardous waste (§260.22).	Demonstration samples must consist of enough representative samples, but in no case less than four samples, taken over a period of time sufficient to represent the variability or the uniformity of the waste.	*Petitions to Delist Hazardous Waste–A Guidance Manual*. 2nd ed. (USEPA 1993d) *Region 6 RCRA Delisting Program Guidance Manual for the Petitioner* (USEPA 1996d)
Part 262 - Subpart A - Purpose, Scope, and Applicability (including §262.11 - Hazardous Waste Determination)	Generators must make the following determinations if a secondary material is a solid waste: 1) whether the solid waste is excluded from regulation; 2) whether the waste is a listed waste; and 3) whether the waste is characteristic waste (§262.11)	Generators must document their waste determination and land disposal restriction determination.	*Waste Analysis at Facilities That Generate, Treat, Store, and Dispose of Hazardous Wastes, a Guidance Manual*, EPA530-R-94-024 (USEPA 1994a)
Part 262 - Subpart C - Pre-Transport Requirements	Under §262.34(a)(4), if generators are performing treatment within their accumulation units, they must comply with the waste analysis plan requirements of §268.7(a)(5).	Generators must develop a waste analysis plan (kept on-site for three years) which details the treatment they are performing to meet LDR treatment standards and the type of analysis they are performing to show completion of treatment.	*Waste Analysis at Facilities That Generate, Treat, Store, and Dispose of Hazardous Wastes, a Guidance Manual*, EPA530-R-94-024 (USEPA 1994a)

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40 CFR Citation and Description	***Applicable Standards***	***Requirements for Demonstrating Attainment of or Compliance With the Standards***	***Relevant USEPA Guidance***
	Waste Analysis Drivers in Other RCRA Regulations (continued)		
Part 264 - Subpart A - Purpose, Scope, and Applicability	§264.1(j)(2) - In an exemption established by the HWIR-media rulemaking, remediation waste can be exempt under circumstances that require chemical and physical analysis of a representative sample of the hazardous remediation waste to be managed at the site.	The analysis, at a minimum, must contain all the information needed to treat, store, or dispose of the waste according to Part 264 and Part 268. The waste analysis must be accurate and up-to-date.	See the final *Federal Register* notice from November 30, 1998 (63 *FR* 65873) For further documentation, see the following web site: http://www.epa.gov/epaoswer/hazwaste/id/hwirmdia.htm
Parts 264/265 - Subpart B - General Facility Standards	§264/265.13 - General waste analysis requirements specify: (a) Detailed chemical and physical analysis of a representative sample is required before an owner treats, stores, or disposes of any hazardous waste. Sampling method may be those under Part 261; and (b) Owner/operator must develop and follow a written waste-analysis plan.	All requirements are case-by-case and are determined in the facility permit.	*Waste Analysis at Facilities That Generate, Treat, Store, and Dispose of Hazardous Wastes, a Guidance Manual*, EPA530-R-94-024 (USEPA 1994a)

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40 CFR Citation and Description	***Applicable Standards***	***Requirements for Demonstrating Attainment of or Compliance With the Standards***	***Relevant USEPA Guidance***
Waste Analysis Drivers in Other RCRA Regulations (continued)			
Part 264 - Subpart F - Groundwater Monitoring	Groundwater monitoring wells must be properly installed so that samples will yield representative results. All monitoring wells must be lined, or cased, in a manner that maintains the integrity of the monitoring well bore hole (§264.97(c)). Poorly installed wells may give false results. There are specific monitoring standards for all three sub-programs: • Detection Monitoring (§264.98); • Compliance Monitoring (§264.99); and • Corrective Action Program (§264.100). The Corrective Action Program is specific to the Groundwater Monitoring Program.	At a minimum, there must be procedures and techniques for sample collection, sample preservation and shipment, analytical procedures, and chain-of-custody control (§264.97(d)). Sampling and analytical methods must be appropriate for groundwater sampling and accurately measure the hazardous constituents being analyzed. The owner and operator must develop an appropriate sampling procedure and interval for each hazardous constituent identified in the facility's permit. The owner and operator may use an alternate procedure if approved by the RA. Requirements and procedures for obtaining and analyzing samples are detailed in the facility permit, usually in a Sampling and Analysis Plan.	*Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities (Interim Final Guidance)*. Office of Solid Waste (USEPA 1989b) *RCRA Ground-Water Monitoring: Draft Technical Guidance*. (USEPA 1992c) *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities Addendum to Interim Final Guidance* (USEPA 1992b) *Methods for Evaluating the Attainment of Cleanup Standards. Volume 2: Ground Water* (USEPA. 1992i)

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40 CFR Citation and Description	***Applicable Standards***	***Requirements for Demonstrating Attainment of or Compliance With the Standards***	***Relevant USEPA Guidance***
Waste Analysis Drivers in Other RCRA Regulations (continued)			
Part 265 - Subpart F - Ground-water Monitoring	To comply with Part 265, Subpart F, the owner/operator must install, operate, and maintain a ground-water monitoring system capable of representing the background groundwater quality and detecting any hazardous constituents that have migrated from the waste management area to the uppermost aquifer. Under Part 265, Subpart F, there are two types of groundwater monitoring programs: an indicator evaluation program designed to detect the presence of a release, and a ground-water quality assessment program that evaluates the nature and extent of contamination.	To determine existing ground-water conditions at an interim status facility, the owner and operator must install at least one well hydraulically upgradient from the waste management area. The well(s) must be able to accurately represent the background quality of ground water in the uppermost aquifer. The owner and operator must install at least three wells hydraulically downgradient at the limit of the waste management area, which are able to immediately detect any statistically significant evidence of a release. A separate monitoring system for each management unit is not required as long as the criteria in §265.91(a) are met and the system is able to detect any release at the edge of the waste management area.	*Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities (Interim Final Guidance)*. Office of Solid Waste (USEPA 1989b) *RCRA Ground-Water Monitoring: Draft Technical Guidance*. (USEPA 1992c) *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities Addendum to Interim Final Guidance* (USEPA 1992b)
Part 264/265 - Subpart G - Closure and Post-Closure	The closure plan must include a detailed description of the steps for sampling and testing surrounding soils and criteria for determining the extent of decontamination required to satisfy the closure performance standards. (§264/265.112(b)(4))	All requirements are facility-specific and are set forth in the facility permit.	Closure/Postclosure Interim Status Standards (40 CFR 265, Subpart G): Standards Applicable to Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities Under RCRA, Subtitle C, Section 3004 *RCRA Guidance Manual for Subpart G Closure and Postclosure Care Standards and Subpart H Cost Estimating Requirements* (USEPA 1987)

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Waste Analysis Drivers in Other RCRA Regulations (continued)			
Part 264 - Subpart I - Use and Management of Containers	Spilled or leaked waste and accumulated precipitation must be removed from the sump or collection area in as timely a manner as is necessary to prevent overflow of the collection system (§264.175).	If the collected material is a hazardous waste under part 261 of this Chapter, it must be managed as a hazardous waste in accordance with all applicable requirements of parts 262 through 266 of the chapter. If the collected material is discharged through a point source to waters of the United States, it is subject to the requirements of section 402 of the Clean Water Act, as amended. Testing scope and requirements are site-specific and are set forth in the facility waste analysis plan.	*Waste Analysis at Facilities That Generate, Treat, Store, and Dispose of Hazardous Wastes, a Guidance Manual*, EPA530-R-94-024 (USEPA 1994a) *Guidance for Permit Writers: Facilities Storing Hazardous Waste in Containers*, 11/2/82, PB88-105 689 *Model RCRA Permit for Hazardous Waste Management Facilities*, 9/15/88, EPA530-SW-90-049
Parts 264/265 - Subpart J - Tank Systems	Demonstrate the absence or presence of free liquids in the stored/treated waste using EPA Method 9095 (Paint Filter Liquid Tests) of SW-846 (§§264/265.196).	The Paint Filter Liquid Test is a positive or negative test.	*Method 9095* of *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, Updates I, II, IIA, IIB, III, and IIIA. SW-846*. (USEPA 1986a)

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Waste Analysis Drivers in Other RCRA Regulations (continued)			
Part 264/265 - Subpart M - Land Treatment	To demonstrate adequate treatment (treatment demonstration), the permittee must perform testing, analytical, design, and operating requirements. (§264.272) Demonstration that food-chain crops can be grown on a treatment unit can include sample collection with criteria for sample selection, sample size, analytical methods, and statistical procedures. (§264/265.276) Owner/operator must collect pore-water samples and determine if there has been a statistically significant change over background using procedures specified in the permit. (§264/265.278) During post-closure period, owner may conduct pore-water and soil sampling to determine if there has been a statistically significant change in the concentration of hazardous constituents. (§264/265.280)	All requirements are facility-specific and are set forth in the facility permit.	See Chapters Twelve in *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, Updates I, II, IIA, IIB, III, and IIIA. SW-846*. (USEPA 1986a) *Guidance Manual on Hazardous Waste Land Treatment Closure/Postclosure (40 CFR Part 265)*, 4/14/87, PB87-183 695 *Hazardous Waste Land Treatment*, 4/15/83, SW-874 *Permit Applicants' Guidance Manual for Hazardous Waste Land Treatment, Storage, and Disposal Facilities; Final Draft*, 5/15/84, EPA530-SW-84-004 *Permit Guidance Manual on Hazardous Waste Land Treatment Demonstrations*, 7/15/86, EPA530-SW-86-032 *Permit Guidance Manual on Unsaturated Zone Monitoring for Hazardous Waste Land Treatment Units*, 10/15/86, EPA530-SW-86-040

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Waste Analysis Drivers in Other RCRA Regulations (continued)			
Part 264 - Subpart O - Incinerators	There are waste analysis requirements to verify that waste fed to the incinerator is within physical and chemical composition limits specified in the permit. (§§264/265.341) The owner/operator must conduct sampling and analysis of the waste and exhaust emissions to verify that the operating requirements established in the permit achieve the performance standards of §264.343 (§§264/265.347)	All requirements are facility-specific and are set forth in the facility permit.	See Chapter Thirteen in *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, Updates I, II, IIA, IIB, III, and IIIA. SW-846*. (USEPA 1986a)

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Waste Analysis Drivers in Other RCRA Regulations (continued)			
Corrective Action for Solid Waste Management Units	EPA includes corrective action in permits through the following statutory citations: Section 3008(h) - provides authority to require corrective action at interim status facilities Section 3004(u) - requires corrective action be addressed as a condition of a facility's Part B permit Section 3004(v) - provides authority to require corrective action for releases migrating beyond the facility boundary Section 3005(c)(3) - provides authority to include additional requirements in a facility's permit, including corrective action requirements Section 7003 - gives EPA authority to take action when contamination presents an imminent hazard to human health or the environment	Often the first activity in the corrective action process is the RCRA facility Assessment (RFA), which identifies potential and actual releases from solid waste management units (SWMUs) and make preliminary determinations about releases, the need for corrective action, and interim measures. Another activity in the corrective action process is the RCRA Facility Investigation (RFI), which takes place when a release has been identified and further investigation is necessary. The purpose of the RFI is to gather enough data to fully characterize the nature, extent, and rate of migration of contaminants to determine the appropriate response action. Once the implementing agency has selected a remedy, the facility enters the Corrective Measures Implementation (CMI) phase, in which the owner and operator of the facility implements the chosen remedy. Corrective action may include various sampling and monitoring requirements.	There is a substantial body of guidance and publications related to RCRA corrective action. See the following link for further information: http://www.epa.gov/epaoswer/hazwaste/ca/resource.htm
§264.552 - Corrective Action Management Units	There are ground-water monitoring, closure, and post-closure requirements for CAMUs.	All requirements are case-by-case and are determined in the facility permit.	There are numerous guidance documents available. See the following link for further information: http://www.epa.gov/epaoswer/hazwaste/ca/resource.htm

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Waste Analysis Drivers in Other RCRA Regulations (continued)			
Parts 264/265 - Subpart AA - Air Emission Standards	The following types of units are subject to the Subpart AA process vent standards: • Units subject to the permitting standards of Part 270 (i.e., permitted or interim status) • Recycling units located at hazardous waste management facilities otherwise subject to the permitting standards of Part 270 (i.e., independent of the recycling unit, the facility has a RCRA permit or is in interim status) • Less than 90-day large quantity generator units.	Testing and statistical methods are specified in the regulations at §264.1034(b).	The primary source of guidance is the regulations. See also the final rulemakings that promulgated the regulations: June 21, 1990 (55 *FR* 25494) November 25, 1996 (62 *FR* 52641) June 13, 1997 (62 *FR* 32462)
Parts 264/265 - Subpart BB - Air Emission Standards	The following types of units are subject to the Subpart BB equipment leak standards: • Units subject to the permitting standards of Part 270 (i.e., permitted or interim status) • Recycling units located at hazardous waste management facilities otherwise subject to the permitting standards of Part 270 (i.e., independent of the recycling unit, the facility already has a RCRA permit or is in interim status) • Less than 90-day large quantity generator units	The standards specify the type and frequency of all inspection and monitoring activities required. These requirements vary depending on the piece of equipment at the facility. Testing and statistical methods are specified in the regulations at §264.1063(c).	The primary source of guidance is the regulations. See also the final rulemakings that promulgated the regulations: June 21, 1990 (55 *FR* 25494) June 13, 1997 (62 *FR* 32462)

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Waste Analysis Drivers in Other RCRA Regulations (continued)			
§266.112 - Regulation of Residues	A residue from the burning or processing of hazardous waste may be exempt from hazardous waste determination if the waste derived residue is either: substantially similar to normal residue or below specific health based levels for both metal and nonmetal constituents.	Concentrations must be determined based on analysis of one or more samples obtained over a 24-hour period. Multiple samples may be analyzed and composite samples may be used provided the sampling period does not exceed 24 hours. If more than one sample is analyzed to represent the 24-hour period, the concentration shall be the arithmetic mean of the concentrations in the samples.	The regulations under §266.112 have specific sampling and analysis requirements Part 266, Appendix IX
Part 270 - Subpart B - Permit Application, Hazardous Waste Permitting	Provides the corresponding permit requirement to the general requirements (including the requirement for a waste analysis plan) under §270.14. There are also unit-specific waste analysis, monitoring, and sampling requirements incinerators (§270.19) and boilers and industrial furnaces (§270.22). There are also specific requirements for dioxin listings handled in waste piles (§270.18) and landfills (§270.21).	The permittee must conduct appropriate sampling procedures, and retain results of all monitoring. All requirements are facility specific and are set forth in the permit and waste analysis plan.	*Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, Updates I, II, IIA, IIB, III, and IIIA. SW-846*. (USEPA 1986a) *Waste Analysis at Facilities That Generate, Treat, Store, and Dispose of Hazardous Wastes, a Guidance Manual*, EPA530-R-94-024 (USEPA 1994a)
Part 270 - Subpart C - Conditions Applicable to All Permits	Under §270.30, there are specific requirements for monitoring and recordkeeping. Section270.31 requires monitoring to be detailed in the permit.	The permittee must conduct appropriate sampling procedures, and retain results of all monitoring. All requirements are facility specific and are set forth in the permit and waste analysis plan.	*Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, Updates I, II, IIA, IIB, III, and IIIA. SW-846*. (USEPA 1986a) *Waste Analysis at Facilities That Generate, Treat, Store, and Dispose of Hazardous Wastes, a Guidance Manual*, EPA530-R-94-024 (USEPA 1994a)

Table B-1. Summary of Waste Analysis Drivers for Major RCRA Regulatory Program Areas

40 CFR Citation and Description	***Applicable Standards***	***Requirements for Demonstrating Attainment of or Compliance With the Standards***	***Relevant USEPA Guidance***
Waste Analysis Drivers in Other RCRA Regulations (continued)			
Part 270 - Subpart F - Special Forms of Permits	Specifies sampling and monitoring requirements based on trial burns for incinerators (§270.62) and Boiler and Industrial Furnaces (§270.66).	Waste analysis and sampling requirements are site specific and set forth in each facility's waste analysis plan required under 264.13.	*Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, Updates I, II, IIA, IIB, III, and IIIA. SW-846*. (USEPA 1986a) *Waste Analysis at Facilities That Generate, Treat, Store, and Dispose of Hazardous Wastes, a Guidance Manual*, EPA530-R-94-024 (USEPA 1994a)
Part 273 - Universal Wastes	Handlers and transporters of universal wastes must determine if any material resulting from a release is a hazardous waste. (§273.17(b) for small quantity handlers, §273.37(b) for large quantity handlers, and §273.54 for transporters of universal wastes) Also, if certain universal wastes are dismantled, such as batteries or thermostats, in certain cases the resulting materials must be characterized for hazardous waste purposes. (§§273.13(a)(3) and (c)(3)(i))	Sampling and analysis requirements are identical to hazardous waste identification requirements.	*Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, Updates I, II, IIA, IIB, III, and IIIA. SW-846*. (USEPA 1986a) *Universal Waste Final Rule, 60 FR 25492; May 11, 1995* Final rule adding Flourescent Lamps, *64 FR 36465; July 6, 1999*

Table B-1. Summary of Waste Analysis Drivers for Major RCRA Regulatory Program Areas

40 CFR Citation and Description	*Applicable Standards*	*Requirements for Demonstrating Attainment of or Compliance With the Standards*	*Relevant USEPA Guidance*
Waste Analysis Drivers in Other RCRA Regulations (continued)			
Part 279 - Standards for the Management of Used Oil	Specifies sampling and analysis procedures for owners or operators of used-oil processing and re-refining facilities.	Under §279.55, owners or operators of used oil processing and re-refining facilities must develop and follow a written analysis plan describing the procedures that will be used to comply with the analysis requirements of §279.53 and/or §279.72. The plan must be kept at the facility.	Sampling: Part 261, Appendix I *Hazardous Waste Management System; Identification and Listing of Hazardous Waste; Recycled Used Oil Management Standards*, 57 FR 41566, September 10, 1992 *Part 279 Requirements: Used Oil Management Standards*, EPA530-H-98-001

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APPENDIX C

STRATEGIES FOR SAMPLING HETEROGENEOUS WASTES

C.1 Introduction

"Heterogeneous wastes" include structures, demolition debris, waste-construction materials, containers (e.g., drums, tanks, and paint cans), solid waste from laboratories and manufacturing processes, and post-consumer wastes (e.g., electronics components, battery casings, and shredded automobiles) (USEPA and USDOE 1992). Heterogeneous wastes can pose challenges in the development and implementation of a sampling program due to the physical variety in size, shape, and composition of the material and the lack of tools and approaches for sampling heterogeneous waste. The application of conventional sampling approaches to heterogeneous waste is difficult and may not provide a representative sample.

