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Project Summary

Preparation of Soil Sampling Protocols: Sampling Techniques and Strategies

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This document is designed to serve as a companion to the *Soil Sampling Quality Assurance User's Guide, Second Edition.* In order to make it current with the state-of-the-art, the predecessor document, published in 1983, has been thoroughly reviewed and revised. The two documents together provide methods, techniques, and procedures for designing a variety of soil measurement programs and associated quality assurance project or program plans, implementing those programs, and then analyzing, interpreting, and presenting the resultant data.

This Project Summary was developed by EPA's Environmental Monitoring Systems Laboratory, Las Vegas, NV, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

During the initiation of any project in which the conceptual model of the site indicates that soil is one of the key factors, proper planning and selection of the techniques and strategies for collecting the samples is essential. Proper planning in the early stages of a project can ensure that the final data received will be of sufficient quality and adequately represent the site to allow for the correct decision to be made concerning the "fate" of the site. In contrast, the lack of proper planning often leads to data being generated that do not sufficiently meet the initial project goals, even if laboratory analyses are perfect. If this situation occurs, the time and expense of sampling and analysis are lost and resampling of the site may be necessary to allow for a competent decision to be made.

During the preliminary phase of planning a soil sampling project, several general characteristics of the site and/or problem must be considered. These characteristics include:

- the type and distribution of the contaminant (or other constituent of interest),
- the natural soil characteristics that can influence the distribution of the contaminant of concern, and
- the nature of the media to be sampled (i.e., soil vs. non-soil materials, or a combination of the two distinctly different media).

These general components provide the project planner with the necessary information required for the development of a proper soil sampling protocol.

Once the basic characteristics of the site and problem have been clearly identified, the strategy and techniques to collect the samples must be developed. During this phase in the development of soil sampling protocols, the investigator should consider the following issues:

- the size or area of contamination,
- particulate sampling theory to address proper sample and subsample collection,
- statistical aspects pertaining to soil sampling,

- the use of relevant historical data,
- sampling designs and their appropriate use,
- proper sample collection procedures,
- other types of sampling of soil materials, and
- interpretation of the final results.

When each of these issues is properly considered and addressed, a solid basis for the development of a soil sampling protocol will have been established.

The Size or Area of Contamination

The concept of a "support" as it applies to soil sampling and the determination of the size of the site (or subunits within a site) has been presented. The specific size, shape, orientation, and spatial arrangement of the samples to be collected constitute the "support". Risk and exposure assessment data can often be used to assist in defining an "action support" or can be used in the application of an action level over a particular support.

Particulate Sampling Theory

The minimum amount of soil required to make up the "support" can be determined using the concepts developed in particulate sampling theory. Gy's theory (developed by Dr. Pierre Gy of the Paris School of Mines) is based upon the relationship between the variability of the material, particle sizes in the material, distribution of the component of interest, and size of the sample taken. The variability found in particulate material, such as soil, is based upon the number of individual particles in the sample. Therefore, the controlling factor in the collection of a correct soil sample is the size of the largest particle. Thus, samples that have been screened prior to analysis with the coarser fractions being discarded, can produce greatly biased results. Fortunately, most soils have particle-size ranges in which the "typical" sample size collected is adequate to address this concern. In cases where a fine-textured soil has an abundance of cobbles and gravels or where wastes such as rubble, construction debris, or battery cases are present in the soil, the validity of the contaminant concentration data may be questionable if appropriate steps are not taken to account for the occurrence of these large "particles".

Additionally, particulate sampling theory directly addresses the process of obtaining of a correct sample by providing the basis for extracting the sample from the site and for aliquoting a subsample in the laboratory. Seven sources of sampling error have been clearly delineated, thereby allowing the study planner to properly take steps to reduce these errors. Techniques and suggestions are presented to extract an unbiased soil sample and thus control or at least allow for the estimation of the size of these errors.

Statistical Aspects Pertaining to Soil Sampling

Several of the sample handling techniques that are often used to reduce sample variability (or sampling error) include:

- subsampling and sample size reduction,
- composite sampling, and
- sample homogenization.

Since these processes are incorporated in the initial sampling program and can affect the final data, the investigator must weigh the value of the information gained versus information lost by performing the various sample handling operations to more accurately assess which techniques can be used to meet the project goals.

