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Project Summary

Soil Vapor Extraction Technology Reference Handbook

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Soil vapor extraction (SVE) systems are being used in increasing numbers because of the many advantages these systems hold over other soil treatment technologies. SVE systems appear to be simple in design and operation, yet the fundamentals governing subsurface vapor transport are quite complex.

In view of this complexity, an expert workshop was held to discuss the state of the art of the technology, the best approach to optimize system application, and the process efficiency and limitations. As a result of the workshop, an SVE Technology Assessment report was produced. This report discusses the basic science of the subsurface environment and subsurface vapor flow, site investigations, SVE system design and operation, and includes selected papers from the expert workshop. Additional research activities being conducted include a field demonstration of a structured SVE system design approach, a laboratory column study to determine and characterize residuals following vapor extraction, an assessment of secondary emissions and regulations governing releases from SVE systems, cost of SVE implementation and operation, and a survey of techniques to enhance vapor removal.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, 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

SVE is being used with increasing frequency throughout the country for the remediation of unsaturated zone soils that have become contaminated with volatile organics. SVE, also known as vacuum extraction, *in situ* vaporization, or soil venting, has many positive features that gives it an advantage over other soil treatment techniques such as excavation and offsite treatment, soil flushing, or biotreatment. Some of the features that make this technology applicable to a broad spectrum of sites are:

- SVE is an *in situ* technology, so there is a minimum of site disturbance; often, business operations at the site need not be interrupted;
- SVE can treat large volumes of soil at reasonable costs;
- SVE is easily installed and uses standard, readily-available equipment, which allows for rapid mobilization and implementation of remedial activities;
- SVE is effective in reducing the concentration of volatile organic compounds (VOCs) in the vadose zone, reducing the potential for further migration; and
- SVE complements groundwater pump and treat techniques, which may be instituted concurrently.

These features, combined with the apparent simplicity of SVE system design, implementation, and operation, have combined to make SVE one of the fastest growing remediation choices. This growth has not necessarily been accompanied by

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a broader expansion of the knowledge base to properly design and operate an SVE system. Indeed, the ease with which SVE systems can be installed and operated belies the very complex nature of subsurface vapor behavior and transport.

Much of the technical information regarding the design, construction, and operation of an extraction system is held by the SVE technology developers and vendors. Engineering practices, which are often considered proprietary by the developers may be based in large part on each developer's experiences. This atmosphere does not encourage rigorous objective review of design or operating methods and makes it more difficult to analyze the results of SVE use. This lack of knowledge poses limitations to regulatory agency personnel and others attempting to interpret system operating results.

The increased use of SVE systems and the need for a greater understanding of the principles that underlie soil vapor behavior and other issues related to SVE led the U.S. Environmental Protection Agency's Office of Research and Development, through its Risk Reduction Engineering Laboratory, Releases Control Branch (RREL-RCB) to initiate SVE research efforts. The initial step in these efforts was the convening of an expert workshop in Edison, NJ, on June 28 and 29, 1989. Workshop participants included SVE technology vendors, petroleum industry representatives, university researchers, consulting engineers, regulatory agency representatives, and others who were familiar with this technology. The workshop had dual objectives. One was to discuss the state of the art of SVE-related topics, such as: site characterization, pilot systems, full scale system design and operation, vapor treatment options, establishing and attaining cleanup goals, and monitoring SVE treatment progress. Some presenters discussed actual case studies; and others discussed a structured framework for conducting site investigations and system design, the use of modeling to help design extraction systems, and other research on SVE currently in progress. The second objective of the workshop was to discuss additional research needs. Panel discussions were held with workshop attendees regarding areas for future research and topics needing immediate attention. The regulatory climate was also discussed, including suggested remediation standards and methods to determine cleanup attainment. As a result of this workshop, an SVE Technology Reference Handbook was developed.

Reference Handbook

The main text of this document is an assessment of the state of the art of soil vapor extraction technology. It was written specifically for state and local regulators, agency staff, environmental managers, remedial contractors and consultants who desire a basic understanding of SVE principles, applicability, operation, and cost.

A general overview of the theoretical considerations applicable to soil vapor extraction is provided in Section 2. This section includes discussions of the effect on SVE of contaminant properties, including vapor pressure, solubility, Henry's law constant, boiling point, soil sorption coefficient, contaminant composition and weathering, and soil properties such as structure, moisture content, texture, air permeability, and temperature. Section 2 also discusses gaseous flow in the subsurface environment, including the equations that govern subsurface vapor flow. Finally, several field methods of determining the soil's air permeability are presented.