To develop a sampling strategy for heterogeneous waste, it is first important to understand the scale, type, and magnitude of the heterogeneity. This appendix provides an overview of *large-scale heterogeneity* and provides some strategies that can be used to obtain samples of heterogeneous wastes. See also Section 6.2.1 for a description of other types of heterogeneity including short range (small-scale) heterogeneity (which includes distribution and constitution heterogeneity).

Additional guidance on sampling heterogeneous waste can be found in the following documents:

- *Characterizing Heterogeneous Wastes: Methods and Recommendations* (USEPA and USDOE 1992)

- *Standard Guide for Sampling Strategies for Heterogeneous Waste* (ASTM D 5956-96)

- *Pierre Gy's Sampling Theory and Sampling Practice: Heterogeneity, Sampling Correctness, and Statistical Process Control*. 2nd ed. (Chapter 21) (Pitard 1993), and

- *Geostatistical Error Management: Quantifying Uncertainty for Environmental Sampling and Mapping* (Myers 1997).

C.2 Types of Large-Scale Heterogeneity

The notion of heterogeneity is related to the scale of observation. An example given by Pitard (1993) and Myers (1997) is that of a pile of sand. From a distance of a few feet, a pile of sand appears to be uniform and homogeneous; however, at close range under magnification a pile of sand is heterogeneous. Substantial differences are found between the individual grains in their sizes, shapes, colors, densities, hardness, mineral composition, etc. For some materials, the differences between individual grains or items are not measurable or are not significant relative to the project objectives. In such a case, the degree of heterogeneity is so minor that for practical purposes the material can be considered homogeneous. The *Standard Guide for Sampling Strategies for Heterogeneous Waste* (ASTM D 5956-96) refers to this condition as "practical homogeneity," but recognizes that true homogeneity does not exist.

At a larger scale, such as an entire waste site, long-range (or large-scale) nonrandom heterogeneity is of interest. Large-scale heterogeneity reflects local trends and plays an important role in deciding whether to use a geostatistical appraisal to identify spatial patterns at the site, to use stratified sampling design to estimate a parameter (such as the overall mean), or to define the boundaries of the sampling problem so that it comprises two or more decision units that are each internally relatively homogeneous.

Items, particles, or phases within a waste or site can be distributed in various ways to create distinctly different types of heterogeneity. These types of heterogeneity include:

- **Random heterogeneity** – occurs when dissimilar items are randomly distributed throughout the population.

- **Non-random heterogeneity –** occurs when dissimilar items are nonrandomly distributed, resulting in the generation of strata. The term *strata* refers to subgroups of a population separated in space, in time, or by component from the remainder of the population. Strata are internally consistent with respect to a target constituent or a property of interest and are different from adjacent portions of the population.

The differences between items or particles that result in heterogeneity are due to differences in their composition or properties. One of these properties – particle size – deserves special consideration because significant differences in particle size are common and can complicate sampling due to the fundamental error. Fundamental error can be reduced only through particle-size reduction or the collection of sufficiently large samples. (Section 6 describes the impacts that fundamental error and particle size can have on sampling error.)

Figure C-1 depicts populations exhibiting the three types of heterogeneity described in ASTM D 5956-96 *Standard Guide for Sampling Strategies for Heterogeneous Waste*: (1) homogeneous, (2) randomly heterogeneous, (3) and nonrandomly heterogeneous populations. The drum-like populations portray different types of *spatial* distributions while the populations being discharged through the pipes represent different types of *temporal* distributions.

In the first scenario, very little spatial or temporal variation is found between the identical particles of the "homogeneous" population; however, in the second scenario, spatial and temporal variations are present due to the difference between the composition of the particles or items that make up the waste. ASTM D 5956-96 refers to this as a "randomly heterogeneous" population. In the third scenario, the overall composition of the particles or items remain the same as in the second scenario, but the two different components have segregated into distinct strata (e.g., due to gravity), with each strata being internally homogeneous. ASTM D 5956-96 refers to waste with this characteristic as "non-randomly heterogeneous."

C.3 Magnitude of Heterogeneity

The *magnitude* of heterogeneity is the degree to which there are differences in the characteristic of interest between fragments, particles, or volumes within the population. The magnitude of heterogeneity can range from that of a population whose items are so similar that it is practically

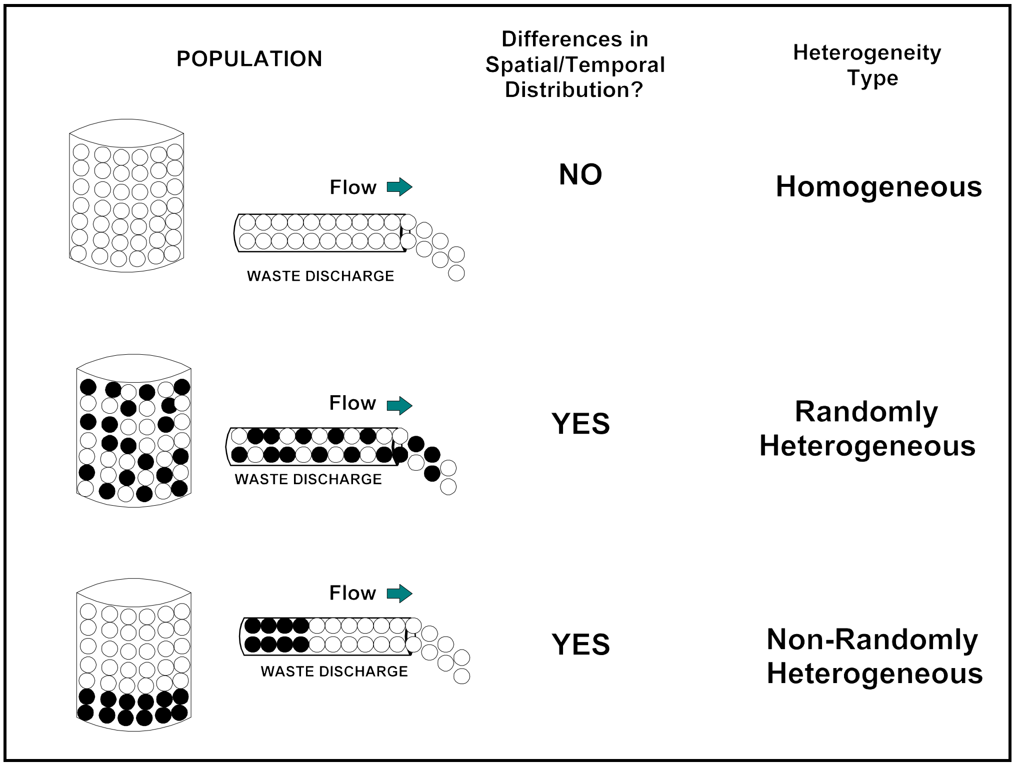

Figure C-1. Different types of spatial and temporal heterogeneity.

homogeneous to a population whose items are all dissimilar. Statistical measures of dispersion, the variance and standard deviation, are useful indicators of the degree of heterogeneity within a waste or waste site (assuming sampling error is not a significant contributor to the variance -- an optimistic assumption).

If the waste exhibits *nonrandom* heterogeneity and a *high magnitude* of heterogeneity, then consider segregating (e.g., at the point of generation) and managing the waste as two or more separate decision units (if physically possible and allowed by regulations). This approach will require prior knowledge (for example, from a pilot study) of the portions of the waste that fall into each specified category (such as hazardous debris and nonhazardous debris).

C.4 Sampling Designs for Heterogeneous Wastes

The choice of a sampling design to characterize heterogeneous waste will depend upon the regulatory objective of the study (e.g., waste identification or classification, site characterization, etc.), the data quality objectives, the type and magnitude of the heterogeneity, and practical considerations such as access to all portions of the waste, safety, and the availability of equipment suitable for obtaining and preparing samples.

As described in Section 5 of this document, there are two general categories of sampling designs: *probability* sampling design and *authoritative* (nonprobability) sampling designs. Probability sampling refers to sampling designs in which all parts of the waste or media under study have a known probability of being included in the sample. This assumption may be difficult to support when sampling highly heterogeneous materials such as construction debris.

All parts of a highly heterogeneous waste may not be accessible by conventional sampling tools, limiting the ability to introduce some form of randomness into the sampling design.

Random Heterogeneous Waste: For random heterogeneous waste, a probability sampling design such as simple random or systematic sampling can be used. At least one of two sample collection strategies, however, also should be used to improve the precision (reproducibility) of the sampling design: (1) take very large individual samples (to increase the sample support), or (2) take many increments to form each individual sample (i.e., use composite sampling). The concept of sample support is described in Section 6.2.3. Composite sampling is discussed in Section 5.3.

Non-Random Heterogeneous Waste: For non-random heterogeneous wastes, one of two strategies can be used to improve sampling: (1) If the objective is to estimate an *overall* population parameter (such as the mean), then stratified random sampling could be used. Stratified random sampling is discussed in detail in Section 5.2.2. (2) If the objective is to characterize each stratum separately (e.g., to classify the stratum as either a hazardous waste or a nonhazardous waste), then an appropriate approach is to separate or divert each stratum at its point of generation into discrete, nonoverlapping decision units and characterize and manage each decision unit separately (i.e., to avoid mixing or managing hazardous waste with nonhazardous waste).

If some form of stratified sampling is used, then one of three types of stratification must be considered. There are three types of stratification that can be used in sampling:

- stratification by space
- stratification by time
- stratification by component.

The choice of the type of stratification will depend on the type and magnitude of heterogeneity present in the population under consideration.

Figure C-2 depicts these different types of strata which are often generated by different processes or a significant variant of the same process. The different origins of the strata usually result in a different concentration or property distribution and different mean concentrations or average properties. While stratification over time or space is widely understood, stratification by component is less commonly employed. Some populations lack obvious spatial or temporal stratification yet display high levels of heterogeneity. If these populations contain easily identifiable components, such as bricks, gloves, pieces of wood or concrete, then it may be advantageous to consider the population as consisting of a number of component strata. An advantage of component stratification is that it can simplify the sampling and analytical process and allow a mechanism for making inferences to a highly stratified population. Component stratification shares many similarities with the gender or age stratification applied to demographic data by pollsters (i.e., the members of a given age bracket belonging to the same stratum regardless of where they reside). Component stratification is used by the mining industry to assay gold ore and other commodities where the analyte of interest is found in

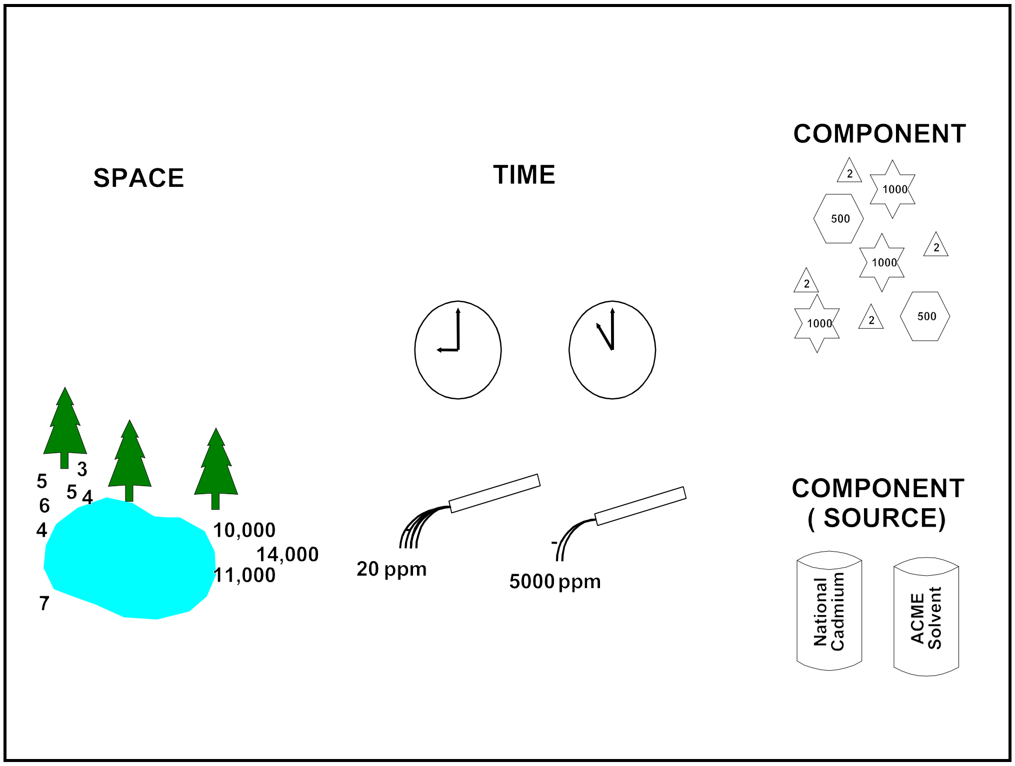

Figure C-2. Three different types of strata (from ASTM 5956-96)

discrete particles relative to a much greater mass of other materials.

Component stratification, although not commonly employed, is applicable to many waste streams, including the more difficult-to-characterize waste streams such as building debris. Additional guidance on stratification by component can be found in ASTM D 5956-96.

Table C-1 offers practical examples when wastes considered “non-randomly heterogeneous” might be good candidates for stratification across space, time, or by component.

The stratification approach can result in a more precise estimate of the mean compared to simple random sampling. However, keep in mind that greater precision is likely to be realized only if a waste exhibits substantial nonrandom chemical heterogeneity and stratification efficiently "divides" the waste into strata that exhibit maximum between-strata variability and minimum within-strata variability. If that does not occur, stratified random sampling can produce results that are less precise than in the case of simple random sampling; therefore, it is reasonable to employ stratified sampling only if the distribution of chemical contaminants in a waste is sufficiently known to allow an intelligent identification of the strata and at least two or three samples can be collected in each stratum.

Note that failure to recognize separate strata might lead one to conclude incorrectly, via a statistical test, that the underlying population is lognormal or some other right-skewed distribution.

Table C-1. Examples of Three Types of Stratification

Type of Stratification	***Example Scenario***
Stratification Across Space	A risk-based cleanup action requires a site owner to remove the top two feet of soil from a site. Prior to excavation, the waste hauler wants to know the average concentration of the constituent of concern in the soil to be removed. The top six inches of soil are known to be more highly contaminated than the remaining 18-inches of soil. Sampling of the soil might be carried out more efficiently by stratifying the soil into two subpopulations - the upper six-inch portion and the lower 18-inch portion.
Stratification Across Time	A waste discharge from a pipe varies across time. If the objective is to estimate the overall mean, then an appropriate sampling design might include stratification across time.
Stratification by Component	Construction debris covered with lead-based paint in the same structure with materials such as glass and unpainted wood could be sampled by components (lead-based paint debris, glass, and unpainted wood). This strategy is known as "stratification by component" (from ASTM D 5956-96).

C.5 Sampling Techniques for Heterogeneous Waste

Due to practical constraints, conventional sampling approaches may not be suitable for use in sampling of heterogeneous wastes. For example, sampling of contaminated debris can pose significant challenges due to the high degree of heterogeneity encountered. Methods used to sample contaminated structures and debris have included the following:

- Coring and cutting pieces of debris followed by crushing and grinding of the matrix (either in the field or within the laboratory) so the laboratory can handle the sample in a manner similar to a soil sample (Koski, et al 1991)
- Drilling of the matrix (e.g., with a hand held drill) followed by collection of the cuttings for analysis. This technique may require 20 to 50 drill sites in a local area to obtain a sufficient volume for an individual field sample (Koski, et al 1991)
- Grinding an entire structure via a tub grinder followed by conventional sampling approaches (AFCEE 1995).

ASTM has published a guide for sampling debris for lead-based paint (LBP) in ASTM E1908-97 *Standard Guide for Sample Selection of Debris Waste from a Building Renovation or Lead Abatement Project for Toxicity Characteristic Leaching Procedure (TCLP) testing for Leachable Lead (Pb)* .

