United States Environmental Protection Agency

Office of Solid Waste and Emergency Response

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Guide for Conducting Treatability Studies under CERCLA: Soil Vapor Extraction

Office of Emergency and Remedial Response
Hazardous Site Control Division OS-220

QUICK REFERENCE FACT SHEET

Section 121(b) of CERCLA mandates EPA to select remedies that "utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable" and to prefer remedial actions in which treatment that "permanently and significantly reduces the volume, toxicity, or mobility of hazardous substances, pollutants, and contaminants is a principal element." Treatability studies provide data to support remedy selection and implementation. They should be performed as soon as it becomes evident that the available information is insufficient to ensure the quality of the decision. Conducting treatability studies early in the remedial investigation/feasibility study (RI/FS) process should reduce uncertainties associated with selecting the remedy and should provide a sound basis for the Record of Decision (ROD). Regional planning should factor in the time and resources required for these studies.

This fact sheet provides a summary of information to facilitate the planning and execution of soil vapor extraction (SVE) remedy screening and remedy selection treatability studies in support of the RI/FS and the remedial design/remedial action (RD/RA) processes. Detailed information on designing and implementing remedy screening and remedy selection treatability studies for SVE is provided in the "Guide for Conducting Treatability Studies Under CERCLA: Soil Vapor Extraction," Interim Guidance, EPA/540/2-91/019A, September 1991.

INTRODUCTION

There are three levels or tiers of treatability studies: remedy screening, remedy selection, and remedy design. The "Guide for Conducting Treatability Studies Under CERCLA: Soil Vapor Extraction" discusses all three levels of treatability studies.

Remedy screening studies provide a quick and relatively inexpensive indication of whether SVE is a potentially viable remedial technology. Remedy selection studies provide data that permit evaluation of SVE's ability to meet expected site cleanup goals and provide information in support of the detailed analysis of the alternative (i.e., seven of the nine evaluation criteria specified in the EPA's RI/FS Interim Final Guidance Document, OSWER-9335.301). Remedy selection tests generally have moderate costs and may require weeks to months to complete. Remedy design testing provides quantitative performance, cost, and design information for remediating the operable unit. Remedy design studies are of moderate to high costs and may require months to complete.

TECHNOLOGY DESCRIPTION AND PRELIMINARY SCREENING

Technology Description

The SVE process is an in situ technique for the removal of volatile organic compounds (VOCs), and some semivolatile organic compounds (SVOCs), from the vadose zone. The vadose zone is the subsurface soil zone located between the surface soil and the top of the water table. SVE is used with other technologies in a treatment train since it transfers contaminants from soil to air and water wastestreams.

Figure 1 is a generalized schematic diagram of an SVE system. SVE treatment is conducted as follows. Vapor extraction wells or vents (1) are installed in the contaminated zone. As air is removed from the soil, ambient air is injected (2) or is drawn into the subsurface at locations around the contaminated site. When ambient air passes through the soil, contaminants are volatilized and removed. Entrained liquids are separated (3) from the contaminated air stream and the liquids

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are treated (6) to remove contaminants. The contaminated gas is drawn through a blower (4), treated (5), and discharged to the atmosphere.

As of fiscal year 1991 (FY 91), SVE has been selected as the remedial technology, or a component thereof, for over 30 sites. SVE was chosen as a component of the ROD at 10 sites in 1988, and 17 sites in 1989. SVE has had widespread use in cleaning up spills and leaks of hydrocarbons and other volatile organics at non-Superfund sites.

Prescreening Characteristics

The determination of the need for and the appropriate tier of treatability study required is dependent on the literature information available on the technology, expert technical judgment, and site-specific factors. The first two elements - the literature search and expert consultation - are critical factors of the prescreening phase in determining whether adequate data are available or whether a treatability study is needed.

Information on the technology applicability, the latest performance data, the status of the technology, and sources for further information are provided in one of a series of engineering bulletins being prepared by the EPA Risk Reduction Engineering Laboratory in Cincinnati, Ohio.