When a sample of any population, such as soil, is collected, it is usually necessary to reduce its original size to some smaller quantity of material for chemical analysis (i.e., a subsample). The guiding principle for the subsample selection is that the probability of collection of all fractions of the soil must be equal. If any fraction is excluded or favored, sampling is not correct and the results will be biased.

One of the key elements of Gy's particulate sampling theory is the identification of the size or weight of sample that must be taken in order to insure a predetermined level of reliability. If proper techniques are used and if an appropriate sample weight is collected for the given particle-size range in the sample, then subsampling techniques can be a means for reducing the bias and error within the sample. If an inadequate subsample size is collected or improper techniques are used, then an unknown level of bias exists and consequently may affect the final decision to be made concerning the site.

Several techniques, including the use of riffle splitters, alternate shoveling, or incremental sampling, can be used to reduce the volume of sampled material to an appropriate subsample. Riffle splitters are an effective means to reduce sample size but only work with freely flowing materials. The alternate shoveling method can be used in the field or laboratory if the material is not cohesive. Incremental sampling involves extraction of one or more distinct increments of material for inclusion in the final sample. With the exception of incremental sampling, these methods will not work with samples being tested for volatile organic compounds.

The standard deviation around a mean estimate obtained from a series of soil samples is often quite large. One technique to reduce the variability is to composite samples. Composite samples can be created from a well homogenized sample made up of a number of increments or from several samples collected from the support. The use of composite samples is often recommended as a means of reducing the cost of sampling at a particular site. When properly used, compositing can provide a means of quickly assessing the average pollutant concentration and if an area needs further sampling. One problem with compositing samples is the loss of individual sample information and concentration sensitivity due to the dilution of the samples (i.e., a "hot spot" may be unidentifiable due to the inclusion of one increment from the "hot spot" into the composite sample with multiple increments from the "clean" background soil).

Homogenization is not a statistical concept; however, it is used to control the variance within a sample. The mixing of the sample reduces the distribution and segregation errors, as defined in Gy's particulate sampling theory, and thereby increases the probability of obtaining a more representative sample or subsample than if homogenization is not performed. It should be noted that complete homogeneity in a soil sample is impossible to attain even though a sample may appear to be homogeneous visually on the macroscale.

The Use of Relevant Historical Data

Too little time is usually spent in preliminary data collection, evaluation, and planning. It is difficult, if not impossible, to undertake a reliable soils study without reviewing existing data and developing a conceptual model of the pollutant behavior at the site. Any information on the pollutants, potential routes of migration, and potential effects of migration is extremely useful during the development of soil sampling protocols. Any historical site information that includes:

- geologic character (e.g., parent material, bedrock type)

- soil characteristics (e.g., clay and organic matter contents, presence of hardpans)
- land use, past and present

should also be collected and used during the planning process. Some of the best sources of information are previously conducted environmental studies and remote sensing imagery.

Sampling Designs

The selection of a sampling design depends upon the purpose of the sampling program. A research project that is attempting to identify the source of a particular pollutant may be able to make collect samples from a known contamination source. On the other hand, an investigative soil sampling program where suspected contaminant dumping has occurred will require an entirely different sampling strategy.

Properly designed sampling plans based upon the laws of probability provide a means of making decisions that have a sound basis and are not likely to be biased. The use of statistical concepts during the planning of a soil sampling program allows the investigator to address concerns about the program's DQOs, in terms of precision, accuracy, and bias, as well as provides insight into the influence that various sample handling operations may have on the collected samples.

Perhaps the most effective sampling program occurs when the sampling can be carried out in multiple phases. The first phase is a preliminary or pilot study designed to determine the components of variance for a particular material, to develop estimates of the variability found in the soil/waste combination, and to work out the necessary sampling protocols for the later phases. The later sampling protocols are thus more efficient in their use of both time and financial resources to meet the goals of the sampling program.

Some of the most common sampling designs include:

- random sampling which is used when inadequate site information is available,
- stratified random sampling which is used when distinct layers or locations with varying contaminant concentrations can be identified,
- systematic sampling which is used to provide superior site coverage,
- judgmental sampling which is used in conjunction with the other sampling designs and in "unusual" situations or where effects have been seen in the past, and
- background sampling which is used to determine the extent and presence of local contamination.