Additional methods are described in Chapter Five, "Sample Acquisition," of *Characterizing Heterogeneous Wastes: Methods and Recommendations* (USEPA and USDOE 1992) and in Rupp (1990).

APPENDIX D

A QUANTITATIVE APPROACH FOR CONTROLLING FUNDAMENTAL ERROR

This appendix provides a basic approach for determining the particle-size sample-weight relationship sufficient to achieve the fundamental error level specified in the DQOs. The procedure is based on that described by Pitard (1989, 1993), Gy (1998), and others; however, a number of simplifying assumptions have been made for ease of use. *The procedure described in this appendix is applicable to sampling of granular solid media (including soil) to be analyzed for nonvolatile constituents. It is not applicable to liquids, oily wastes, or debris.*

The mathematical derivation of the equation for the fundamental error is complex and beyond the scope of this guidance. Readers interested in the full documentation of the theory and underlying mathematics are encouraged to review Gy (1982) and Pitard (1993). Several authors have developed example calculations for the variance of the fundamental sampling error for a "typical" contaminated soil to demonstrate its practical application.[1] Examples found in Mason (1992), and Myers (1997) may be particularly useful.

The equation for the variance of the fundamental error is extremely practical for optimization of sampling protocols (Pitard 1993). In a relatively simple "rule of thumb" form, the equation for the variance of the fundamental error (s_{FE}^2) is estimated by

$$S_{FE}^2 = \frac{\mathrm{f}\lambda}{\mathrm{M_s}}\left(\frac{1}{\mathrm{a_{LC}}} - 2\right)d^3 \qquad \textbf{Equation D.1}$$

where

- f = a dimensionless "shape" factor for the shape of particles in the material to be sampled where cubic = 1.0, sphere = 0.523, flakes = 0.1, and needles = 1 to 10
- λ = average density (gm/cm^3) of the material
- $\mathrm{M_s}$ = the sample weight (or mass of sample) in grams
- $\mathrm{a_{LC}}$ = proportion of the sample with a particle size less than or equal to the particle size of interest
- d = diameter of the largest fragment (or particle) in the waste, in centimeters.

Pitard's methodology suggests the particle size of interest should be set at 95 percent of the largest particle in the population (or "lot"), such that $\mathrm{a_{LC}}$ = 0.05. Equation D.1 then reduces to

$$s_{FE}^2 = \frac{\mathrm{f}\lambda}{\mathrm{M_a}} 18d^3 \qquad \textbf{Equation D.2}$$

---

[1] It is important to note that discussion of the "variance of the fundamental error" refers to the relative variance, which is the ratio of the sample variance over square of the sample mean ($s^2/\bar{x}^2$). The relative variance is useful for comparing results from different experiments.

The equation demonstrates that the variance of the fundamental error is directly proportional to the size of the largest particle and inversely proportional to the mass of the sample. To calculate the appropriate mass of the sample, Equation D.2 easily can be rearranged as

$$\mathrm{M_a} = \frac{\mathrm{f}\lambda}{(s_{FE})^2} 18d^3 \qquad \textbf{Equation D.3}$$

Pitard (1989, 1993) proposed a "Quick Safety Rule" for use in environmental sampling using the following input assumptions for Equation D.3:

f = 0.5 (dimensionless shape factor for a sphere)
λ = 2.7 (density of a waste in gm/cm^3)
s_{FE} = $\pm 5\%$ (standard deviation of the fundamental error).

By putting these assumed factors into Equation D.3, we get:

$$\mathrm{M_s} = \frac{0.5 \times 2.7}{(0.05)^2} 18d^3 \qquad \textbf{Equation D.4}$$

Pitard (1993) rounds up, to yield the relationship

$$\mathrm{M_s} \geq 10000d^3 \qquad \textbf{Equation D.5}$$

Alternatively, if we are willing to accept $s_{FE} = \pm 16\%$, Equation D.4 yields

$$\mathrm{M_s} \geq 1000d^3 \qquad \textbf{Equation D.6}$$

Equation D.4 was used to develop Table D-1 showing the maximum particle size that is allowed for a given sample mass with the standard deviation of the fundamental error (s_{FE}) prespecified at various levels (e.g., 5%, 10%, 16%, 20%, and 50%). A table such as this one can be used to estimate the optimal weight of field samples and the optimal weight of subsamples prepared within the laboratory. An alternative graphical method is presented by Pitard (1993) and Myers (1997).

An important feature of the fundamental error is that it does not "cancel out." On the contrary, the variance of the fundamental error adds together at each stage of subsampling. As pointed out by Myers (1997), the fundamental error can quickly accumulate and exceed 50%, 100%, 200%, or greater unless it is controlled through particle-size reduction. The variance of the fundamental error, s_{FE}^2 , calculated at each stage of subsampling and particle-size reduction must be added together at the end to derive the total s_{FE}^2 .

Table D-1. Maximum Allowable Particle Size (cm) for a Given Sample Mass for Selected Standard Deviations of the Fundamental Error

Sample Mass (g)	***Maximum Allowable Particle Size d (cm)***				
	S_{FE} = 5%	***S_{FE} = 10%***	***S_{FE} = 16%****	***S_{FE} = 20%***	***S_{FE} = 50%***
0.1	0.02	0.03	0.05	0.05	0.10
1	0.05	0.07	0.10	0.12	0.22
2	0.06	0.09	0.13	0.15	0.27
3	0.07	0.11	0.15	0.17	0.31
4	0.07	0.12	0.16	0.19	0.35
5	0.08	0.13	0.17	0.20	0.37
10	0.10	0.16	0.22	0.25	0.47
20	0.13	0.20	0.28	0.32	0.59
30	0.15	0.23	0.32	0.37	0.68
40	0.16	0.25	0.35	0.40	0.74
50	0.17	0.27	0.37	0.43	0.80
75	0.20	0.31	0.43	0.50	0.92
100	0.22	0.35	0.47	0.55	1.01
500	0.37	0.59	0.81	0.94	1.73
1000	0.47	0.74	1.02	1.18	2.17
5000	0.80	1.27	1.74	2.02	3.72

*A maximum standard deviation of the fundamental error of 16% has been recommended by Pitard (1993) and is included in this table as a point of reference only. Project-specific fundamental error rates should be set in the DQO Process.

Two important assumptions underlie the use of Table D-1:

1. The table is valid only if each and all steps of the sampling and subsampling minimize other sampling error through use of careful and correct sampling procedures

2. The table is valid only for wastes or soils with a shape factor (f) and density (λ) similar to that used to derive the table; otherwise, waste-specific tables or graphical methods (see Pitard 1993, Mason 1992, or Myers 1997) should be used.

Hypothetical Example

Suppose we have a waste that is a particulate solid to be analyzed for total metals. The laboratory requires an analytical sample of only 1 gram. The DQO planning team wants to maintain the total standard deviation of the fundamental error (s_{FE}) within $\pm 16\%$. The sample masses are determined at each stage of sampling and subsampling as follows:

Primary Stage: Based on prior inspection of the waste, it is known that 95 percent of the particles are 0.47 cm in diameter or less. Using Table D-1, we determine that a field sample of 1,000 grams (or 1 Kg) will generate a fundamental error s_{FE} not greater than $\pm 5\%$.

Secondary Stage: After shipment of the 1,000-gram sample to the laboratory, particle-size reduction to about 0.23 cm (2.36 mm or a No. 8 sieve) is performed, and a 30-gram subsample is taken. This step generates a fundamental error s_{FE} of $\pm 10\%$.

Final Stage: A 1-gram subsample is required for the analysis. Particle-size reduction to 0.07 cm or less (e.g., a No. 30 sieve) is performed, and a 1-g subsample is taken. This step generates a fundamental error s_{FE} of $\pm 10\%$.

The variance (s_{FE}^2) from each stage is then summed to determine the *total* variance of the fundamental error. As shown in Table D-2, the total standard deviation of the fundamental error is less than ±16 percent and the DQO is achieved.

Table D-2. Example Calculation of the Total Variance of the Fundamental Error

Sampling and Subsampling Stage	***Mass (grams)***	***d (cm)***	s_{FE}	s_{FE}^2
Primary Stage	1000	0.47	.05	.0025
Secondary Stage	30	0.23	.10	.01
Final Stage	1	0.07	.10	.01
Sum of the variances of the fundamental errors (s_{FE}^2)				s_{FE}^2 = 0.0225
Total standard deviation of the fundamental error (s_{FE}) (DQO = 16%)				s_{FE} = 0.15 or 15%

One final word of caution is provided regarding the use of the particle-size reduction and subsampling routine outlined above. The approach can reduce bias and improve precision of analyses for *total* constituent analyses, but the particle-size reduction steps may actually *introduce bias* when used in conjunction with some leaching tests. For example, the TCLP specifies a minimum sample mass of 100 grams (for nonvolatile extractions) and maximum particle size of 9.5 mm. While this combination would generate a s_{FE} of almost ±50 percent, excessive particle-size reduction below 9.5 mm to lower s_{FE} would *increase* the leachability of the material during the test due to the increased surface area-to-volume ratio of smaller particles. Therefore, it is important to remember that particle-size reduction to control fundamental error is beneficial when total constituent analyses are performed, but may introduce bias for some leaching tests. Furthermore, particle-size reduction below 9.5 mm is *not required* by Method 1311 (TCLP) (except during Step 7.1.4, “Determination of Appropriate Extraction Fluid”).

APPENDIX E

SAMPLING DEVICES

The key features of recommended sampling devices are summarized in this appendix. For each sampling device, information is provided in a uniform format that includes a brief description of the device and its use, advantages and limitations of the device, and a figure to indicate the general design of the device. Each summary also identifies sources of other guidance on each device, particularly any relevant ASTM standards.

Much of the information in this appendix was drawn from ASTM standards (see also Appendix J for summaries of ASTM standards). In particular, much of the information came from ASTM D 6232, *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities*.

Devices not listed in this appendix or described elsewhere in this chapter also may be appropriate for use in RCRA-related sampling. For example, other more innovative or less common technologies may allow you to meet your performance goals and may be appropriate for your sampling effort. Therefore, we encourage and recommend the selection and use of sampling equipment based on a performance-based approach. In future revisions to this chapter, we will include new technologies, as appropriate.

Internet Resource

Information on sampling devices can be found on the Internet at the Federal Remediation Technologies Roundtable site at http://www.frtr.gov/. The Field Sampling and Analysis Technologies Matrix and accompanying Reference Guide are intended as an initial screening tool to provide users with an introduction to innovative site characterization technologies and to promote the use of potentially cost-effective methods for onsite monitoring and measurement.

This appendix is divided into subsections based on various categories of sampling technologies. The categories are based on those listed in ASTM D 6232. The equipment categories covered within this appendix are as follows:

E.1 Pumps and Siphons
E.2 Dredges
E.3 Discrete Depth Samplers
E.4 Push Coring Devices
E.5 Rotating Coring Devices
E.6 Liquid Profile Devices
E.7 Surface Sampling Devices

E.1 Pumps and Siphons

Pumps and siphons can be used to obtain samples of liquid wastes and ground water. For detailed guidance on the selection and use of pumps for sampling of ground water, see *RCRA Ground-Water Monitoring: Draft Technical Guidance* (USEPA 1992c).

In this section, you will find summaries for the following pumps or siphons:

E.1.1 Automatic Sampler

An automatic sampler (see Figure E-1) is a type of pumping device used to periodically collect samples. It is recommended for sampling surface water and point discharges. It can be used in waste-water collection systems and treatment plants and in stream sampling investigations. An automatic sampler designed for collection of samples for volatile organic analyses is available.

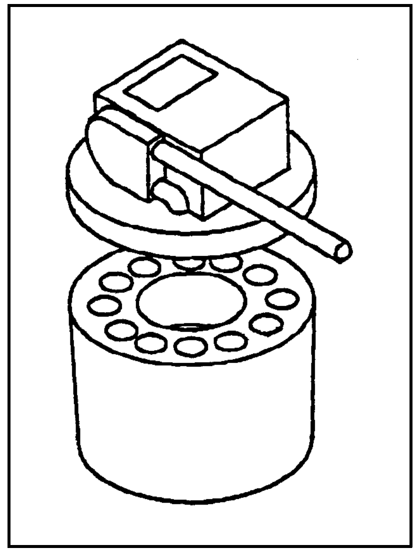

Figure E-1. Automatic sampler

An automatic sampler typically uses peristaltic pumps as the sampling mechanism. It can be programmed to obtain samples at specified intervals or to obtain a continuous sample. It also can be programmed to collect time composite or flow proportional samples.

Advantages

- Can provide either grab sample or composite samples over time.
- Operates unattended, and it can be programmed to sample variable volumes at variable times.

Limitations

- Requires power to operate (either AC or battery power).
- May be difficult to decontaminate.
- May not operate correctly when sampling liquid streams containing a high percentage of solids.
- Highly contaminated water or waste can degrade sampler components.

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities*, ASTM D 6232.

E.1.2 Bladder Pump

The bladder pump is recommended for the sampling of surface water, ground water, and point discharges. It also can be used to sample other liquids in surface impoundments.

A bladder pump consists of a flexible membrane (bladder) enclosed by a rigid sample container and can be constructed of a variety of materials, such as neoprene, rubber, stainless steel, nitrile, etc. There are two types of bladder pumps - the squeeze type and the expanding type (see Figure E-2). The squeeze type has the bladder connected to the sample discharge line. The chamber between the bladder and the sampler body is connected to the gas line. The expanding type has the bladder connected to the gas line. In this type of bladder pump, the chamber between the bladder and the sampler body is connected to the sample discharge line.

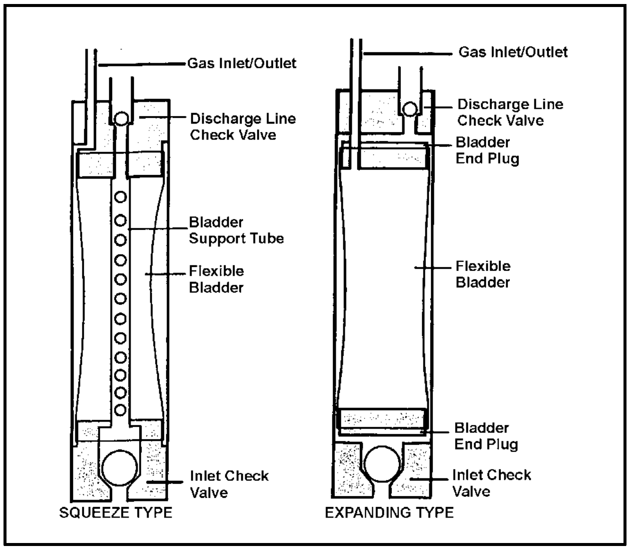

Figure E-2. Bladder pump

During sampling, water enters the sampler through a check valve at the bottom of the device. Compressed air or gas is then injected into the sampler. This causes the bladder to expand or compress depending on the type of bladder pump. The inlet valve closes and the contents of the sampler are forced through the top check valve into the discharge line. The top check valve prevents water from re-entering the sampler. By removing the pressure, the process is repeated to collect more sample. Automated sampling systems have been developed to control the time between pressurization cycles.

Advantages

- Is suitable for sampling liquids containing volatile compounds.
- Can collect samples up to a depth of 60 m (200 ft.) (ASTM D 6232).

Limitations

- Operation requires large volumes of compressed air or gas and a controller.
- Requires a power source.
- Can be heavy and difficult to operate.
- Decontamination can be difficult.

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities,* ASTM D 6232

- *Standard Guide for Sampling Groundwater Monitoring Wells*, ASTM D 4448

E.1.3 Peristaltic Pump

A peristaltic pump (Figure E-3) is a suction lift pump used at the surface to collect liquid from ground-water monitoring wells or surface impoundments. It can be used for sampling surface water, ground water, point discharges, impounded liquids, and multi-layer liquid wastes.

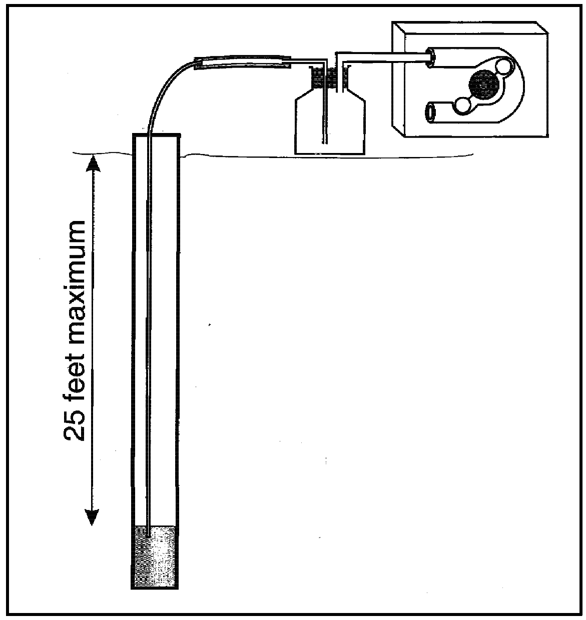

Figure E-3. Peristaltic pump

A peristaltic pump consists of a rotor with ball bearing rollers and it has a piece of flexible tubing threaded around the pump rotor and connected to two pieces of polytetrafluroethylene (PTFE) or other suitable tubing. One end of the tubing is placed in the sample. The other end is connected to a sample container. Silicone tubing is commonly used within the pumphead; however, for organic sampling purposes, medical grade silicone is recommended to avoid contamination of the sample (ASTM D 4448). Fluorocarbon resin tubing is also sometimes used for high hazard materials and for samples to be analyzed for organics (ASTM D 6063). The device can be modified to avoid contact of the sample with the flexible tubing. In such a case, the pump is connected to a clean glass container using a PTFE insert. A second PTFE tubing is used to connect the glass container to the sample source.