A literature search should be performed to determine the physical and chemical properties of the contaminants of interest. In conjunction with the site conditions and soil properties, contaminant properties will dictate whether SVE is feasible. SVE is most effective at removing compounds which have high vapor pressure and which exhibit significant volatility at ambient temperatures in contaminated soil. Low molecular weight, volatile compounds are most easily removed by SVE. Trichloroethene, trichloroethane, tetrachloroethene, and many gasoline constituents have been effectively removed by SVE. Compounds which are less suitable for removal include less volatile contaminants such as trichlorobenzene, heavy petroleum fuels, and extremely water-soluble volatiles such as acetone.

The soil characteristics of the site have a significant effect on the applicability of SVE. The air permeability of the contaminated soils controls the rate at which air can be drawn through the soil by the applied vacuum. The soil moisture content or degree of saturation is also important. It is usually easier to extract VOCs from drier soils due to the greater availability of pore area, which permits higher air-flow rates. However, extremely dry soils may tenaciously hold VOCs, which are more easily desorbed when water competes with them for adsorption sites. This phenomenon, which may be important in the southwestern states, favors a certain quantity of moisture to prevent sorption of contaminants.

Soils with high clay or humic content generally provide high adsorption potential for VOCs, thus leading to higher residual levels of adsorbed contaminants in these matrices. Clayey or silty soils, however, may be effectively ventilated by the usual levels of vacuum developed in an SVE system. The success of SVE in these soils may depend on the presence of more permeable strata (as would be expected in alluvial settings) or on relatively low moisture contents in

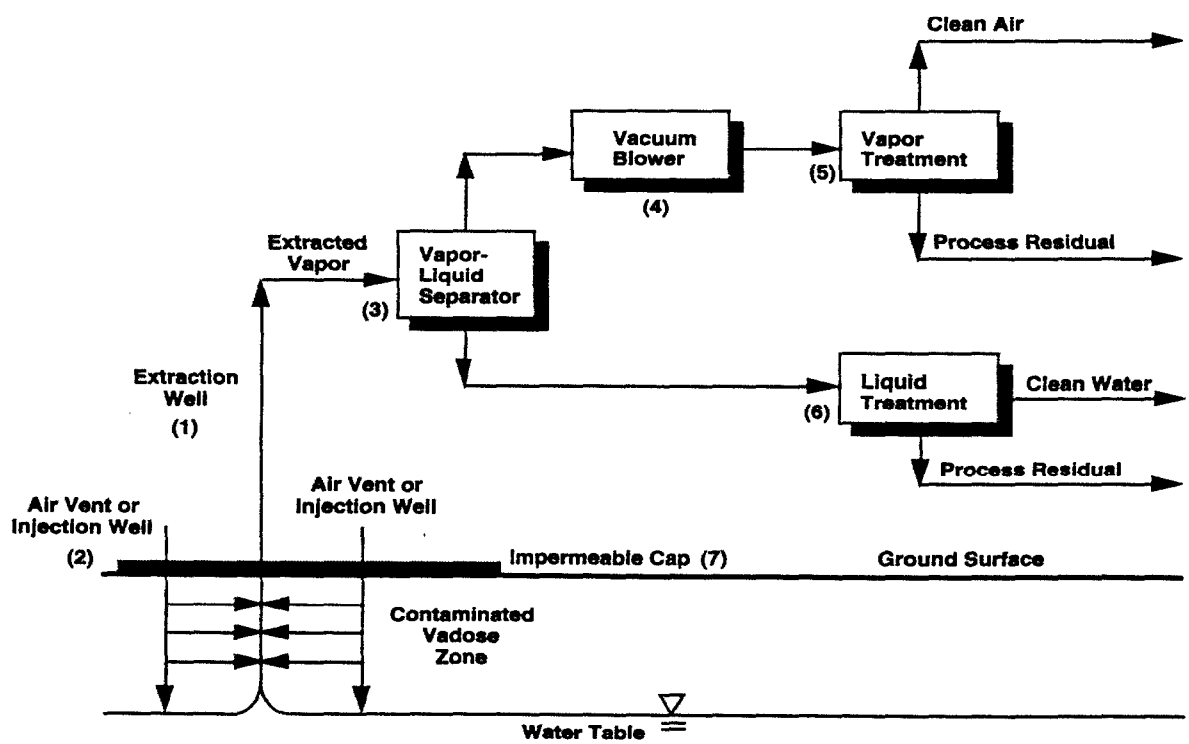

Figure 1. Generic Soil Vapor Extraction System.

the finer grained soils. Soil and ambient temperatures affect the performance of an SVE system primarily because they influence contaminant vapor pressure. At lower temperatures the potential for contaminant volatilization decreases.

