United States
Environmental Protection
Agency

Research and Development

Risk Reduction
Engineering Laboratory
Cincinnati, OH 45268

EPA/600/SR-92/173 September 1992

EPA

Project Summary

A Technology Assessment of Soil Vapor Extraction and Air Sparging

Mary E. Loden

In recent years, there has been a strong movement away from the traditional methods of remediating sites contaminated with volatile organic compounds (VOC), (capping the site and pumping and treating groundwater), to the more cost effective treatment consisting of *in situ* air sparging and soil vapor extraction (SVE). SVE, by itself, has enjoyed an excellent acceptance in treating VOC contaminated vadose zones. Air sparging of the saturated zone has added an important new dimension to the *in situ* treatment of contaminated sites. Areas below and in the water table are able to be stripped of VOCs using this technology, thus making it possible to substantially decrease the length of time required to achieve site closure.

The full report discusses the basics of *in situ* air sparging system design, presents case studies of documented applications, includes a section on process component costs including a conceptual cost estimate for a hypothetical site, and finally outlines the research needs required.

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 ordering information at back).

Introduction

Air sparging, also called "*in situ* air stripping" and "*in situ* volatilization," is a technology used to remove VOCs from the subsurface saturated zone. It introduces contaminant-free air into an affected aquifer system; this forces contaminants to transfer from subsurface soil and groundwater into sparged air bubbles. The air streams are then transported into soil pore spaces in the unsaturated zone where they can be removed by SVE.

Air sparging systems must operate in tandem with SVE systems that capture volatile contaminants stripped from the saturated zone. Using air sparging without accompanying SVE could create a net-positive, subsurface pressure that could extend contaminant migration to as-yet-unaffected areas and increase the overall zone of contamination. Without SVE, uncontrolled contaminated soil vapor could also flow into buildings (e.g., basements) or utility conduits (e.g., sewers), creating potential explosion or health hazards.

The effectiveness of combined SVE/air sparging systems results from two major mechanisms: contaminant mass transport and biodegradation. Depending on the system configuration, the operating parameters, and contaminant types found onsite, one mechanism usually predominates. In both remediation mechanisms, oxygen transport in the saturated and unsaturated zones plays a key role.

The nature of air transport affects mass transfer to and from the groundwater regime. Bubbles exhibit higher surface area for transfer of oxygen to the groundwater and for volatile migration to the unsaturated zone than does the area provided by continuous, irregular air-flow pathways.

Printed on Recycled Paper

SVE/Air Sparging Technology

Mass Transfer

Mass transfer employs several mechanisms that move contaminants from saturated zone groundwater to unsaturated soil vapors. Figure 1 illustrates the following major mechanisms: (a) dissolving soil-sorbed contaminants from the saturated zone to groundwater; (b) displacing water in soil pore spaces by introducing air; (c) causing soil contaminants to desorb; (d) volatilizing soil contaminants, and (e) enabling soil contaminants to enter the saturated zone vapor phase. Due to the density difference between air and water, the sparged air migrates upwards in the aquifer. The pressure gradient resulting from the creation of a vacuum in the unsaturated zone pulls the contaminant vapors toward and into the SVE wells.

Biodegradation Mechanism

Aerobic biodegradation of contaminants by indigenous microorganisms requires the presence of a carbon source, nutrients, and oxygen. Air sparging increases the oxygen content of the groundwater and thus enhances aerobic biodegradation of contaminants in the subsurface. Certain organic contaminants, such as petroleum constituents, serve as a carbon source for microorganisms under naturally occurring conditions. The rate of biodegradation can be enhanced by optimizing nutrient status of the system.

Remediation of an aquifer via the biodegradation mechanism has distinct advantages since a portion of the contaminants will be biologically degraded to carbon dioxide, water, and biomass — yielding a lower level of VOCs in the extracted air. This in turn can substantially reduce vapor treatment costs. The possibility of offsite contaminant vapor migration is also reduced when sparged vapors entering the vadose zone contain lower levels of contaminants.

Certain contaminants, such as chlorinated solvents, can undergo biodegradation under anaerobic conditions. Air sparging, in these instances, could adversely affect this biodegradation process.

Requirements for Effective Air Sparging

Applicability of Air Sparging

Some of the conditions that affect the applicability of this technology are:

- depth to groundwater — a water table located at a shallow depth (<5 ft) may increase the difficulty of recovering vapors with the technology.
- volatility of contaminants — compounds should have a high volatility. With Henry's Law Constants of at least 10^5 atm-m^3/mol.
- solubility of contaminants — in general, compounds that are very soluble in water are not easily air stripped.
- soil permeability — injected air must flow freely throughout the saturated zone to achieve adequate removal rates. Soil permeability should be at least 10^{-3} cm/sec for air sparging to be effective.
- aquifer type — generally, air sparging should only be used on sites with unconfined aquifers.