During operation, the rotor squeezes the flexible tubing, causing a vacuum to be applied to the inlet tubing. The sample material is drawn up the inlet tubing and discharged through the outlet end of the flexible tubing. In the modified peristaltic pump, the sample is emptied into the glass container without coming in contact with the flexible tubing. To sample liquids from drums, the peristaltic pump is first used to mix the sample. Both ends of the tubing are placed in the sample and the pump is turned on. Once the drum contents are mixed, the sample is collected as described above. To collect samples for organic volatile analyses, the PTFE tubing attached to the intake end of the pump is filled with the sample and then disconnected from the pump. The tube is then drained into the sample vials.

Advantages

- Can collect samples from multiple depths and small diameter wells.

- Easy to use and readily available.

- The pump itself does not need to be decontaminated. The tubing can be either decontaminated or replaced.

Limitations

- The drawing of a vacuum to lift the sample may cause the loss of volatile contaminants.
- Sampling depth cannot exceed about 7.6 m (25 ft.) (ASTM D 6232).
- Requires a power source.
- Flexible tubing may be incompatible with certain matrices.

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities*, ASTM D 6232
- *Standard Guide for Sampling of Drums and Similar Containers by Field Personnel*, ASTM D 6063
- *Standard Guide for Sampling Groundwater Monitoring Wells,* ASTM D 4448

E.1.4 Centrifugal Submersible Pump

The centrifugal submersible pump (Figure E-4) is a type of pump used for purging and sampling monitoring wells, sampling of waste water from impoundments, and sampling point discharges.

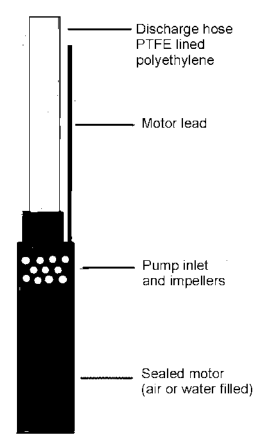

Figure E-4. Centrifugal submersible pump

A centrifugal submersible pump uses a set of impellers, powered by an electric motor, to draw water up and through a discharge hose. Parts in contact with liquid may be made of PTFE and stainless steel. The pump discharge hose can be made of PTFE or other suitable material. The motor cavity is filled with either air or deionized or distilled water that may be replaced when necessary. Flow rates for centrifugal submersible pumps range from 100 mL per minute to 9 gallons per minute (ASTM D 6232).

During operation, water is drawn into the pump by a slight suction created by the rotation of the impellers. The impellers work against fixed stator plates and pressurize the water which is driven to the surface through the discharge hose. The speed at which the impellers are driven controls the pressure and, thus, the flow rate.

Advantages

- Can be constructed of materials (PTFE and stainless steel) that are chemically resistant.
- Can be used to pump liquids up to a 76 m (250 ft) head (ASTM D 6232).
- Flow rate is adjustable.

Limitations

- May be incompatible with liquids containing a high percentage of solids.
- May not be appropriate for collection of samples for volatile organics analysis. Loss of volatiles can occur as a result of motor heating and sample pressurization.
- Requires an electric power source; e.g., either a 12 v (DC) or a 110/220 v (AC) converter (ASTM D 6232).
- May require a winch or reel system for portable use.

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities*, ASTM D 6232

E.1.5 Displacement Pumps

The displacement pump (Figure E-5) is a type of pump used for the sampling of surface water, ground water, point discharges and other liquids (e.g., in impoundments).

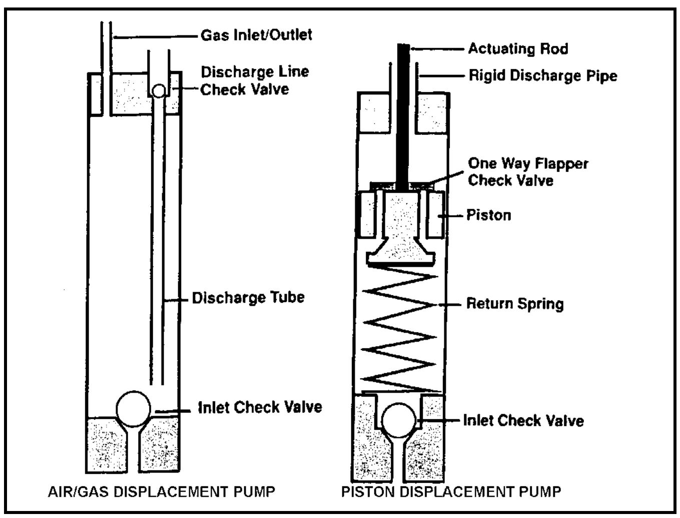

Figure E-5. Displacement pump

A displacement pump forces a discrete column of water to the surface via a mechanical lift. During sampling, water enters the sampler through the check valve at the bottom of the device. It is commonly constructed of PVC, stainless steel, or both. It also can be made of PTFE to reduce the risk of contamination when collecting samples with trace levels of organic compounds. Two common types of displacement pumps include the air/gas and piston displacement pumps.

The air/gas displacement pump uses compressed gas and it operates by applying positive pressure to the gas line. This causes the inlet check valve to close and the discharge line check valve to open, forcing water up the discharge line to the surface. Removal of the gas pressure causes the top valve to close and the bottom valve to open. Water enters the sampler and the process is repeated.

The piston displacement pump uses an actuating rod powered from the surface or from an air or electric actuator. The mechanically operated plunger delivers the sample to the surface at the same time the chamber fills. It has a flap valve on the piston and an inlet check valve at the bottom of the sampler.

Advantages

- Can be constructed of PTFE to reduce the risk of contamination caused by materials of construction when collecting samples for trace levels of organics.

Limitations

- May be difficult to decontaminate.
- Displacement pumps require large volumes of air or gas and a power source.
- Loss of dissolved gases or sample contamination from the driving gas may occur during sampling.
- Displacement pumps may be heavy.

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities*, ASTM D 6232
- *Standard Guide for Sampling Groundwater Monitoring Wells*, ASTM D 4448

E.2 Dredges

Dredges include equipment that is often used to collect bottom material (e.g., sediments) from beneath a layer of stationary or moving liquid. A variety of dredges are available including the **Ekman** bottom grab sampler and the **Ponar** dredge. The Ponar dredge is described below.

E.2.1 Ponar Dredge

The ponar dredge is recommended for sampling sediment. It has paired jaws that penetrate the substrate and close to retain the sample. The sample volume range is 0.5 to 3.0 liters (ASTM D 6232).

The Ponar dredge is lowered slowly with controlled speed so that the dredge will properly land and avoid blowout of the surface layer to be sampled. The weight of the dredge causes it to penetrate the substrate surface. The slack in tension unlocks the open jaws and allows the dredge to close as it is raised. The dredge is raised slowly to minimize disturbance and sample washout as the dredge is retrieved through the liquid column. The collected sample is emptied into a suitable container. Auxiliary weight may be added to the dredge to increase penetration.

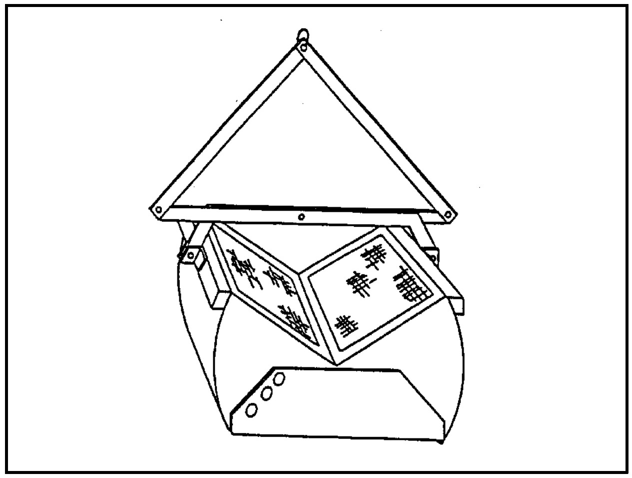

Figure E-6. Ponar dredge

Advantages

- Reusable
- Can obtain samples of most types of stationary sediments ranging from silt to granular material
- Available in a range of sizes and weights
- Some models may be available in either stainless steel or brass.

Limitations

- Not capable of collecting undisturbed samples
- May be difficult to decontaminate (depending upon the dredge's design and characteristics of the sampled material)
- Cannot collect a representative lift or repeatedly sample to the same depth and position
- Can be heavy and require a winch or portable crane to lift; however, a smaller version, the petit Ponar, is available and can be operated by a hand-line (ASTM D 4342).

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities*, ASTM D 6232
- *Standard Practice for Collecting of Benthic Macroinvertebrates with Ponar Grab Sampler*, ASTM D 4342
- *Standard Guide for Selecting Grab Sampling Devices for Collecting Benthic Macroinvertebrates*, ASTM D 4387

- "Sediment Sampling" (USEPA 1994e)

E.3 Discrete Depth Samplers

Discrete depth samplers include equipment that can collect samples at a specific depth. Such samplers are sometimes used to collect samples from layered liquids in tanks or surface impoundments. You will find summaries for the following discrete depth samplers in this section:

E.3.1 Bacon Bomb
E.3.2 Kemmerer Sampler
E.3.3 Syringe Sampler
E.3.4 Lidded Sludge/Water Sampler
E.3.5 Discrete Level Sampler

Besides the samplers listed below, a self-purging, discrete depth sampler is available for sampling ground-water monitoring wells. It fills when stopped at the desired depth and eliminates the need for well purging. It samples directly into a 40-mL glass VOA sample vial contained within the sampler; therefore, the loss of volatile organic compounds is minimized.

E.3.1 Bacon Bomb

A bacon bomb (Figure E-7) is a type of discrete level sampler that provides a sample from a specific depth in a stationary body of water or waste. A bacon bomb is recommended for sampling surface water and is usually used to collect samples from a lake or pond. It can also be used to collect liquid waste samples from large tanks or lagoons. It originally was designed to collect oil samples. The sample volume range is from 0.1 to 0.5 liters (100 to 500 mL) (ASTM D 6232).

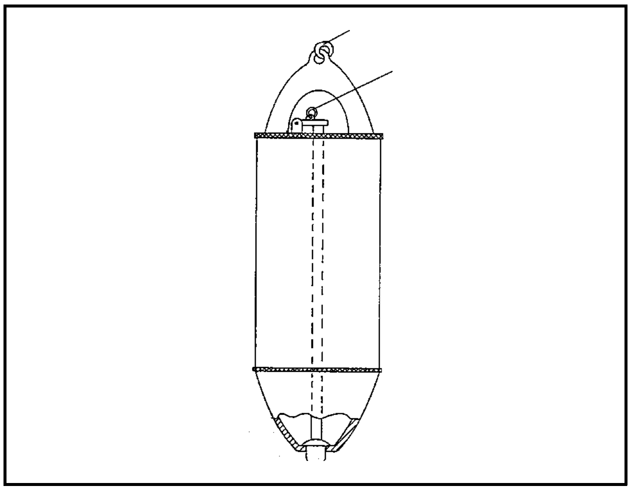

Figure E-7. Bacon bomb

A bacon bomb has a cylindrical body sometimes constructed of stainless steel, but it is sometimes made of chrome-plated brass and bronze. It is lowered into material by a primary support line and has an internal tapered plunger that acts as a valve to admit the sample. A secondary line attached to the top of the plunger opens and closes the plunger valve. The top cover has a locking mechanism to keep the plunger closed after sampling. The bacon bomb remains closed until triggered to collect the sample. Sample collection is triggered by raising the plunger line and allowing the sampler to fill. The device is then closed by releasing the plunger line. It is returned to the surface by raising the primary support line, and the sample is transferred directly to a container.

Advantages

- Collects a discrete depth sample; it is not opened until the desired depth.
- Easy to use, without physical requirement limitations.

Limitations

- May be difficult to decontaminate due to design or construction materials.
- Maximum sample capacity is only 500 mL.
- Materials of construction may not be compatible with parameters of concern.

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities*, ASTM D 6232
- "Tank Sampling" (USEPA 1994c)

E.3.2 Kemmerer Sampler

A kemmerer sampler (Figure E-8) is a type of discrete level sampler that provides a sample from a specific depth. Recommended for sampling surface water, it is usually used to collect samples from a lake or pond. It can also be used to collect liquid waste samples from large tanks or lagoons. The sample volume range is from 1 to 2 liters (ASTM D 6232).

The sampler comprises a stainless steel or brass cylinder with rubber stoppers for the ends, but all PFTE construction also is available. The ends are left open while being lowered in a vertical position, allowing free passage of water or liquid through the cylinder. When the device is at the designated depth, a messenger is sent down a rope to close the stoppers at each end. The cylinder is then raised and the sample is removed through a valve to fill sample containers.

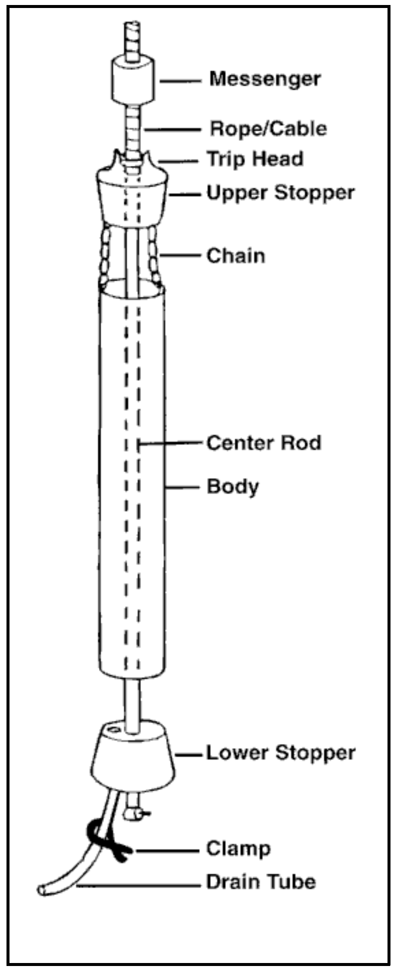

Figure E-8. Kemmerer sampler

Advantages

- Can collect a discrete depth sample.

- Provides correct delimitation and extraction of sample (Pitard 1989)
- Easy to use
- All PTFE construction is available.

Limitations

- May be difficult to decontaminate due to construction or materials.
- The sampler is exposed to the medium at other depths while being lowered to a sampling point at the desired depth.
- Materials of construction may not be compatible with parameters of concern.

Other Guidance:

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities,* ASTM D 6232

E.3.3 Syringe Sampler

A syringe sampler (Figure E-9) is a discrete depth sampler used to sample liquids. With the optional coring tip, it can be used as a coring device to sample highly viscous liquids, sludges, and tar-like substances. It is used to collect samples from drums, tanks, and surface impoundments, and it can also draw samples when only a small amount remains at the bottom of a tank or drum. The sample volume range is 0.2 to 0.5 liters (ASTM D 6232).

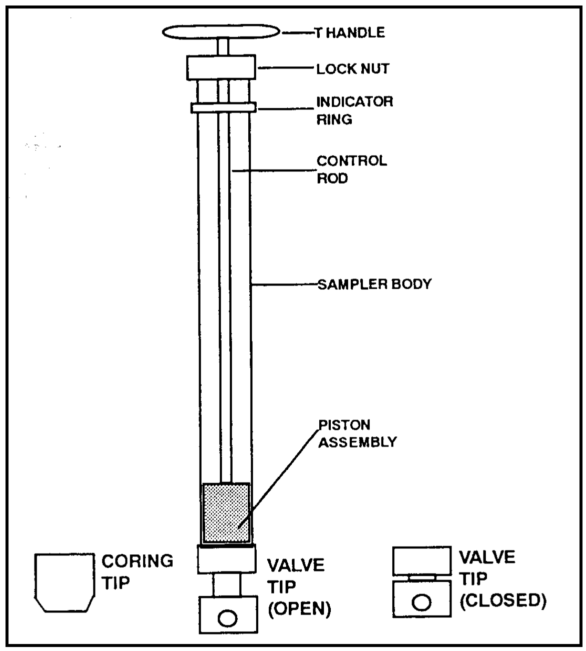

Figure E-9. Syringe sampler

A syringe sampler generally is constructed of a piston assembly that comprises a T-handle, safety locking nut, control rod, piston body assembly, sampling tube assembly, and two tips for the lower end (a closeable valve and a coring tip). When used as a syringe, the sampler is slowly lowered to the sampling point and the T-handle is gradually raised to collect the sample. Once the desired sample is obtained, the lock nut is tightened to secure the piston rod and the bottom valve is closed by pressing down on the sampler against the side or bottom of the container. When used as a coring device, the sampler is slowly pushed down into the material. Once the desired sample is obtained, the lock nut is tightened to secure the piston rod and the sampler is removed from the media. The sample material is extruded into the sample container by opening the bottom valve (if fitted), loosening the lock nut, and pushing the piston down.