Prescreening of SVE examines the field data for types of contaminant, concentration of the contaminant, and soil temperature to determine contaminant vapor pressure. If the vapor pressure of the contaminants of concern is below 0.5 mm of Hg, SVE is considered to be generally unsuitable. If the vapor pressure at the temperature of the soil is above 0.5 mm of Hg, treatability testing should be conducted.

Technology Limitations

Limitations of the SVE technology are those characteristics of the contaminants, soil, and site that hinder the extraction of the contaminants from the unsaturated soil. Low vapor pressure of the contaminants and low air permeability of the soil are the two most important factors that limit SVE technology.

Uncertainty appears to limit SVE as well as other in situ technologies. Areas of uncertainty include lack of precise information on site heterogeneities and contaminant location, inability to predict cleanup times, and doubt in some cases whether cleanup goals can be achieved (e.g., operation in fractured bedrock or at sites with very low cleanup targets). These areas of uncertainty must be recognized when conducting the treatability studies and when applying the technology.

THE USE OF TREATABILITY STUDIES IN REMEDY EVALUATION

Treatability studies should be performed in a systematic fashion to ensure that the data generated can support the remedy evaluation process. The results of these studies must be combined with other data to fully evaluate the technology.

There are three levels or tiers of treatability studies: remedy screening, remedy selection, and remedy design. Some or all of the levels may be needed on a case-by-case basis. The need for and the level of treatability testing are management-based decisions in which the time and cost of testing are balanced against the risks inherent in the decision (e.g., selection of an inappropriate treatment alternative). These decisions are based on the quantity and quality of data available and on other decision factors (e.g., State and community acceptance of the remedy or new site data).

Technologies may be evaluated first at the remedy screening level and progress through the remedy selection to the remedy design level. A technology may enter, however, at whatever level is appropriate based on experience with the technology and contaminants of concern and site-specific factors. Figure 2 shows the relationship of three levels of treatability study to each other and to the RI/FS process.