Section 3 provides an overview of site investigation approaches that can be used to obtain data necessary to determine if vapor extraction is a viable remedial option and, if so, obtain critical design information. This section also includes references to field techniques and equipment used to evaluate the site-specific feasibility of vapor extraction.

General design approaches, including the determination of the air permeability, well selection, and system configuration, are described in Section 4. In addition, this section discusses the components that comprise an SVE system. The purpose of this section is to provide the reader with a qualitative analysis of the design procedure and the individual components to aid in the preliminary design of such a system.

Operation, maintenance, and monitoring of SVE systems are discussed in Section 5. This section also includes discussions of enhanced biotreatment due to SVE; cleanup attainment determination, including new methods for measuring residuals; and other issues related to system operation.

Section 6 discusses emission control methods available to treat the extracted vapors. Discussions are included on activated carbon adsorption, thermal and catalytic incineration, internal combustion engines, packed bed thermal processors, biotreatment, and direct discharge to the atmosphere.

The costs related to SVE implementation and operation are discussed in Section 7. This section discusses costs for a site investigation, component-by-component capital costs for SVE equipment, costs for prepackaged units, and operations and monitoring costs for these systems.

Ten appendices contain selected papers presented at the Edison, NJ, workshop. Papers reprinted here were selected as representative of the wide range of topics discussed. Appendix A is a review of existing SVE operations by N.E. Hutzler, B.E. Murphy, and J.S. Gierke. This section reports on various aspects of SVE operations, including number, type, and layout of wells, type of blower or pump used, emission control units, and additional operational information. The section provides the reader with a sound historical basis with which to view other sections.

In Appendix B, J. Danko discusses the applicability and limitations of SVE operation. This paper describes the advantages of SVE and discusses, from an engineering viewpoint, some practical observations and advice.

Appendix C contains a report by H.B. Kerfoot on the use of soil gas surveys in the design of SVE systems. Soil gas surveys are frequently used during the site investigation phase to help delineate the extent of contamination and determine the types and relative concentrations of compounds in the ground. With this information, a judgment can often be rendered regarding the applicability of SVE for that site.

Appendix D, by R.E. Hinchee, D.C. Downey, and R.N. Miller, discusses the enhancement of biodegradation that accompanies the use of soil vapor extraction.

P.C. Johnson, M.W. Kemblowski, J.D. Colthart, D.L. Byers, and C.C. Stanley contribute "A Practical Approach to the Design, Operation, and Monitoring of *In Situ* Soil Venting Systems" in Appendix E. This report presents a structured logical approach that forms a "decision-tree" for deciding if SVE is appropriate to be used and, if so, describes the steps to be taken during system design, operation, and monitoring.

Appendix F contains a scientific approach to SVE design in a paper by M.C. Marley, S.D. Richter, B.L. Cliff, and P.E. Nangeroni. This paper describes, among other things, the use of a computer model to calibrate data obtained during a field air permeability test.

L.R. Silka, H.D. Cirpili, and D.C. Jordan discuss in Appendix G modeling of subsurface vapor flow and the applications of modeling to SVE.

D.W. DePaoli, S.E. Herbes, and M.G. Elliot describe in Appendix H the performance of SVE at a jet fuel spill site in Utah. This paper contains knowledge and experience gained during SVE operation,

operational results, and a discussion of various aspects of SVE.

Appendix I contains actual case history results for an industrial site that has contamination from several volatile organic and base neutral compounds in a report by R.D. Mutch, Jr., A.N. Clarke, D.J. Wilson, and P.D. Mutch. This interim report focuses on the measured zone of influence of the extraction well, the composition of the extracted gas and its changes with time, the treatability of the extracted vapor by granular activated carbon, temperature variations that occur in the system, and groundwater upwelling due to the induced vacuum. The authors also describe the use of a mathematical model in their work.

A report by G.E. Hoag in Appendix J comments on recent SVE research developments and research needs. These discussions follow a summary of SVE "research milestones."

Appendices K and L contain responses to a state-by-state survey conducted in August 1989 regarding the allowable soil residual and air discharge criteria.

This book is not intended for use as a design manual, but it documents all of the latest state of the art of the soil vapor extraction technology.

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The complete report, entitled "Soil Vapor Extraction Technology Reference Handbook," (Order No. PB91-168476/AS; Cost: $39.00, subject to change) will be available only from:
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