Advantages

- The syringe sampler is easy to use and decontaminate.
- The syringe sampler can sample at discrete depths, including the bottom of a container.

Limitations

- The syringe sampler can be used to depths of about 1.8 meters only (ASTM D 6232).
- Material to be sampled must be viscous enough to remain in the device when the coring tip is used; the valve tip is not recommended for viscous materials (ASTM D 6063).

Other Guidance

- *Standard Guide for Sampling Single or Multilayered Liquids,* ASTM D 5743
- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities*, ASTM D 6232
- *Standard Guide for Sampling of Drums and Similar Containers by Field Personnel,* ASTM D 6063

E.3.4 Lidded Sludge/Water Sampler

A lidded sludge/water sampler (Figure E-10) is a type of discrete depth device that provides a sample from a specific depth. It is used to collect sludges or waste fluids from tanks, tank trucks, and ponds. It can sample liquids, multi-layer liquid wastes, and mixed-phase solid/liquid wastes. The typical sample volume is 1.0-liter (ASTM D 6232).

A lidded sludge/water sampler comprises a removable glass jar, sometimes fitted with a cutter for sampling materials containing more than 40-percent solids (ASTM D 6232), that is mounted on a stainless steel device.

The sampler is lowered into the material to be sampled and opened at the desired depth. The top handle is rotated to upright the jar and open and close the lid. Then, the device is carefully retrieved from the material. The jar is removed from the sampler by lifting it from the holder, and

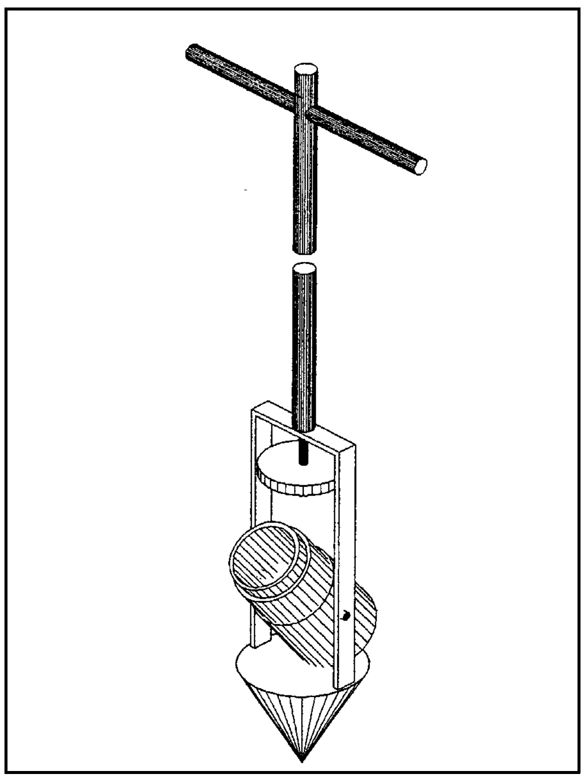

Figure E-10. Lidded sludge/water sampler the jar serves as a sample container so there is no need to transfer the sample.

Advantages

- The jar in the sampling device also serves as a sample container reducing the risk of cross-contamination.
- Bottles and lids are unique to each sample, therefore, decontamination of an intermediate transfer container is not required.

Limitations

- Heavy and limited to one bottle size
- Thick sludge is difficult to sample (ASTM D 6232).

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities,* ASTM D 6232

E.3.5 Discrete Level Sampler

A discrete level sampler (Figure E-11) is a dismountable cylindrical sampler fitted with a manually-operated valve(s). It is recommended for sampling surface water, ground water, point discharges, liquids, and multi-layer liquids and is used for sampling drums, tanks, containers, wells, and surface impoundments. The typical sample volume range is 0.2 to 0.5 liters (ASTM D 6232).

A discrete level sampler is made from PTFE and stainless steel and is designed to be reusable. It comprises a tube fitted with manually-operated valve or valves, which are operated by a control assembly attached to the upper end of the sampler. This assembly consists of a rigid tube and rod or a flexible tube and inner cable. The standard level sampler has a manually operated upper valve and a lower spring-retained bottom dump valve. The dual valve model may be emptied by opening the valves manually or with a metering device attached to the lower end of the sampler (not shown).

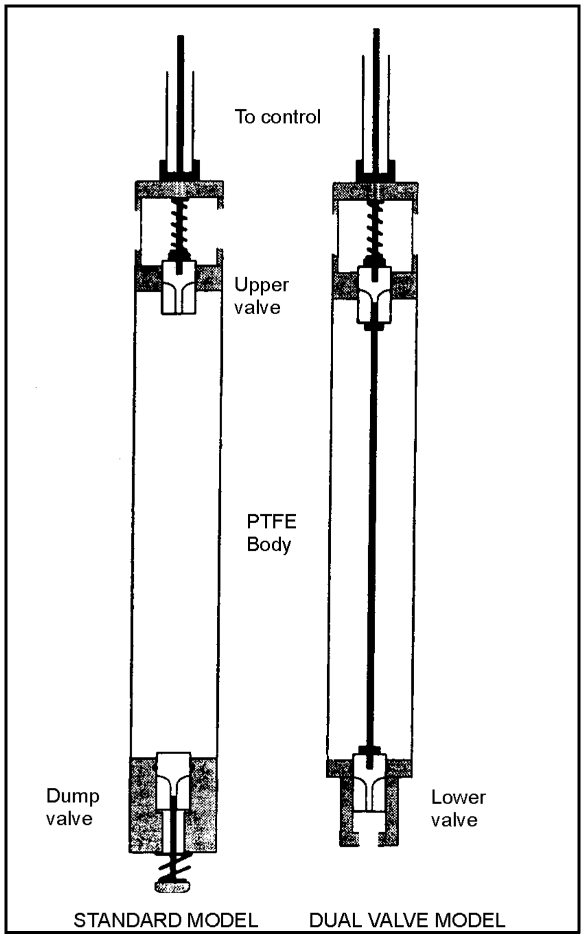

Figure E-11. Discrete level sampler

To collect a sample, the discrete level sampler is lowered into the sample material to the desired sampling depth. The valve or valves are opened manually to collect the sample and closed before retrieving the sampler. The standard model is emptied by pressing the dump valve against the side of the sample container. The dual valve sampler is emptied by opening the valves manually. Alternatively, the collected sample may be taken to the laboratory in the sampler body by replacing the valves with solid PTFE end caps.

Advantages

- Relatively easy to decontaminate and reuse
- May be used to sample liquids in most environmental situations.
- Can be remotely operated in hazardous environments.
- Sample representativeness is not affected by liquids above the sampling point.
- The sampling body can be used for sample storage and transport.

Limitations

- Limited to sample chamber capacities of 240-475 mL (ASTM D 6232).
- May be incompatible with liquids containing a high percentage of solids.

Other Guidance

- Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities, ASTM D 6232

E.4 Push Coring Devices

Push coring devices include equipment that use a pushing action to collect a vertical column of a solid sample. You will find summaries for the following push coring devices in this section:

E.4.1 Penetrating Probe Sampler
E.4.2 Split Barrel Sampler
E.4.3 Concentric Tube Thief
E.4.4 Trier
E.4.5 Thin-Walled Tube
E.4.6 Coring Type Sampler (with Valve)
E.4.7 Miniature Core Sampler
E.4.8 Modified Syringe Sampler

E.4.1 Penetrating Probe Sampler

The penetrating probe sampler (Figure E-12) is a push coring device and, therefore, provides a core sample. The probe sampler is recommended for sampling soil and other solids. The sample volume range is 0.2 to 2.0 liters (ASTM D 6232).

The probe sampler typically consists of single or multiple threaded steel tubes, a threaded top cap, and a detachable steel tip. The steel tubes are approximately 1 inch or less in diameter. Specialized attachments may be used for various matrices. Some probes are equipped with adjustable screens or retractable inner rods to sample soil vapor or ground water.

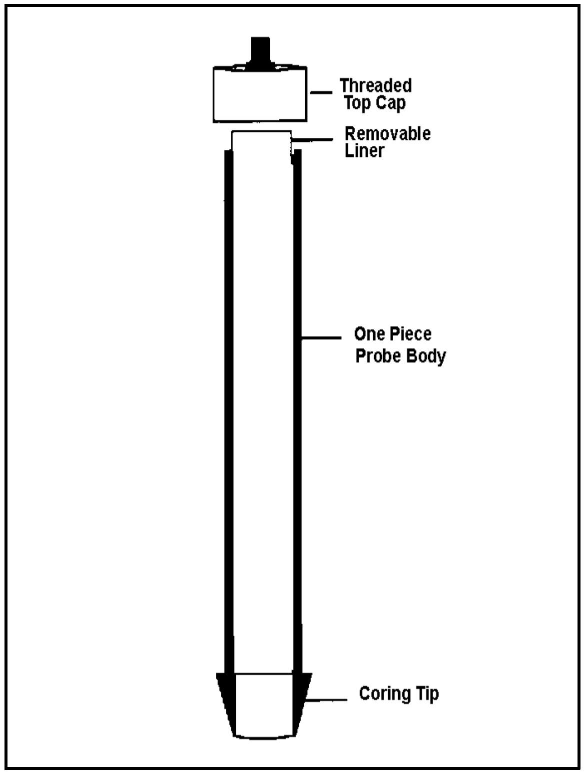

Figure E-12. Probe sampler

Advantages

- Easy to decontaminate and is reusable.
- Can provide samples for onsite analysis (ASTM D 6232).
- Versatile and may sample 15 to 20 locations a day for any combination of matrices (ASTM D 6232).
- Can reduce quantity of investigative derived wastes.

Limitations

- May be heavy and bulky depending on the size used.
- Limited by composition of subsurface materials and accessibility to deeper depth materials.
- May be inappropriate for sampling materials that require mechanical strength to penetrate.

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities,* ASTM D 6232

E.4.2 Split Barrel Sampler

A split barrel sampler (Figure E-13) is a push coring device often used with a drill rig to collect deep subsurface samples. The device is recommended for soil sampling, but can be used to sample other solids. The materials to be sampled should be moist enough to remain in the sampler. The sample volume range is 0.5 to 30.0 liters (ASTM D 6232).

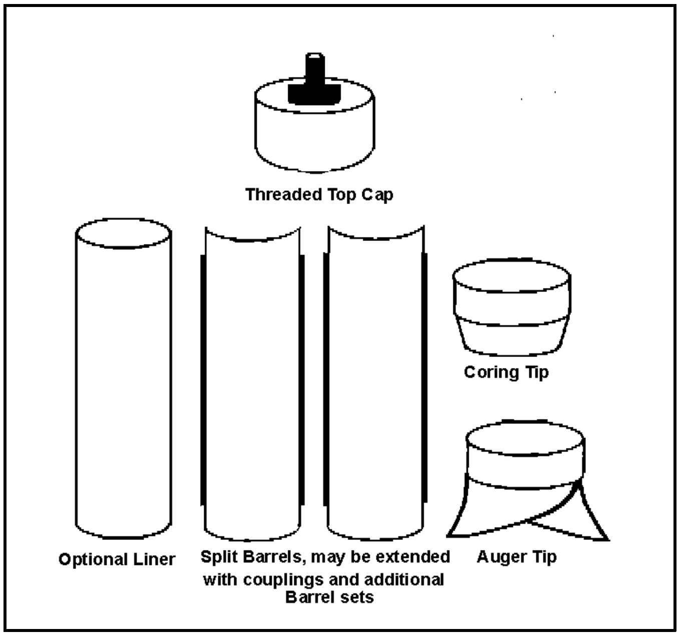

Figure E-13. Split barrel sampler

The sampler consists of a length of steel tubing split longitudinally and equipped with a drive shoe, made of steel, and a drive head. The drive shoe is detachable and should be replaced when dented or distorted. The samplers are available in a variety of diameters and lengths. The split barrel is typically 18 to 30 inches in length with an inside diameter of 1.5 to 2.5 inches (ASTM D 4700, ASTM D 1586). The split barrel sampler can be used to collect relatively undisturbed soil samples at considerable depths.

The split barrel sampler may be driven manually, but is usually driven with a drill rig drive weight assembly or hydraulically pushed using rig hydraulics. The sampler is placed on the surface of the material to be sampled, then pushed downward while being twisted slightly. Because pushing by hand may be difficult, a drop hammer typically is attached to a drill rig used to finish inserting the sampler. When the desired depth is reached the sampler is twisted again to break the core; then, the sampler is pulled straight up and out of the material. The sample may be removed from the barrel or the liner may be capped off for analysis. Barrels may be extended to 5 inches in diameter (ASTM D 6232). Liners often are used when sampling for volatile organic compounds or other trace constituents of interest. With a liner, the sample can be removed with a minimum amount of disturbance. Liners must be compatible with the matrix and compounds of interest; plastic liners may be inappropriate if analyzing for organics.

Advantages

- Reusable, easily decontaminated, and easy to use.
- Provides a relatively undisturbed sample, therefore, can minimize the loss of volatile organic compounds.

Limitations

- Requires a drill or direct push rig for deep samples.
- Made of steel and may penetrate underground objects such as a pipe or drum.

- Only accommodates samples that contain particles smaller than the opening of the drive shoe (ASTM D 4700).

Other Guidance:

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities,* ASTM D 6232

- *Standard Guide for Soil Sampling from the Vadose* Zone, ASTM D 4700

- *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils,* ASTM D 1586

E.4.3 Concentric Tube Thief

The concentric tube thief (also known as a grain sampler) (Figure E-14) is a push coring device that the user directly pushes into the material to be sampled. It can be used to sample powdered or granular solids and wastes in piles or in bags, drums, or similar containers. The concentric tube thieves are generally 61 to 100 cm (24 to 40 inches) long by 1.27 to 2.54 cm (½ to 1 inch) in diameter (USEPA 1994i). The sample volume range is 0.5 to 1.0 liters (ASTM D 6232).

The concentric tube thief consists of two slotted telescoping tubes, which are constructed of stainless steel, brass, or other material. The outer tube has a conical pointed tip on one end which allows the thief to penetrate the material being sampled. The thief is opened and closed by rotating the inner tube, and it is inserted into the material while in the closed position. Once inserted, the inner tube is rotated into the open position and the device is wiggled to allow the material to enter the open slots. The thief then is closed and withdrawn.

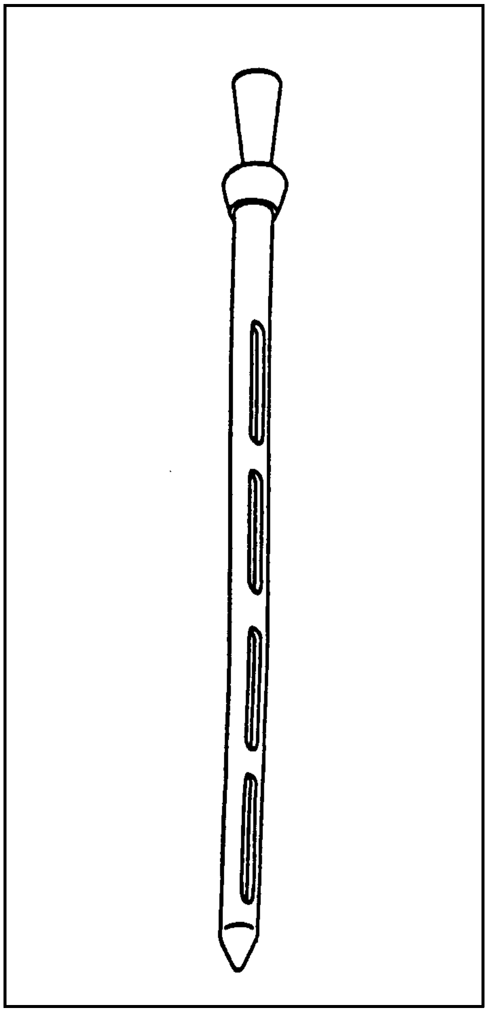

Figure E-14. Concentric tube thief

Advantages

- Is a good direct push sampler for dry unconsolidated materials.

- Easy to use.

Limitations

- May be difficult to decontaminate, depending on the matrix
- Not recommended for sampling of moist or sticky materials.
- Does not collect samples containing all particle sizes if the diameter of the largest solid particle is greater than one-third of the slot width (ASTM D 6232). Most useful when the solids are no greater than 0.6 cm (1/4-inch) in diameter (USEPA 1994i).
- Depth of sample is limited by the length of the thief.
- Not recommended for use when volatiles are of interest. Collects a somewhat disturbed sample, which may cause loss of some volatiles.

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities*, ASTM D 6232
- “Waste Pile Sampling” (USEPA 1994d)

E.4.4 Trier

A trier (Figure E-15) is a push coring device that resembles an elongated scoop and is used to sample moist or sticky solids with a particle diameter less than one-half the diameter of the tube portion. The trier can be used to sample soils and similar fine-grained cohesive materials. The typical sample volume range is 0.1 to 0.5 liters (ASTM D 6232).