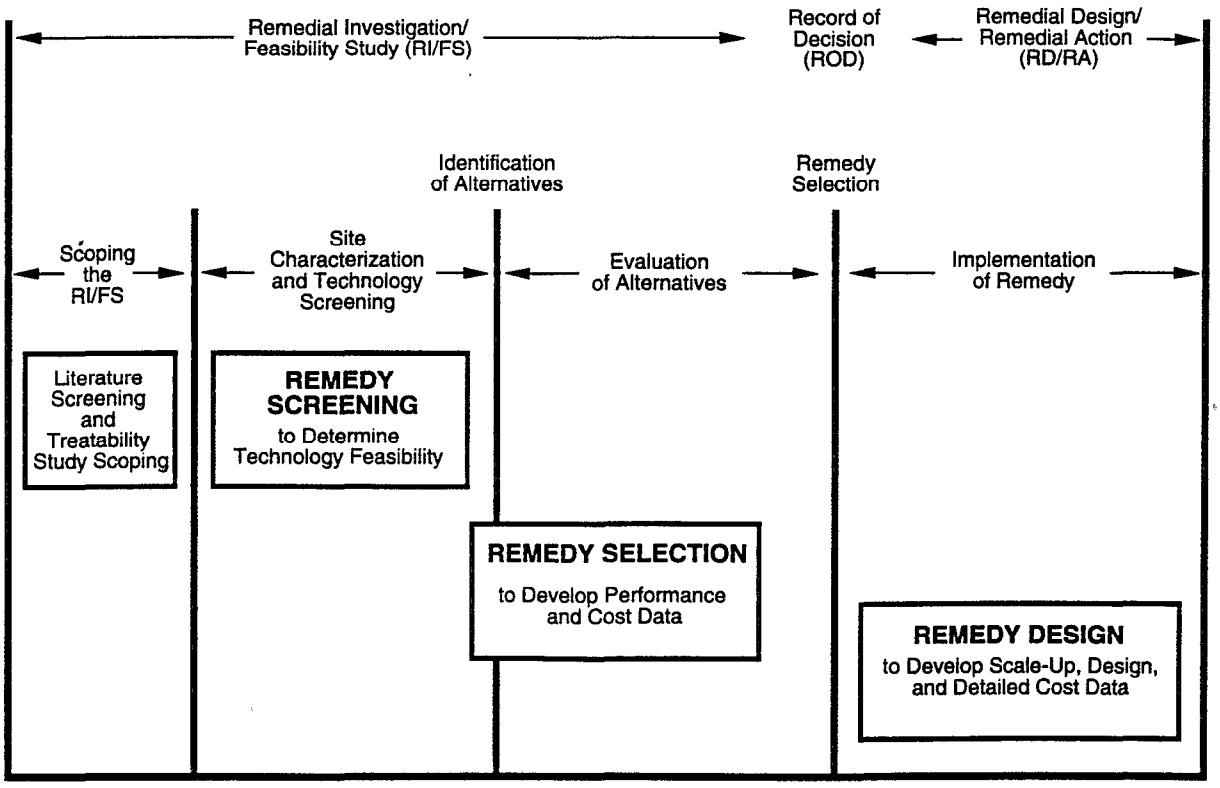

Figure 2. The Role of Treatability Studies in the RI/FS and RD/RA Process.

Remedy Screening

Remedy screening, the first tier of testing, is used to screen the ability of a technology to treat a contaminated soil using simple column tests. These studies are generally low cost (e.g., $10,000 to $50,000) and usually require days to complete. This tier is frequently skipped for evaluation of SVE technology.

Remedy Selection

Remedy selection, the second tier of testing, is used to evaluate the technology's performance on a contaminant-specific basis for an operable unit. These studies generally have moderate costs (e.g., $30,000 to $100,000 for SVE) and may require weeks to months to complete. They yield data that verify the technology's ability to meet expected cleanup goals and provide information in support of the detailed analysis of alternatives in the CERCLA Feasibility Study (FS). Column tests are run until an end-point is achieved. Treatability studies may be supplemented with field air permeability tests and mathematical modeling during the remedy selection phase. The combination of column tests, field air permeability tests, and mathematical modeling provide quantitative and qualitative performance information for the evaluation of SVE, as well as some cost and design information. However, due to the high degree of uncertainty associated with implementation of SVE, pilot-scale testing is often appropriate to support the remedy selection phase.

Column tests establish whether SVE can potentially meet expected target concentrations for a given site. They can also provide information on the contaminant distribution functions (partition functions) for use with certain mathematical models. Column tests do not, however, give reliable air permeability data. They do not permit the determination of whether mass transfer limitations will occur in the field application of SVE. The duration and cost of column testing for SVE depend primarily on the soil characteristics, the contaminants, the analyses being performed, and the number of replicates required for adequate testing. Most remedy selection column testing can be performed within 3 to 7 weeks at a cost between $30,000 and $50,000.

Air permeability tests should be conducted at the site after the column tests show that SVE can meet the expected target concentrations. Air permeability tests provide information on the air permeability of the different geological soil formations in the vadose zone at the site. Air permeability data can be used during the initial design to determine the radius of influence of vapor extraction wells, expected air-flow rates, moisture removal rates, and initial contaminant flow rates (when the effluent gas is analyzed). The air permeability tests cost about $1,500 to $2,500 per well. Total costs may run from $10,000 to $50,000. They are normally performed within a time range of 2 to 5 days.

Mathematical modeling can be used to provide rough estimates of the cleanup times required to achieve contaminant reductions to the target goals. These predictions are needed to evaluate health risks associated with short-term effectiveness and to estimate the total cost of the remediation. Mathematical modeling can also provide sensitivity analyses for critical variables such as air permeability, radius of influence, and vacuum applied. To be most effective, the modeling should use field-measured data on contaminant concentrations, air permeability, location of contaminants, soil porosity, soil moisture content, and soil temperature. Partition coefficients are obtained from column test measurements. The above field and column test data are the input variables to the model.

Pilot-scale testing for remedy selection is required for sites that have contamination in the bedrock, and complex sites that are very heterogeneous. Sites that contain pools of NAPL may also require pilot-scale testing. Pilot-scale tests determine whether sufficient air flow can be achieved in the zones of contamination to produce adequate cleanup rates. Pilot-scale data can also be used to determine the radius of influence of the vapor extraction wells, moisture-removal rates, and contaminant flow rates.