Sample Collection Procedures

There are two portions of the soil that are important to the environmental investigator. The surface layer (0-6 inches; 0-15 cm) reflects the deposition of airborne pollutants, especially recently deposited pollutants, and pollutants that are strongly bonded to soil particles. On the other hand, pollutants that have been deposited by liquid spills, by long-term deposition of water soluble materials, or by burial may be found at considerable depth. The methods of sampling each of these are slightly different, but all make use of one of two basic techniques. Samples can either be collected with some form of core sampler or auger device, or they may be collected by use of excavations or trenches.

For sampling soil in the upper meter 15 centimeters (6 inches), devices such as soil punches, short King-tube samplers, ring samplers, scoops, and shovels are commonly used. These devices are easy to use, allow for the rapid sampling of the soil surface, are adaptable to a number of analytical schemes or needs, but are generally limited to the upper 20 centimeters (8 inches) of soil.

Sampling pollutants that have moved into the lower soil horizons to depths greater than 15 cm require the use of a device that will extract a longer core. Examples of the devices used for sampling these deeper soils are soil probes (often called King-tube samplers), augers, and power-driven corers.

Trench sampling is used to carefully remove soil sections during studies where detailed examination of pollutant pathways or detailed soil structure are required. Trench sampling may be the only way to sample sites where there is considerable rubble, wood, rock, scrap metal, or other obstructions. A trench is initially dug using a backhoe and layers or "steps" are then sequentially sampled from the surface downward. The surface of each step is cleaned and sampled by passing the sampler completely through the step before proceeding to the next step.

The guiding principle to reduce sampling collection error, regardless of which tool is used, is to insure that the tool traverses the *entire* strata or portion of the strata that is considered the sampling unit and that the entire sample is collected by the tool.

Other Types of Sampling of Soil Materials

The development of a number of remediation technologies has created areas where soil materials must be sampled for quality assurance purposes (i.e., replicates, independent laboratory confirmation samples, etc.), remedial compliance, and estimating the quantities of material that must be handled. Examples of these "new" areas for sampling of soils include process conveyor belt and stockpile sampling.

The correct sampling procedure for materials on process conveyor belts requires that all of the materials in a segment of the process flow be taken by sampling across the path of the flow. A tool that collects a segment of material having parallel sides perpendicular to the flow of materials is required. Cross stream samples should be taken at periodic intervals while the process is operating.

Correct sampling of stockpiled material requires taking a number of cuts completely through a flattened pile. Unfortunately, flattening large waste piles is generally not practical so samples are often taken from a cut in the pile and sampling from the cut face. This is not the most desirable approach but it can be used. If enough increments are taken from the face, a reasonable estimate of the average concentration can be made. Compositing the samples for the entire face is not recommended.

Another circumstance in which soil sampling is required is during site remediation. The investigator may be asked to provide quality assurance oversight on a contractor charged with the cleanup of the site. Systematic grid sampling appears to offer the most advantageous approach in these situations. Random samples can be used as an additional assurance that no major areas of contamination are being missed.

Interpretation of the Final Results

The final step in any study protocol is the interpretation of the data. There are numerous statistical tests available for handling data collected by each sampling design. *Prior* to attempting to use any of the designs, a statistician versed in environmental sampling design should be consulted to assure that the appropriate design is being used. However, the person doing the final data analysis must keep in mind the purpose for which the samples were collected to properly interpret the data. Additionally, the field scientist's impressions and observations noted during

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on-site activities may provide valuable information on the processes affecting the behavior of the pollutant and thus, how the data is interpreted.

With the marked advances in geostatistics, techniques such as kriging are becoming more commonly employed in soil mapping, isopleth development, and evaluation of the spatial distribution of soil and waste properties. The primary use of kriging is for data interpolation within the system of samples. Block kriging is perhaps the most useful approach for pollutant studies, however, punctual kriging is also commonly used. Block kriging allows the investigator to estimate the average concentration over a block of soil that represents a risk to the environment and thus decide the "fate" of the block (i.e., whether further sampling is required, whether the unit must be remediated, whether the unit is "clean", potential sample locations, etc.).

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The complete report, entitled "Preparation of Soil Sampling Protocols: Sampling Techniques and Strategies," (Order No. PB92-220532/AS; Cost: $26.00; subject to change) will be available only from:
National Technical Information Service
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