Air Sparging Apparatus

The major components of an air sparging system include:

- extraction, sparging, and monitoring wells.
- mechanical equipment — air compressors and vacuum blowers.
- vapor treatment system including air/water separator, emissions control systems such as granular activated carbon canisters, thermal oxidizers, and catalytic oxidizers.
- instrumentation — analytical equipment.

The combination of air sparging and SVE systems provides a cost-effective *in situ* technology for the remediation of VOC contaminated sites.

Future Research

Despite the many air sparging installations — over 30 in Europe alone — there is much about the technology that still requires further investigation. The nature

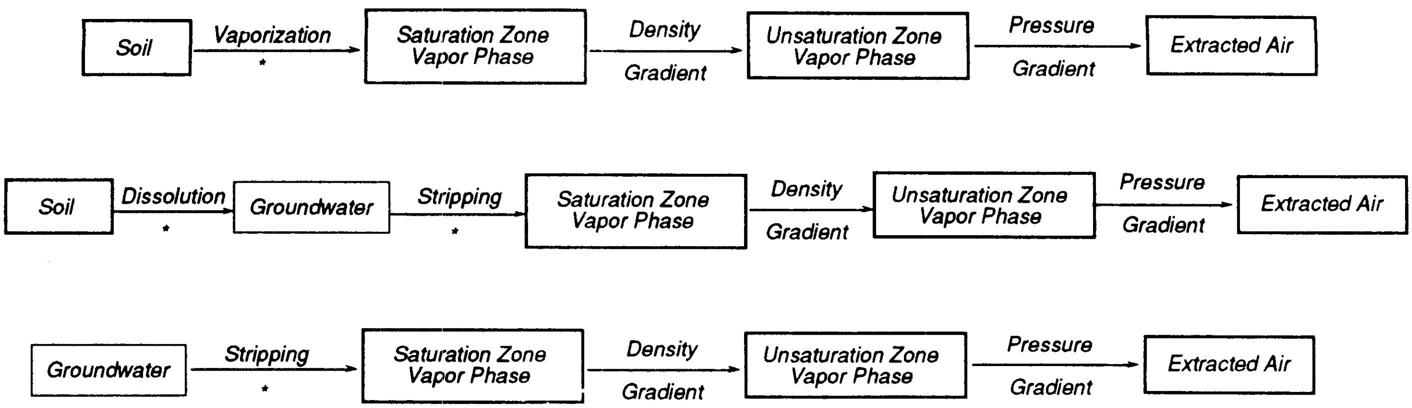

***Figure 1.** Mechanisms of mass transport during air sparging. (* Mechanisms enhanced by air sparging.)*

of the saturated zone vapor phase requires further definition. Subsurface air injection requires additional study including the researching of phenomena such as dissolution and partitioning. Validation of developed mathematical models is an area of key interest.

Document Contents

The document summarized here presents an overview and an assessment of the state-of-the-art in SVE and air sparging technology. It was written specifically for state and local regulators, agency staff, and those involved in remedial design and operations who desire a basic understanding of the technology's principles, applicability, operations, and cost.

Section 2 provides a description of the process including subsurface mechanisms involved in stripping contaminants from the saturated zone. Various parameters that affect the applicability of the technology are discussed such as depth to groundwater, volatility of contaminants, solubility of contaminants, site permeability, aquifer type, and soil type.

Section 3 presents a description of and details on a number of actual air sparging installations both in the United States and in Europe.

Section 4 gives an overview of the design considerations for the various elements that go into the makeup of an SVE and air sparging installation including injection well characteristics, configurations, and radius of influence. The factors that go into the selection of mechanical equipment are also discussed.

Section 5 discusses the capital costs and operating costs of the components of the technology, including well installation, mechanical equipment such as compressors and vacuum blowers, emission control equipment, and instrumentation. A conceptual estimate for a hypothetical site contaminated by petroleum hydrocarbons from a leaking underground storage tank is presented.

Section 6 discusses future research needs in the areas of further definition of saturated zone mechanisms and system design and operations.

The full report was submitted in fulfillment of Contract No. 68-03-3409, by Camp Dresser and McKee, Inc. under the sponsorship of the U.S. Environmental Protection Agency.

☆U.S. GOVERNMENT PRINTING OFFICE: 1993 - 750-071/80106

Mary E. Loden is with Camp Dresser and McKee, Inc.,Cambridge Center, Cambridge, MA 02142-1401
***Chi-Yuan Fan** is the EPA Project Officer (see below).*
The complete report, entitled "A Technology Assessment of Soil Vapor Extraction and Air Sparging," (Order No. PB93-100154/AS; Cost: $19.00, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Risk Reduction Engineering Laboratory
U.S. Environmental Protection Agency
Edison, NJ 08837

United States
Environmental Protection Agency
Center for Environmental Research Information
Cincinnati, OH 45268

BULK RATE
POSTAGE & FEES PAID
EPA
PERMIT No. G-35

Official Business
Penalty for Private Use
$300

EPA600/SR-92/173