For complete characterization of the SVE process, the mathematical model must simulate both the flow field in the soil and the behavior of the contaminants within the soil matrix. In general, mathematical models provide a lower bound estimate of the time required to remediate a site using SVE. Therefore, lengthy cleanup time predictions from a model must be seriously considered as an indicator for discontinuing treatability assessments of SVE.

Remedy Design

Remedy design is the third tier of testing. It is used to provide quantitative performance, cost, and design information for remediating an operable unit. This level of testing also can produce data required to optimize performance. These studies are of moderate to high cost (e.g., $50,000 to $250,000 for SVE) and may require months to complete. They yield data that verify performance to a higher degree than remedy selection tests and provide detailed design information. Generally, remedy design would be performed by a vendor after the ROD.

TREATABILITY STUDY WORK PLAN

Carefully planned treatability studies are necessary to ensure that the data generated are useful for evaluating the validity or performance of the technology. The Work Plan sets forth the contractor's proposed technical approach to the tasks outlined in the RPM's Work Assignment. It also assigns responsibilities, establishes the project schedule, and estimates costs. The Work Plan must be approved by the RPM before work begins. A suggested organization of the SVE treatability study Work Plan is provided in the "Guide for Conducting Treatability Studies Under CERCLA: Soil Vapor Extraction."

Test Goals

The overall SVE treatability study objectives must meet the specific needs of the RI/FS. There are nine evaluation

criteria specified in the EPA's RI/FS Interim Final Guidance Document (OSWER-9335:301). Treatability studies can provide data upon which seven of these criteria may be evaluated.

Treatability study goals are the specific cleanup standards or removal rates designed to meet the test objectives. Setting goals for the treatability study is critical to the ultimate usefulness of its results. These goals must be well defined before the study is performed. Each tier or phase of the treatability study program requires appropriate performance goals. For example, column tests could answer the question, "Will SVE reduce contaminants to the required concentrations?" The remedy selection column tests measure whether the process could reduce contamination to below the anticipated performance criteria specified in the ROD. This would indicate that the process has potential applicability at the site and further testing is warranted. Bench-scale column tests are used for remedy screening. Remedy screening goals should simply require that the contaminant of interest shows a greater than 80 percent reduction in concentration in soil. The goal is to show SVE has the potential to work at the site. Normally, sufficient information exists about soil conditions and contaminant volatility so that remedy screening tests will not be necessary.

Column tests for remedy selection can determine if ultimate cleanup levels can be met. When SVE is the primary treatment technology, the suggested cleanup goals are set by the ARARs.

Field air permeability tests are conducted during remedy selection. A field air permeability of greater than 10^{-10} cm^2 (0.01 darcies) appears to be the lower feasibility limit for site air permeability. If the permeability is lower, the technology may not be feasible.

Pilot-scale testing frequently is used during remedy selection. Pilot-scale or field venting tests usually encompass the operation of a mobile SVE treatment unit onsite for a period of 1 to 2 months. For more complex sites (e.g., sites with different types of contaminants in separate areas or with varying geological structures), the test rig may need to be moved around the site and much longer overall testing periods may be required. The goal of pilot-scale testing is to confirm that the cleanup levels and treatment times estimated for site remediation are achievable. This goal is accomplished by checking for diffusion control or problems due to the site conditions.

Experimental Design

Careful planning of experimental design and procedures is required to produce adequate treatability study data. The experimental design must identify the critical parameters and determine the number of replicate tests necessary. System design, test procedures, and test equipment will vary among vendors. The information presented in this section provides an overview of the test equipment and procedures as they relate to each type of test.

Properly designed column tests for remedy selection determine the practical cleanup limits of the contaminated soil and the partition coefficient for use with mathematical modeling. The key design variables for SVE column tests are contaminant concentrations and air-flow rates. Composite samples of soil should be prepared for the column tests. Compositing reduces the variability in contaminant concentration, providing more accurate soil concentration data before and after the column testing. Some volatiles will be lost during compositing. Samples should be collected from the zone of maximum contaminant concentrations. They should also be collected from areas of the site that have different types of VOCs or low-boiling semivolatiles. For these purposes, a sufficient number of split spoon samples should be taken from each area of concern to provide enough material for five column tests and for analytical testing for the contaminants of interest. Shelby tube samples should also be taken for moisture, density, and porosity measurements of each contaminated geological structure. Since air-flow rates vary within the zone of influence of a vapor extraction well, column tests should be run at a minimum of two air-flow rates. A total of four tests, conducted at the higher flow rates, may be required to determine the maximum cleanup level.