A trier comprises a handle connected to a tube cut in half lengthwise, with a sharpened tip that allows it to cut into the material. Triers are made of stainless steel, PTFE-coated metal, or plastic. One should be selected who materials of construction are compatible with the sampled material.

A trier, typically 61 to 100 cm long and 1.27 to 2.54 cm in diameter, is used as a vertical coring device when a relatively complete and cylindrical sample can be extracted.

The trier is pushed into the material to be sampled and turned one or two times to cut a

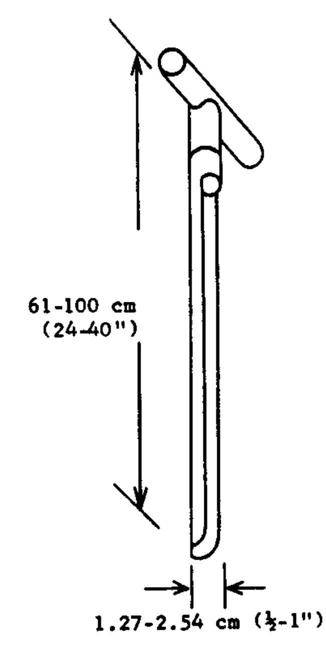

Figure E-15. Trier

core. The rotation is stopped with the open face pointing upward. The core is then carefully removed from the hole, preventing overburden material from becoming a part of the sample. The sample is inspected for irregularities (e.g., pebbles) or breakage. If breakage occurred and if the core does not satisfy minimum length requirements, discard it and extract another from an immediately adjacent location (ASTM D 5451). The sample is emptied into the appropriate container for analysis.

Advantages

- A good direct push sampler for moist or sticky materials.
- Lightweight, easy to use, and easy to decontaminate for reuse.

Limitations

- Limited to sample particle sizes within the diameter of the inserted tube and will not collect particles greater than the slot width.
- Not recommended for sampling of dry unconsolidated materials. (A concentric tube thief is good for such materials.)
- Only for surface sampling, and the depth of sample is limited by the length of the trier.

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities,* ASTM D 6232
- *Standard Practice for Sampling Using a Trier Sampler,* ASTM D 5451
- *Sampling of Drums and Similar Containers by Field Personnel,* ASTM D 6063
- *Standard Practice for Sampling Unconsolidated Solids in Drums or Similar Containers,* ASTM D 5680

E.4.5 Thin-Walled Tube

A thin-walled tube (Figure E-16) is a type of push coring device recommended for sampling cohesive, unconsolidated solids – particularly soil. It is not recommended for gravel or rocky soil. The sample volume range is 0.5 to 5.0 liters (ASTM D 6232).

The tube generally is constructed of carbon stainless steel, but can be manufactured from other metals (ASTM D 4700). It is commonly 30-inches long and is readily available in 2-, 3-, and 5-inch outside diameters (ASTM D 4700). The tube is attached with set screws to a length of a solid or tubular rod, and the upper end of the rod, or sampler head, is threaded to accept a handle or extension rod. Typically, the length of the tube depends on the desired sampling depth. Its advancing end is beveled and has a cutting edge with a smaller diameter than the tube inside diameter. The tube can be used in conjunction with drills – from hand-held to full-sized rigs.

The end of the sampler is pushed directly into the media using a downward force on the handle. It can be pushed downward by hand, with a jack-like system, or with a hydraulic piston. Once the desired depth is reached, the tube is twisted to break the continuity of the tip and is pulled from the media. The sample material is extruded into the sample container by forcing a rod through the tube. A paring device has been developed to remove the outer layer during extrusion (ASTM D 4700). Plastic and PFTE sealing caps for use after sampling are available for the 2-, 3-, and 5-inch tubes.

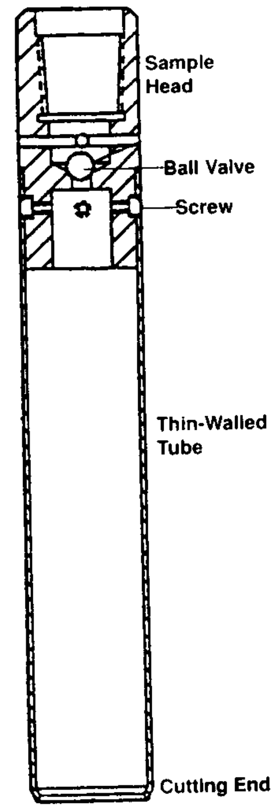

Figure E-16. Thin-walled tube

Advantages

- Readily available, inexpensive, and easy to use.
- Reusable and can be decontaminated.
- Obtains a relatively undisturbed sample.

Limitations

- Some thin-walled tubes are large and heavy.
- The material to be sampled must be of a physical consistency (cohesive sold material) to be cored and retrieved within the tube. It cannot be used to sample gravel or rocky soils.
- Some volatile loss is possible when the sample is removed from the tube.
- The most disturbed portion in contact with the tube may be considered unrepresentative. Shorter tubes provide less-disturbed samples than longer tubes.
- Materials with particles larger than one-third of the inner diameter of the tube should not be sampled with a thin-walled tube.

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities*, ASTM D 6232
- *Standard Guide for Core Sampling of Submerged, Unconsolidated Sediments,* ASTM D 4823
- *Standard Practice for Thin-Walled Type Geotechnical Sampling of Soils,* ASTM D 1587
- *Standard Guide for Soil Sampling from the Vadose Zone,* ASTM D 4700

E.4.6 Coring Type Sampler (with Valve)

A coring type sampler with valve (Figure E-17) is a type of push coring device recommended for wet soil, and can also be used to sample unconsolidated solid waste, mixed-phase solid/liquid waste, and free-flowing powders. The coring device may be used in drums and small containers as well as tanks, lagoons, and waste impoundments. The sample volume range is 0.2 to 1.5 liters (ASTM D 6232).

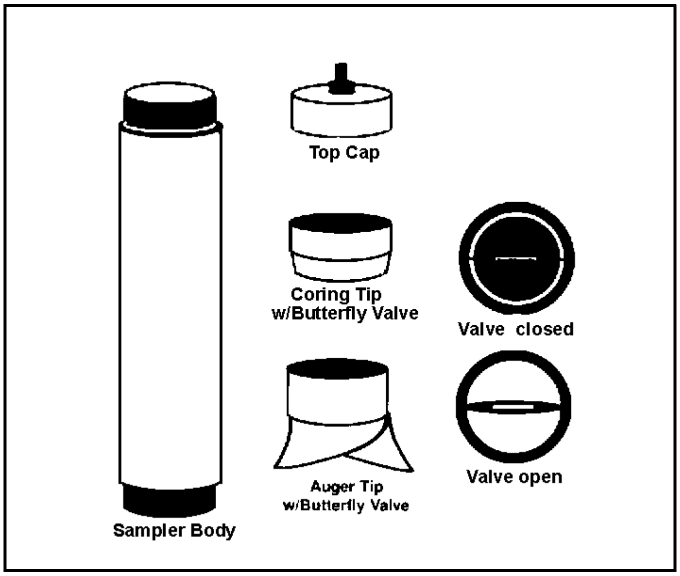

Figure E-17. Coring type sampler (with valve)

The coring type sampler with valve is a stainless steel cylindrical sampler with a coring tip, top cap, an extension with a cross handle, and a non-return valve at the lower end behind a coring or augering tip. The valve is a retaining device to hold the sample in place as the coring device is removed. Samples are normally collected in an optional liner. It is operated by attaching a handle or an extension with a handle to the top of the coring device. The corer is lowered to the surface, pushed into the material being sampled and removed. The top cap is removed and the contents emptied into a sample container. Alternatively, the liner can be removed (with the sampled material retained inside) and capped on both ends for shipment to a laboratory.

Advantages

- Reusable and is easily decontaminated.
- Provides a relatively undisturbed sample if not extruded.
- Can be hand operated and does not require significant physical strength.

Limitations

- Can not be used in gravel, large particle sediments, or sludges.
- When sampling for volatile organic compounds, it must be used with a liner and capped to minimize the loss of volatiles.

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities,* ASTM D 6232
- *Guide for Core Sampling Submerged, Unconsolidated Sediments*, ASTM D 4823

E.4.7 Miniature Core Sampler

The miniature core sampler (Figure E-18) can be used to collect soil and waste samples for volatile organics analysis. These include devices such as the Purge-and-Trap Soil Sampler™, the EnCore™ sampler, or a cut plastic syringe (see Section 6.0 of SW-846 Method 5035). A miniature core sampler is a single-use push coring sampling device that also can be used as an air-tight sample storage and shipping container. It collects a small contained subsample and is particularly useful for the sampling and analysis of volatile organic compounds.

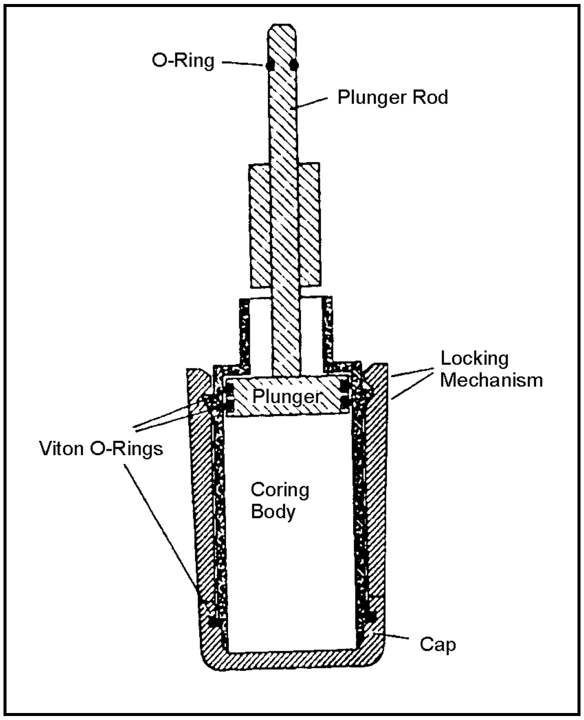

Figure E-18. Miniature core sample (Encore™ sampler)

It is recommended for sampling soil, from the ground or the side of a trench, and may be used for sampling sediment and unconsolidated solid wastes. It cannot be used for sampling cemented material, consolidated material, or material having fragments coarse enough to interfere with proper coring. The EnCore™ sampler can be used to collect subsamples from soil cores and has a sample volume range of 0.01 to 0.05 liters (ASTM D 6232).

The device is available from the manufacturer in two sizes for collection of 5- and 25-gram samples (assuming a soil density of 1.7 g/cm^3). The size is chosen based on the sample size required by the analytical procedure.

SW-846 Method 5035, “Closed-System Purge-and-Trap and Extraction for Volatile Organics in Soil and Waste Samples,” recommends that samples not be stored in the device longer than 48 hours prior to sample preparation for analysis. The manufacturer's instructions for sample extrusion should be followed carefully.

Advantages

- Maintains sample structure in a device that also can be used to store and transport the sample directly to the laboratory.

- Recommended for collecting samples for the analysis of volatile compounds. It collects a relatively undisturbed sample that is contained prior to analysis to minimize the loss of volatile compounds.

- Usually is compatible with the chemicals and physical characteristics of the sampled media.

- No significant physical limitations for its use.

- Cross-contamination should not be a concern if the miniature core sampler is certified clean by the manufacturer and employed as a single-use device.

Limitations

- Cannot be used to sample gravel or rocky soils.

- Instructions must be followed carefully for proper use to avoid trapping air with the sample and to ensure that the sample does not compromise the seals.

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities*, ASTM D 6232

- *Standard Practice for Using the Disposable EnCore™ Sampler for Sampling and Storing Soil for Volatile Organic Analysis,* ASTM D 6418

- *Standard Guide for Sampling Waste and Soils for Volatile Organic Compounds,* ASTM D 4547

E.4.8 Modified Syringe Sampler

A modified syringe sampler (Figure E-19) is a push coring sampling device constructed by the user by modifying a plastic, single-use, medical syringe. It can be used to provide a small, sub-sample of soil, sediments, and unconsolidated solid wastes. It is sometimes used to sub-sample a larger core of soil. It is not recommended for sampling cemented material, consolidated material, or material having fragments coarse enough to interfere with proper coring. Unlike the EnCore™ sampler, it should not be used to store and ship a sample to the laboratory. Instead, the sample should be extruded into another container. Although the modified syringe sampler does not provide as contained a sample as the EnCore™ sampler, it can be used for sampling volatile compounds, as long as sample extrusion into another container is quickly and carefully executed. The modified syringe sample has a volume range of 0.01 to 0.05 liters (ASTM D 6232).

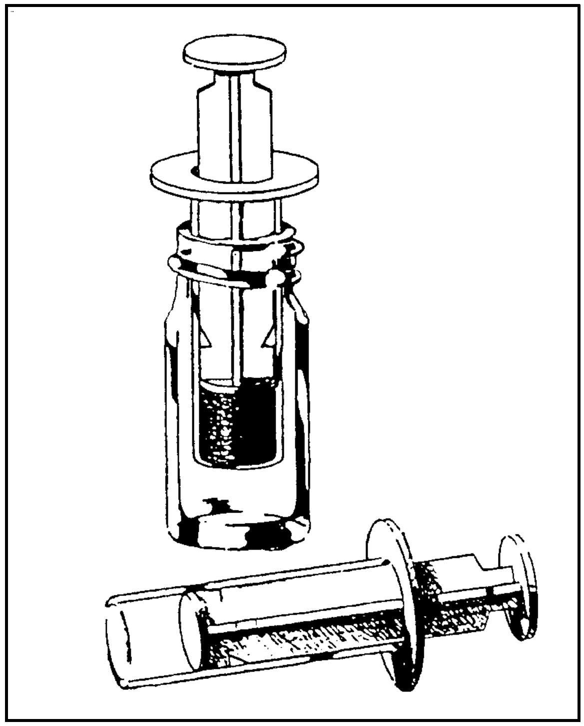

Figure E-19. Modified syringe sampler

A modified syringe sampler is constructed by cutting off the lower end of the syringe attachment for the needle. The rubber cap is removed from the plunger, and the plunger is pushed in until it is flush with the cut end. For greater ease in pushing into the solid matrix, the front edge sometimes can be sharpened (ASTM D 4547). The syringe sampler is then pushed into the media to collect the sample, which then may be placed in a glass VOA vial for storage and transport to the laboratory. The sample is immediately extruded into the vial by gently pushing the plunger. The volume of material collected should not cause excessive stress on the device during intrusion into the material, or be so large that the sample falls apart easily during extrusion.

Advantages

- Obtains a relatively undisturbed profile sample.
- Can be used for the collection of samples for the analysis of volatile compounds as long as sample extrusion is quickly and carefully executed.
- No significant physical limitations for its use.
- Low-cost, single-use device.

Limitations

- Cannot be used to sample gravel or rocky soils.
- Material of construction may be incompatible with highly contaminated media.
- Care is required to ensure that the device is clean before use.
- The device cannot be used to store and transport a sample.

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities,* ASTM D 6232
- *Standard Guide for Sampling Waste and Soils for Volatile Organic Compounds,* ASTM D 4547

E.5 Rotating Coring Devices

Rotating coring devices include equipment that obtains vertical columns of a solid sample through a rotating action. Some of these devices (such as augers) also can be used for just boring a hole for sample collection at a certain depth using another piece of equipment. You will find summaries for the following rotating coring devices in this section:

E.5.1 Bucket Auger
E.5.2 Rotating Coring Device

E.5.1 Bucket Auger

The bucket auger (Figure E-20) is a hand-operated rotating coring device generally used to sample soil, sediment, or unconsolidated solid waste. It can be used to obtain samples from drums, storage containers, and waste piles. The sample volume range is 0.2 to 1.0 liters (ASTM D 6232).

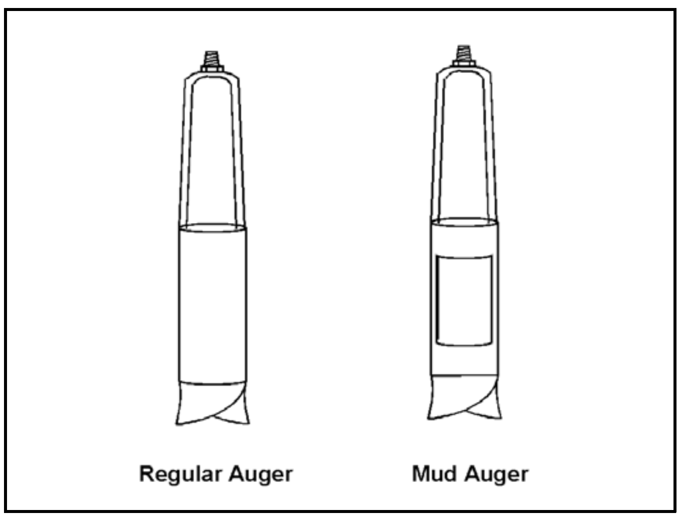

Figure E-20. Bucket auger

The cutting head of the auger bucket is pushed and twisted by hand with a downward force into the ground and removed as the bucket is filled. The empty auger is returned to the hole and the procedure is repeated. The sequence is continued until the required depth is reached. The same bucket may be used to advance the hole if the vertical sample is a composite of all intervals; however, discrete grab samples should be collected in separate clean auger buckets. The top several inches of material should be removed from the bucket to minimize chances of cross-contamination of the sample from fall-in material from the upper portions of the hole.