Onsite air permeability tests should be performed on each geological formation identified during the site characterization. The tests should be performed in areas of high contaminant concentrations and in areas of lower contamination where contaminants with different properties have been found. Figure 3 shows a typical air permeability test. A vapor extraction probe or extraction well is connected to a vacuum pump. Piezometric probes measure soil pressure levels at various horizontal and vertical distances from the extraction point. Contaminant concentrations may be measured with a portable gas chromatograph (GC).

Since mathematical modeling of SVE requires special expertise, modeling experts should be consulted for technical assistance in applying mathematical models. Improper use of mathematical models can lead to incorrect conclusions.

Pilot-scale tests conducted during remedy selection determine whether sufficient air flow can be attained in the zones of contamination to produce adequate cleanup rates. The design should incorporate the available field data, including air permeability measurements, and the locations and concentrations of contaminants. Mathematical modeling may supplement the above data. The pilot-scale unit typically consists of an extraction well, and three or more probes or monitoring wells to measure soil pressures at various depths and distances from the extraction point. An air injection well may also be used to examine the effect of air injection. An impermeable cap may be installed to prevent water infiltration and to increase the radius of influence. If pilot studies are used for remedy selection, the same system can be used for remedy design studies.

SAMPLING AND ANALYSIS PLAN

The Sampling and Analysis Plan (SAP) consists of two parts—the Field Sampling Plan (FSP) and the Quality Assurance Project Plan (QAPjP). The RI/FS requires a SAP for all field activities. The SAP ensures that samples obtained for

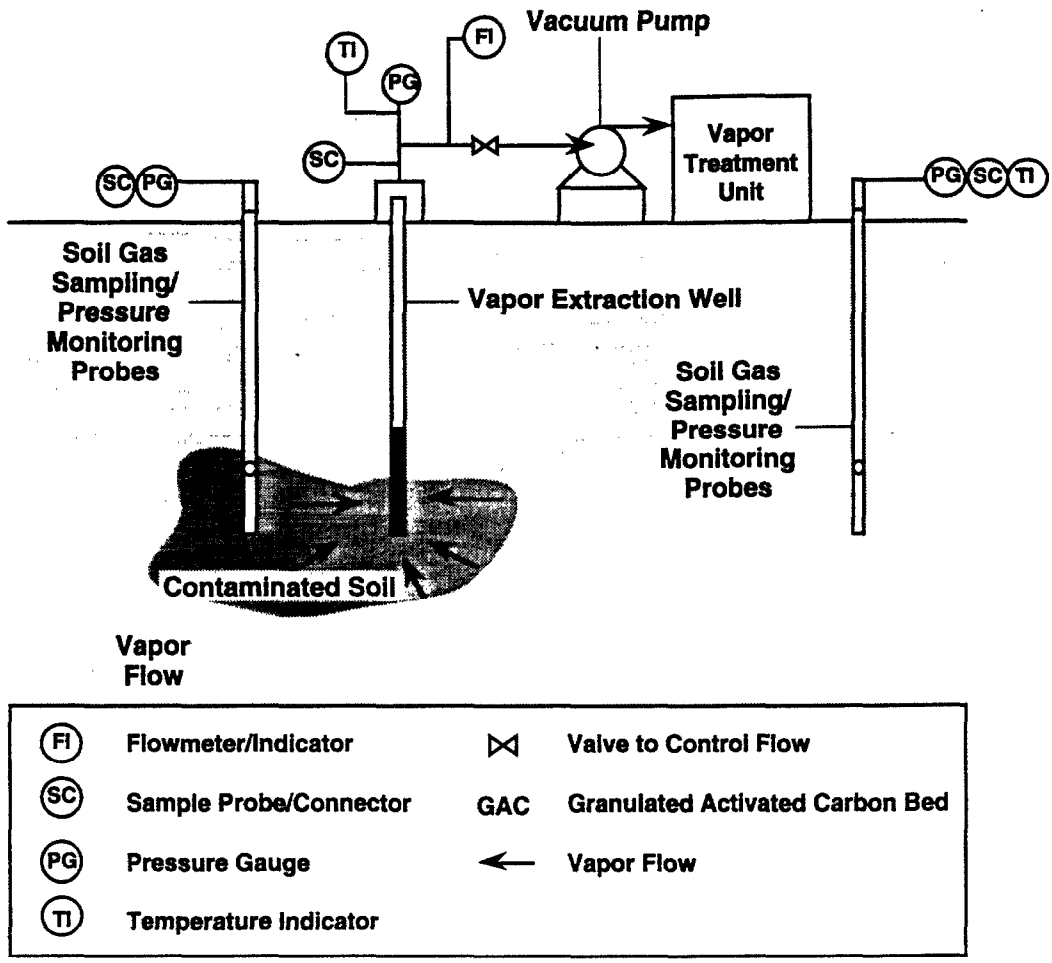

Figure 3. Schematic for Typical Air Permeability Test.

characterization and testing are representative and that the quality of the analytical data generated is known and appropriate. The SAP addresses field sampling, waste characterization, and sampling and analysis of the treated wastes and residuals from the testing apparatus or treatment unit. The SAP is usually prepared after Work Plan approval.

Field Sampling Plan

The FSP component of the SAP describes the sampling objectives; the type, location, and number of samples to be collected; the sample numbering system; the equipment and procedures for collecting the samples; the sample chain-of-custody procedures; and the required packaging, labeling, and shipping procedures.

Quality Assurance Project Plan

The QAPjP should be consistent with the overall objectives of the treatability study.

At the remedy screening level the QAPjP need not be overly detailed. The intended purpose of remedy screening column tests is to determine if the soil gas concentration of each target compound decreases by at least 80 percent. Accurate calibration of the gas chromatograph with the target compounds is required. Duplicate tests are not required for SVE technology at the remedy screening level.

The purpose of the remedy selection treatability study is to determine whether soil vapor extraction can meet cleanup goals and provide information to support the detailed analysis of alternatives (i.e., seven of the nine evaluation criteria). A higher level of QA/QC is required because the data must be validated at this level. Duplicate column tests are required. Concentrations of the target contaminants in the soil should be validated by using matrix spikes. The QAPjP should address the measurement of critical variables. These include the concentrations of target compounds in the initial and treated soil column for remedy selection column tests. Additional variables include air-flow rates, concentration of target compounds, radius of influence, and applied vacuum for air permeability and remedy selection pilot tests.

The methods for analyzing the treatability study samples are the same as those for chemical characterization of field samples. Preference is given to methods in "Test Methods for Evaluating Solid Waste, SW-846, 3rd.Ed.," November 1986. Other standard methods may be used, as appropriate. Methods other than GC/MS techniques are recommended to conserve costs when possible.

TREATABILITY DATA INTERPRETATION

To properly evaluate SVE as a remediation alternative, the data collected during remedy screening and remedy selection phases must be compared to the test goals and other criteria that were established before the tests were conducted. Figure 4 is a flowchart for evaluating SVE as a potential remedy. It presents a framework of the decision-making process that is based on the comparison between the goals and test results. It also includes considerations of contaminant volatility, ability to get air-flow to the contaminant, and predicted cleanup times.

TECHNICAL ASSISTANCE

Literature information and consultation with experts are critical factors in determining the need for and ensuring the usefulness of treatability studies. A reference list of sources on treatability studies is provided in the "Guide for Conducting Treatability Studies Under CERCLA: Soil Vapor Extraction."

It is recommended that a Technical Advisory Committee (TAC) be used. This committee includes experts on the technology who provide technical support from the scoping phase of the treatability study through data evaluation. Members of the TAC may include representatives from EPA (Region and/or ORD), other Federal Agencies, States, and consulting firms.