Note that hand augering may be difficult in tight clays or cemented sands. At depths approaching 20 feet (6 m), the tension of hand auger extension rods may make operation of the auger too difficult. Powered methods are recommended if deeper samples are required (ASTM D 6232).

Advantages

- Reusable and easy to decontaminate.
- Easy to use and relatively quick for shallow subsurface samples.
- Allows the use of various auger heads to sample a wide variety of soil conditions (USEPA 1993c).
- Provides a large volume of sample in a short time.

Limitations

- Depth of sampling is limited to about 20 feet (6 m) below the surface.
- Not suitable for obtaining undisturbed samples.
- Requires considerable strength to operate and is labor intensive.
- Not ideal for sampling soils for volatile organic compounds.

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities*, ASTM D 6232
- *Standard Practice for Soil Investigation and Sampling by Auger Borings,* ASTM D 1452
- *Standard Guide for Soil Sampling from the Vadose Zone,* ASTM D 4700
- *Standard Practice for Sampling Unconsolidated Waste From Trucks*, ASTM D 5658
- *Standard Guide for Sampling of Drums and Similar Containers by Field Personnel,* ASTM D 6063
- “Waste Pile Sampling” (USEPA 1994d)

- "Sediment Sampling" (USEPA 1994e)

E.5.2 Rotating Coring Device

The rotating coring device (Figure E-21) collects vertical columns of a solid sample through a rotating action and can be used in sampling consolidated solid waste, soil, and sediment. The sample volume range is 0.5 to 1.0 liters (ASTM D 6232).

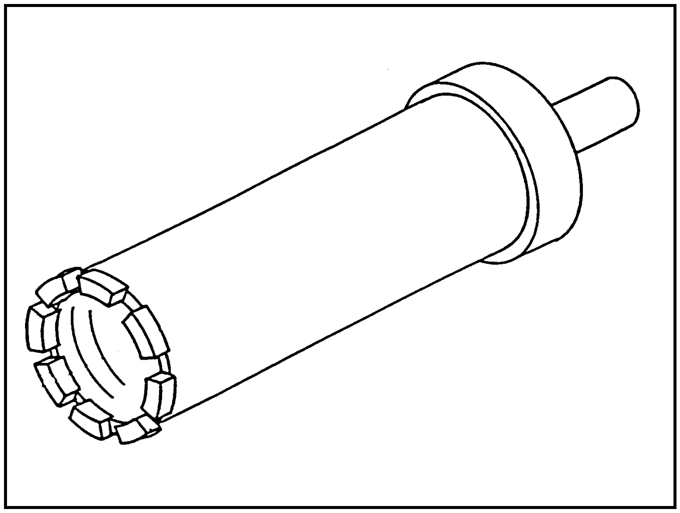

Figure E-21. Rotating coring device

The rotating coring device consists of a diamond- or carbide-tipped open steel cylinder attached to an electric drill. The coring device may be operated with the drill hand-held or with the drill mounted on a stand. When on a portable stand, full-depth core samples can be obtained. The barrel length is usually 1- to 1.5-feet long and the barrel diameter ranges from 2 to 6 inches (ASTM D 6232 and ASTM D 5679). The rotating coring device may be used for surface or depth samples.

The rotating coring device is placed vertical to the surface of the media to be sampled, then turned on before contact with the surface. Uniform and continuous pressure is supplied to the device until the specified depth is reached. The coring device is then withdrawn and the sample is placed into a container for analysis, or the tube itself may be capped and sent to the laboratory. Capping the tube is preferred when sampling for volatile organic compounds. The rotating tube must be cooled and lubricated with water between samples.

Advantages

- Easy to decontaminate.
- Reusable.
- Can obtain a solid core sample.

Limitations

- Requires a battery or other source of power.
- Requires a supply of water, used for cooling the rotating tube.
- Not easy to operate.

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities*, ASTM D 6232
- *Standard Practice for Sampling Consolidated Solids in Drums or Similar Containers*, ASTM D 5679
- “Drum Sampling” (USEPA 1994b)
- “Sediment Sampling” (USEPA 1994e)

E.6 Liquid Profile Devices

Liquid profile devices include equipment that can collect a vertical column of a liquid, sludge, or slurry sample. You will find summaries for the following liquid profile devices in this section:

E.6.1 Composite Liquid Waste Sampler (COLIWASA)
E.6.2 Drum Thief
E.6.3 Valved Drum Sampler
E.6.4 Plunger Type Sampler
E.6.5 Settleable Solids Profiler (Sludge Judge)

E.6.1 COLIWASA (Composite Liquid Waste Sampler)

The COLIWASA (Figure E-22) is a type of liquid profile sampling device used to obtain a vertical column of sampled material. A COLIWASA is recommended for sampling liquids, multi-layer liquid wastes, and mixed-phase solid/liquid wastes and is commonly used to sample containerized liquids, such as tanks and drums. It also may be used for sampling open bodies of stagnant liquids. The sample volume range is 0.5 to 3 liters (ASTM D 6232).

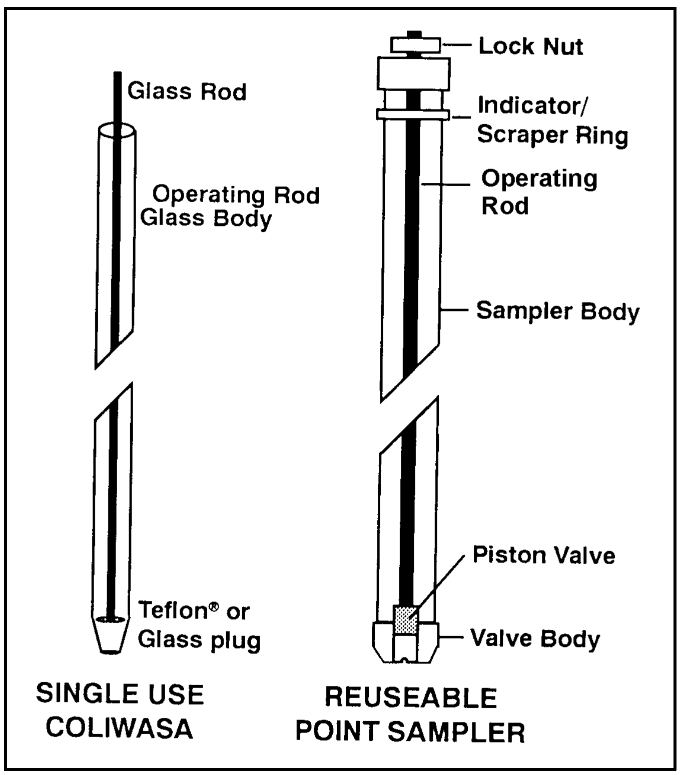

Figure E-22. COLIWASA

A COLIWASA can be constructed of polyvinyl chloride (PVC), glass, metal, PTFE or any other material compatible with the sample being collected. In general, a COLIWASA comprises a tube with a tapered end and an inner rod that has some type of stopper on the end. The design can be modified or adapted to meet the needs of the sampler. One configuration comprises a piston valve attached by an inner rod to a locking mechanism at the other end. Designs are available for specific sampling situations (i.e., drums, tanks). COLIWASAs specifically designed for sampling liquids, viscous materials, and heavy sludges are also available. COLIWASAs come in a variety of diameters (0.5 to 2 inches) and lengths (4 to 20 feet) (ASTM D 6232).

COLIWASAs are available commercially with different types of stoppers and locking mechanisms, but all have the same operating principle. To draw a sample, the COLIWASA is slowly lowered into the sample at a right angle with the surface of the material. (If the COLIWASA sampler is lowered too fast, the level of material inside and outside the sampler may not be the same, causing incorrect proportions in the sample. In addition, the layers of multi-layered materials may be disturbed.) The sampler is opened at both ends as it is lowered to allow the material to flow through it. When the device reaches the desired sampling depth, the sampler is closed by the stopper mechanism and both tubes are removed from the material. The sampled material is then transferred to a sample container by opening the COLIWASA. A COLIWASA can be reused following proper decontamination (reusable point sampler) or disposed after use (single-use COLIWASA). The reusable point sampler is used in the same way as the single use COLIWASA; however, it can also sample at a specific point in the liquid column.

Advantages

- Provides correct delimitation and extraction of waste (Pitard 1989).
- Easy to use.
- Inexpensive.
- Reusable.
- Single-use models are available.

Limitations

- May break if made of glass and used in consolidated matrices.
- Decontamination may be difficult.
- The stopper may not allow collection of material in the bottom of a drum.
- High viscosity fluids are difficult to sample.

Other Guidance

- *Standard Practice for Sampling with a Composite Liquid Waste Sampler* (COLIWASA), ASTM D 5495
- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities,* ASTM D 6232

- *Standard Guide for Sampling Drums and Similar Containers by Field Personnel*, ASTM D 6063
- *Standard Practice for Sampling Single or Multilayered Liquids, With or Without Solids, in Drums or Similar Containers*, ASTM D 5743
- “Drum Sampling” (USEPA 1994b)
- “Tank Sampling” (USEPA 1994c)

E.6.2 Drum Thief

A drum thief (Figure E-23) is an open-ended tube and liquid profile sampling device that provides a vertical column of the sampled material. It is recommended for sampling liquids, multi-layer liquid wastes, and mixed-phase solid/liquid wastes and can be used to sample liquids in drums or similar containers. The typical sample volume range is 0.1 to 0.5 liters (ASTM D 6232).

Drum thieves can be made of glass, stainless steel, or any other suitable material. Drum thieves are typically 6 mm to 16 mm inside diameter and 48-inches long (USEPA 1994c). To sample liquids with low surface tension, a narrow bailer works best. In most cases, tubes with a 1-centimeter inside diameter work best. Wider tubes can be used to sample sludges.

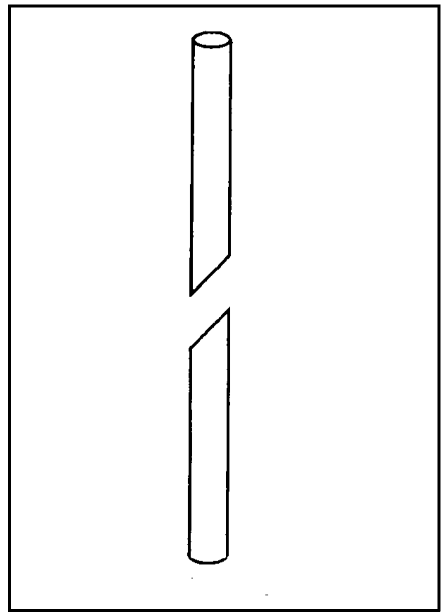

Figure E-23. Drum thief

The drum thief is lowered vertically into the material to be sampled, inserted slowly to allow the level of material inside and outside the tube to be approximately the same. This avoids incorrect proportions in the sample. The upper end is then sealed with the thumb or a rubber stopper to hold the sample in the tube as it is removed from the container. The thief is emptied by removing the thumb or stopper.

Advantages

- Easy to use and inexpensive.
- Available in reusable and single-use models.

Limitations

- Sampling depth is limited to the length of the sampler.
- May not collect material in the bottom of a drum. The depth of unsampled material depends on the density, surface tension, and viscosity of the material being sampled.

- Highly viscous materials are difficult to sample.
- May be difficult to retain sample in the tube when sampling liquids of high specific gravity.
- If made of glass, may break if used in consolidated matrices. In addition, chips and cracks in a glass drum thief may cause an imperfect seal.
- Decontamination is difficult.
- When sampling a drum, repeated use of the drum thief to obtain an adequate volume of sample may disturb the drum contents.
- Drum-size tubes have a small volume and sometimes require repeated use to obtain a sample. Two or more people may be required to use larger sizes.

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities,* ASTM D 6232
- *Standard Guide for Sampling of Drums and Similar Containers by Field Personnel*, ASTM D 6063
- *Standard Practice for Sampling Single or Multilayered Liquids, With or Without Solids, in Drums or Similar Containers*, ASTM D 5743
- "Drum Sampling" (USEPA 1994b)
- "Tank Sampling" (USEPA 1994c)

E.6.3 Valved Drum Sampler

A valved drum sampler (Figure E-24) is a liquid profile device often used to sample liquids in drums or tanks and provides a vertical column of the sampled material. A valved drum sampler is recommended for sampling liquids, multi-layered liquid wastes, and mixed-phase solid/liquid wastes. The typical sample volume range is 0.3 to 1.6 liters (ASTM D 6232).

The sampler can be constructed from PTFE for reuse or polypropylene for single use and comprises a tube fitted with a top plug and a bottom valve. A sliding indicator ring allows specific levels or fluids interfaces to be identified.

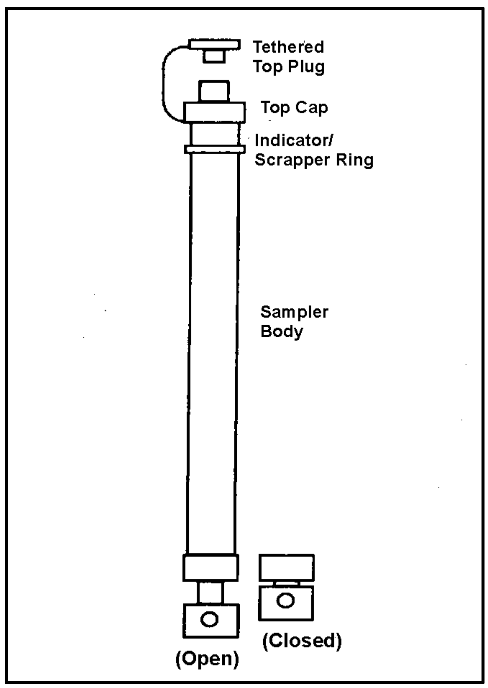

Figure E-24. Valved drum sampler

The valved drum sampler is open at both ends during sample collection and lowered vertically into the material to be sampled. The sampler is inserted slowly to allow the level of material inside and outside the tube to equalize. Once the desired amount of sample is collected, the top plug and the bottom valve are closed. The top plug is closed manually and the bottom valve is closed by pressing against the side or bottom of the container. The sample is poured from the top of the sampler into a suitable container.

Advantages

- Easy to use, inexpensive, and unbreakable.
- Obtains samples to depths of about 8 feet (2.4 m) (ASTM D 6232).
- Reusable if made from PTFE (single-use if made from polypropylene) (ASTM D 6232).

Limitations

- Somewhat difficult to decontaminate
- The bottom valve may prevent collection of the bottom 1.25 cm of material (ASTM D 6232).
- High viscosity fluids are difficult to sample.

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities*, ASTM D 6232

E.6.4 Plunger Type Sampler

The plunger type sampler (Figure E-25) is a liquid profile sampling device used to collect a vertical column of liquid and is recommended for the sampling of single and multi-layered liquids or mixtures of liquids and solids. The plunger type sampler can be used to collect samples from drums, surface impoundments, and tanks. Sample volume is at least 0.2 liters and ultimately depends on the size of the sample container (ASTM D 6232).

A plunger type sampler comprises a sample tube, sample line or rod, head section, and plunger and is made of HDPE, PTFE, or glass. A sample jar is connected to the head section. The sample tube is lowered into the liquid to the desired depth. The plunger is engaged into the tube to secure the sample within the tube and the cord or rod is raised to transfer the sample directly into the

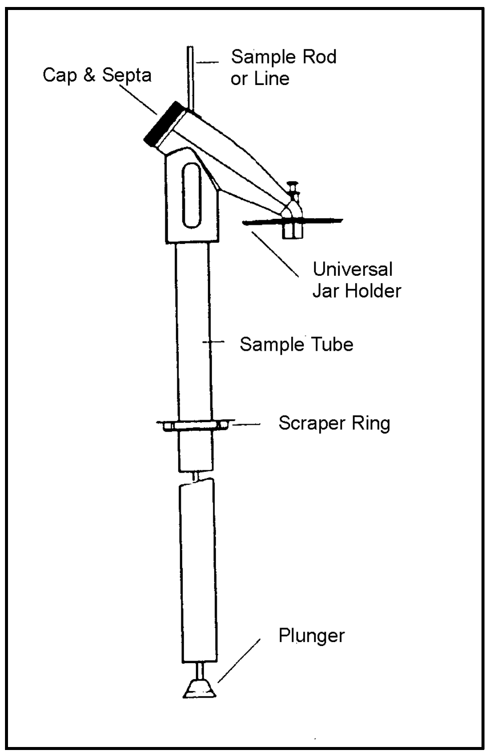

Figure E-25. Plunger type sampler

sampling bottle or jar. The plunger can be pushed back down the sampling tube to reset the sampler.

Advantages

- Easy to use.
- Provides a sealed collection system.
- Relatively inexpensive and available in various lengths.

Limitations

- Care is needed when using a glass sampling tube.
- Decontamination may be difficult, particularly when a glass sampling tube is used.