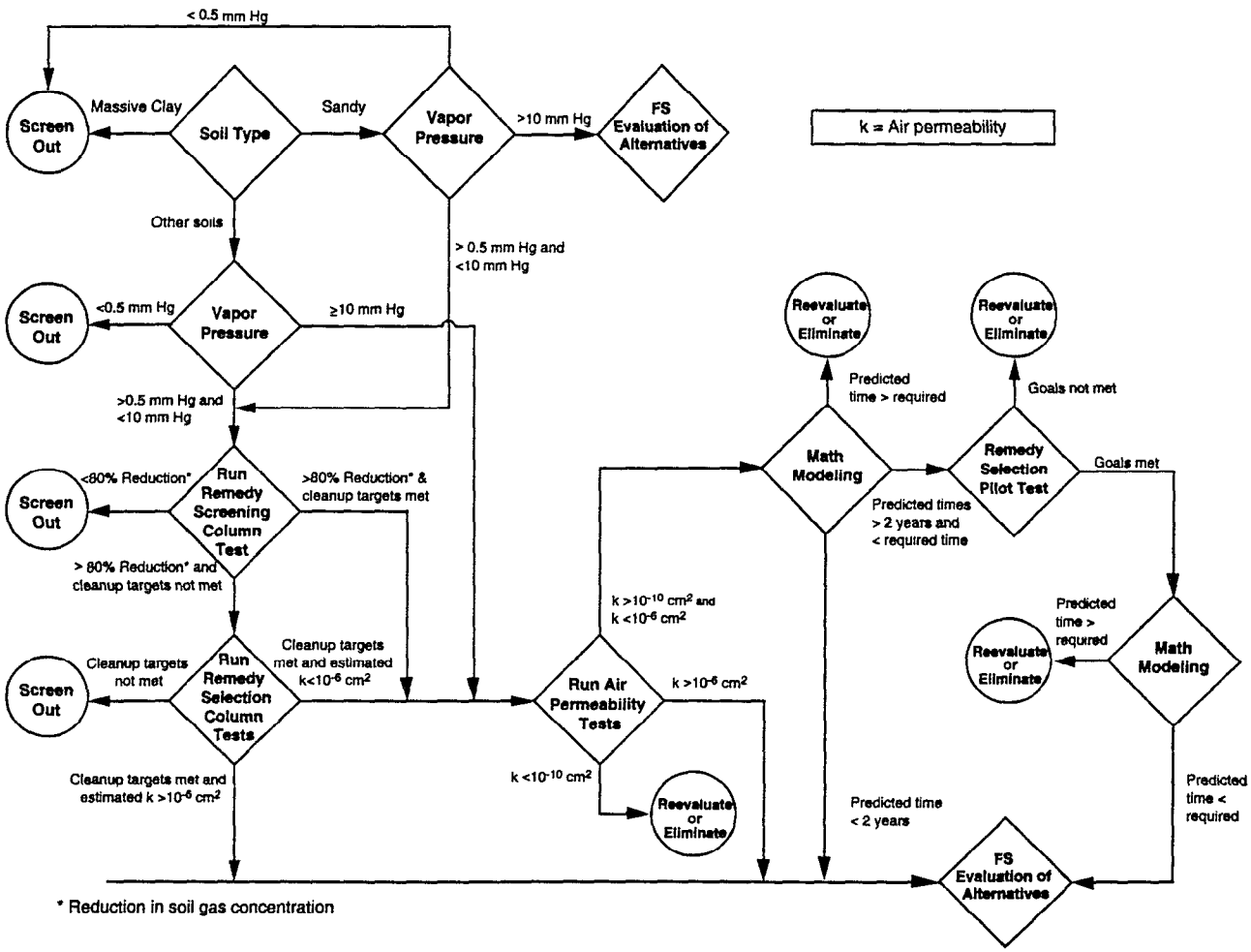

Figure 4. Flow Chart for Evaluating the Feasibility of Soil Vapor Extraction.

OSWER/ORD operate the Technical Support Project (TSP) that provides assistance in the planning, performance, and/or review of treatability studies. For further information on treatability study support or the TSP, please contact:

Groundwater Fate and Transport Technical Support Center
Robert S. Kerr Environmental Research Laboratory (RSKERL), Ada, OK
Contact: Don Draper
FTS 743-2200 or (405) 332-8800

Engineering Technical Support Center
Risk Reduction Engineering Laboratory (RREL), Cincinnati, OH
Contact: Ben Blaney
FTS 684-7406 or (513) 569-7406

FOR FURTHER INFORMATION

In addition to the contacts identified above, the appropriate Regional Coordinator for each Region located in the Hazardous Site Control Division/Office of Emergency and Remedial Response, or the CERCLA Enforcement Division/Office of Waste Programs Enforcement should be contacted for additional information or assistance.

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