Other Guidance:

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities*, ASTM D 6232
- *Standard Practice for Sampling Single or Multilayered Liquids, With or Without Solids, in Drums or Similar Containers*, ASTM D 5743

E.6.5 Settleable Solids Profiler (Sludge Judge)

The settleable solids profiler (Figure E-26), also known as the sludge judge, primarily is used to measure or sample settleable (suspended) solids found in sewage treatment plants, waste settling ponds and impoundments containing waste. It also can be used to sample drums and tanks. It has a sample volume range of 1.3 to 4.0 liters (ASTM D 6232).

The sludge judge is made from clear PVC and has 1-foot-depth markings on its 5-foot-long body sections. It has a check valve on the lower section and a cord on the upper section and is assembled using the threaded connections of the sections to the length needed for the sampling event. The sampler is lowered into the media to allow it to fill. A tug on the cord sets the check valve and it is removed from the sampled material. The level of settleable solids can be measured using the markings. It is emptied by pressing in the protruding pin on the lower end.

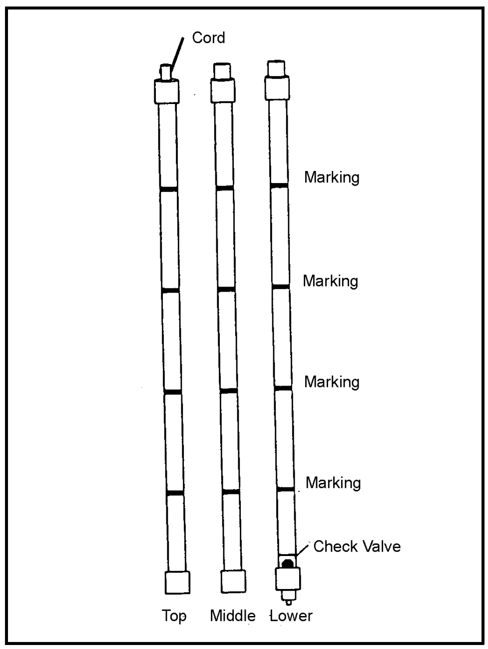

Figure E-26. Settleable solids profiler

Advantages

- Allows measurement of the liquid/settleable solids columns of any length.
- Easy to assemble and use.
- Unbreakable in normal use and reusable.

Limitations

- Suitable for sampling noncaustic liquids only.
- May be difficult to sample high viscosity materials.

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities*, ASTM D 6232

E.7 Surface Sampling Devices

Surface sampling devices include equipment that by design are limited to sample collection at the surface of material or can sample material of limited depth or width only. You will find summaries for the following surface sampling devices in this section:

E.7.1 Bailer
E.7.2 Dipper
E.7.3 Liquid Grab Sampler
E.7.4 Swing Jar Sampler
E.7.5 Spoons, Scoops, Trowels, and Shovels

E.7.1 Bailer

Bailers (Figure E-27) are designed for obtaining samples of ground water; however, they also can be used to obtain samples of liquids and multi-layered liquid wastes from tanks and surface impoundments. Bailers are not suitable for sampling sludges. The sample volume range is 0.5 to 2 liters (ASTM D 6232).

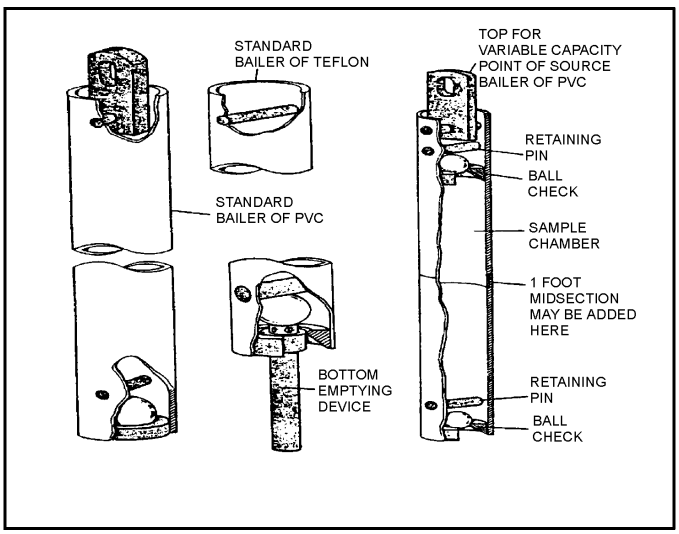

Figure E-27. Bailer

A bailer is a hollow tube with a check valve at the base (open bailer) or valves at both ends (point-source bailer). A bailer can be threaded in the middle so that extension tubes can be added to increase the sampling volume. It can be constructed of stainless steel, PVC, PTFE, or any other suitable material and is available in numerous sizes for use in a variety of well sizes. The bailer is attached to a line and gradually lowered into the sample. As the bailer is lowered, the bottom check valve allows water to flow through the tube. The bailer is then slowly raised to the surface. The weight of the water closes the bottom check valve. A point-source bailer allows sampling at a specific depth. The check valve at the top of the tube limits water or particles from entering the bailer as it is retrieved.

The bailer is emptied either by pouring from the top or by a bottom emptying device. When using a top-emptying bailer, the bailer should be tipped slightly to allow a slow discharge into the sample container to minimize aeration. A bottom-emptying model has controlled flow valves, which is good for collecting samples for volatile organic analysis since agitation of the sample is minimal.

Advantages

- Easy to use, inexpensive, and does not require an external power source.
- Can be constructed of almost any material that is compatible with the parameters of interest.
- Relatively easy to decontaminate between samples. Single-use models are available.
- Bottom-emptying bailers with control valves can be used to obtain samples for volatile compound analysis.

Limitations

- Not designed to obtain samples from specific depths below liquid surface (unless it is a point-source bailer).
- If using a top-emptying bailer, the sample may become aerated if care is not taken during transfer to the sample container.
- May disturb the sample in a water column if it is lowered too rapidly.
- High suspended solids' content or freezing temperatures can impact operation of check valves.
- One of the least preferred devices for obtaining samples of ground water for low concentration analyses due to their imprecision and agitation of the sample (see USEPA 1992a and Puls and Barcelona 1996).

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities*, ASTM D 6232
- *Standard Guide for Sampling Groundwater Monitoring Wells*, ASTM D 4448

- "Tank Sampling" (USEPA 1994c)

E.7.2 Dipper

A dipper (Figure E-28) is a type of surface sampling device used to sample surface samples from drums, surface impoundments, tanks, pipes, and point source discharges. Sampling points are shallow (10 inches) and taken at, or just below, the surface. The typical sample volume range is 0.5 to 1.0 liters (ASTM D 6232).

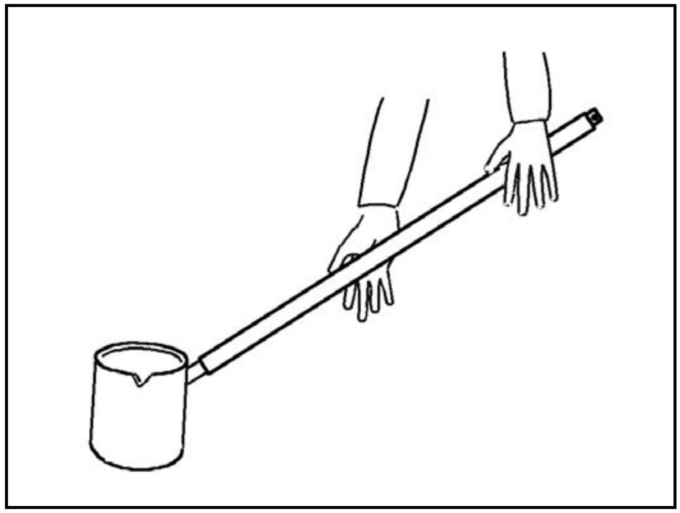

Figure E-28. Dipper

A dipper comprises a glass, metal, or plastic beaker clamped to the end of a two- or three-piece telescoping aluminum or fiberglass pole, which serves as a handle. A dipper may vary in the number of assembled pieces. Some dippers have an adjustable clamp attached to the end of a piece of metal tubing. The tubing forms the handle; the clamp secures the beaker. Another type of dipper is a stainless steel scoop clamped to a movable bracket that is attached to a piece of rigid tube. The scoop may face either toward or away from the person collecting the sample, and the angle of the scoop to the pipe is adjustable. The dipper, when attached to a rigid tube, can reach easily 10 to 13 feet (3 to 4 m) away from the person collecting the samples (ASTM D 6232).

The dipper is used by submerging the beaker end into the material slowly (to minimize surface disturbance). It should be on its side so that the liquid runs into the container without swirling or bubbling. The beaker is filled and rotated up, then brought slowly to the surface. Dippers and their beakers should be compatible with the sampled material.

Advantages

- Inexpensive.

- Easy to construct and adapt to the sampling scenario by modifying the length of the tubing or the type of container.

Limitations

- Not appropriate for sampling subsurface layers or to characterize discrete layers of stratified liquids.

- Can only be used to collect surface samples.

Other Guidance

- *Standard Practice for Sampling with a Dipper or Pond Sampler*, ASTM D 5358
- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities,* ASTM D 6232
- *Standard Practice for Sampling Wastes from Pipes and Other Point Discharges,* ASTM D 5013

E.7.3 Liquid Grab Sampler

A liquid grab sampler (Figure E-29) is a surface sampling device designed to collect samplers at a specific shallow depth beneath the liquid surface. It can be used to collect samples of liquids or slurries from surface impoundments, tanks, and drums. Its sample volume range is from 0.5 to 1.0 liters (ASTM D 6232).

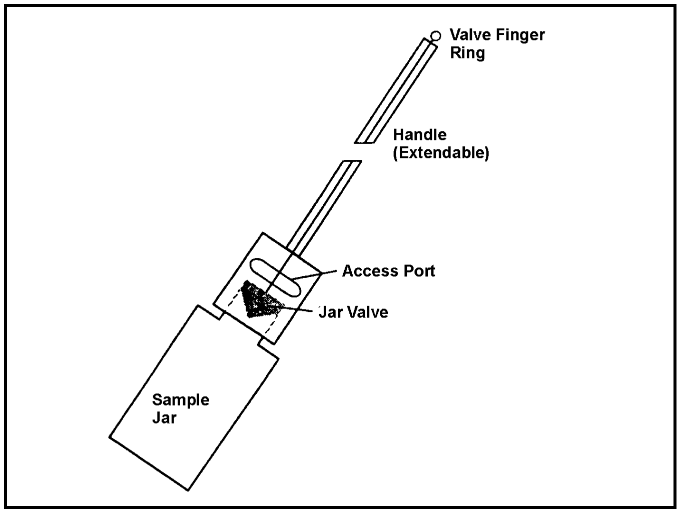

Figure E-29. Liquid grab sampler

The liquid grab sampler is usually made from polypropylene or PTFE with an aluminum or stainless steel handle and stainless steel fittings. The sampling jar is usually made of glass, although plastic jars are available. The jar is threaded into the sampler head assembly, then lowered by the sampler to the desired sampling position beneath the liquid surface. The valve is then opened by pulling up on a finger ring to fill the jar. The valve is closed before retrieving the sample.

Advantages

- Easy to use.
- The sample jar can be capped and used for transport to the laboratory, thus minimizing the loss of volatile organic compounds.
- The closed sampler prevents contaminants in upper layers from compromising the sample.

Limitations

- Care is required to prevent breakage of glass sample jar.
- Materials of construction need to be compatible with the sampled media.

- Cannot be used to collect deep samples.

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities*, ASTM D 6232

E.7.4 Swing Sampler (Swing Jar Sampler)

The swing jar sampler (Figure E-30) is a surface sampler that may be used to sample liquids, powders, or small solids at distances of up to 12 feet (3.5 m). It can be used to sample many different types of units, including drums, surface impoundments, tanks, pipe/point source discharges, sampling ports, and storage bins. It has a sample volume range of 0.5 to 1.0 liters.

The swing jar sampler is normally used with high density polyethylene sample jars and has an extendable aluminum handle with a pivot at the juncture of the handle and the jar holder. The jar is held in the holder with an adjustable clamp. The pivot allows samples to be collected at different angles.

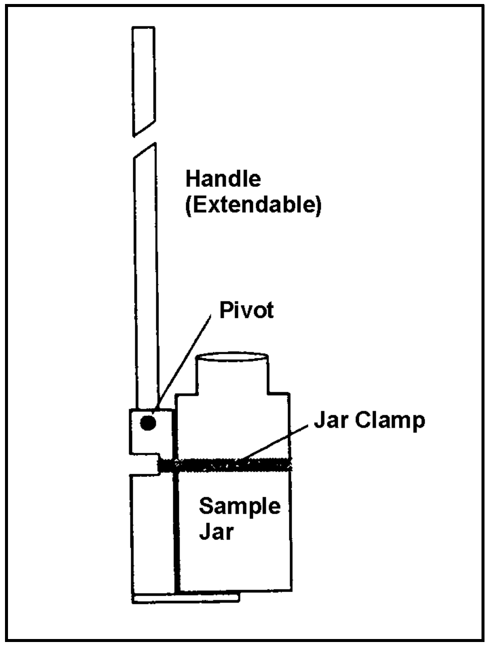

Figure E-30. Swing jar sampler

Advantages

- Easy to use.

- Easily adaptable to samples with jars of different sizes and materials, which can be used to facilitate compatibility with the material to be sampled.

- Can be pivoted to collect samples at different angles.

- Can sample from a wide variety of locations and units.

Limitations

- Cannot collect discrete depth samples.

- Care is required to prevent breakage when using a glass sample jar.

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities*, ASTM D 6232

E.7.5 Spoons, Scoops, Trowels, and Shovels

Spoons, scoops, trowels, or shovels are types of surface sampling devices used to sample sludge, soil, powder, or solid wastes. The typical sample volume range is 0.1 to 0.6 liters for scoops or trowels and 1.0 to 5.0 Liters for shovels (ASTM D 6232). The typical sample volume for a spoon is 10 to 100 grams (USEPA 1993c).

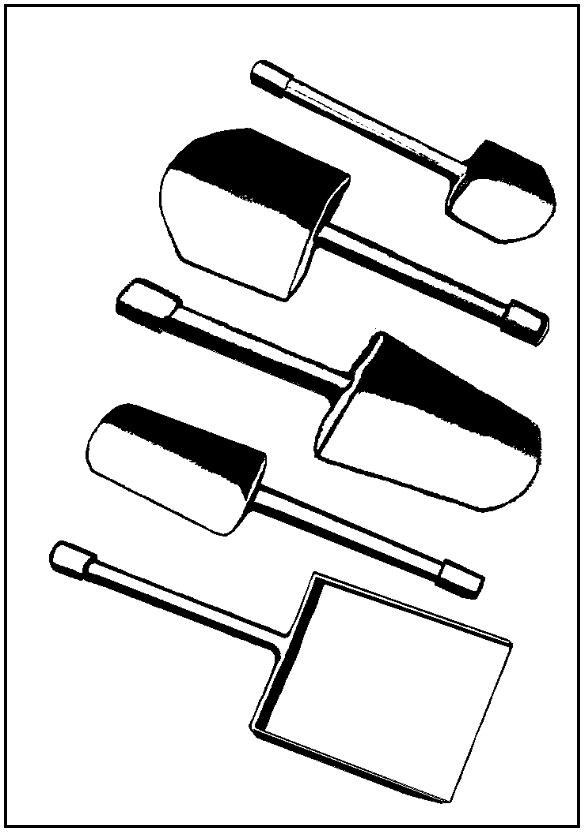

Figure E-31. Scoops

Spoons, available in stainless steel or PTFE (reusable) or in plastic (disposable), easily sample small volumes of liquid or other waste from the ground or a container.

Scoop samplers provide best results when the material is uniform and may be the only sampler possible for materials containing fragments or chunks. The scoop size should be suitable for the size and quantity of the collected material. Scoops and trowels come in a variety of sizes and materials, although unpainted stainless steel is preferred (ASTM D 6232). Scoops may be attached to an extension, similar to the dipper, in order to reach a particular area. Scoops and trowels are used by digging and rotating the sampler. The scoop is used to remove a sample and transfer it into a sample container.

Shovels, usually made from stainless steel or suitable plastic materials, are typically used to collect surface samples or to remove overburden material so that a scoop may remove a sample.

Advantages

- A correctly designed scoop or spatula (i.e., with a flat bottom and vertical sides) is one of the preferred devices for sampling a one-dimensional mass of granular solids (see also Sections 6.3.2.1 and 7.3.3.3).

- Spoons, scoops, trowels, and shovels are reusable, easy to decontaminate, and do not require significant physical strength to use.

- Spoons and scoops are inexpensive and readily available.

- Spoons and scoops are easily transportable and often disposable -- hence, their use can reduce sampling time.

- Shovels are rugged and can be used to sample hard materials.

Limitations

- Spoons, scoops, trowels, and shovels are limited to shallow and surface sampling.

- Shovels may be awkward to handle and cannot be used to easily fill small sample containers.

- Sampling with a spoon, scoop, trowel, or shovel may cause loss of volatile organic compounds through disturbance of the media.

- Spoons, scoops, trowels, and shovels of incorrect design (e.g., with rounded bottoms) can introduce bias by preferentially selecting certain particle sizes.

Other Guidance

- *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities*, ASTM D 6232

- *Standard Practice for Sampling with a Scoop*, ASTM D 5633

- “Waste Pile Sampling” (USEPA 1994d)

- “Sediment Sampling” (USEPA 1994e).