In-Situ Air Sparging

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CHAPTER 1

Introduction

1-1. Purpose.

a. In-situ air sparging (IAS) is a rapidly emerging remediation technology for treatment of contaminants in saturated zone soils and groundwater. Injection below the water table of air, pure oxygen, or other gases may result in removal of contaminants by volatilization or bioremediation. Less commonly, IAS can be used to immobilize contaminants through chemical changes such as precipitation. This course provides guidance for evaluation of the feasibility and applicability of IAS for remediation of contaminated groundwater and soil and, as a secondary objective, describes design and operational considerations for IAS systems.

1-2. References. References are listed in Appendix A. The following references are suggested as key supplementary sources of information on IAS:

a. Technology Overview.

(1) Johnson et al. (1993)

(2) Marley and Bruell (1995)

(3) Reddy et al. (1995)

(4) USEPA (1995a)

(5) Holbrook et al. (1998)

(6) Navy (2001)

(7) Leeson et al. (2002)

b. Monitoring.

(1) Lundegard (1994)

(2) Johnson et al. (1995)

(3) Acomb et al. (1995)

(4) Clayton et al. (1995)

(5) Baker et al. (1996)

c. Pilot Testing and Design.

(1) Wisconsin DNR (1993)

(2) Wisconsin DNR (1995)

(3) Johnson et al. (1993)

(4) Marley and Bruell (1995)

(5) Leeson et al. (2002)

d. Modeling.

(1) Lundegard and Andersen (1996)

(2) Clarke et al. (1996)

(3) Leeson et al. (2002)

e. Equipment Specification and Operation.

(1) USEPA (1992)

(2) Wisconsin DNR (1993)

(3) Wisconsin DNR (1995)

(4) Holbrook et al. (1998)

f. Evaluation of System Performance.

(1) USEPA (1995b)

(2) Holbrook et al. (1998)

(3) Bass et al. (2000)

1-3. Background.

a. In 1997, in-situ air sparging (IAS) was classified as an innovative technology under USEPA's Superfund Innovative Technology Evaluation (SITE) program. IAS is an evolving technology being applied to serve a variety of remedial purposes. While IAS has primarily been used to remove volatile organic compounds (VOCs) from the saturated subsurface through stripping, the technology can be effective in removingvolatile and non-volatile contaminants through other, primarily biological, processes enhanced during its implementation. The basic IAS system strips VOCs by injecting air into the saturated zone to promote contaminant partitioning from the liquid to the vapor phase. Off-gas may then be captured through a soil vapor extraction (SVE) system, if necessary, with vapor-phase treatment prior to its recirculation or discharge. Figure 1-1 depicts a typical IAS system.

b. IAS appears to have first been utilized as a remediation technology in Germany in the mid-1980s, primarily to enhance clean-up of groundwater contaminated by chlorinated solvents (Gudemann and Hiller 1988). Some of the subsequent developmental history of the technical approach may be found in the patent descriptions in paragraph 8-3.

c. Because injected air, oxygen, or an oxygenated gas can stimulate the activity of indigenous microbes, IAS can be effective in increasing the rate of natural aerobic biodegradation. This is particularly important when considering the use of IAS at sites with readily biodegradable hydrocarbons, particularly petroleum-contaminated sites. It has been speculated that, similarly, anaerobic conditions might be able to be created by injecting a non-oxygenated gaseous carbon source to remove the dissolved oxygen from the water. The resulting enhanced degradation of organic compounds, such as chlorinated VOCs, to daughter products would result in increased volatility, which could improve the effectiveness of stripping and phase transfer during IAS.

d. IAS is generally considered to be a mature technology. It is a relatively easy technology to implement; it is well known to regulatory agencies; and the equipment necessary for IAS is generally inexpensive and easily obtained. Therefore, IAS is one of the most practiced engineered technologies for in-situ groundwater remediation. Critical aspects considered by many as likely to govern the effectiveness of an IAS system, such as the presence and distribution of preferential airflow pathways, the degree of groundwater mixing, and potential precipitation and clogging of the soil formation by inorganic compounds, continue to be researched and reported in conference proceedings and technical journals. There are innovative field techniques that can aid the understanding of the effectiveness of IAS, such as neutron probes for measuring the effective zone of influence (ZOI) and distribution of the injected gas. As IAS is often considered to be a straightforward technology, such techniques are not often implemented. However, when such data are collected, it is anticipated that the understanding of the mechanisms and processes induced by IAS will increase, as well as the ability to predict and measure its effectiveness.

1-4. Scope. The primary focus of this course is to provide guidance for assessing the feasibility and applicability of IAS. Secondarily, this course describes design and operational issues related to implementing pilot- and full-scale IAS systems, although it is not meant to address design issues in detail. Because IAS technology is still evolving, this course is intended to consolidate existing guidance and to stimulate the acquisition and reporting of new information that will continue to refine the technology.

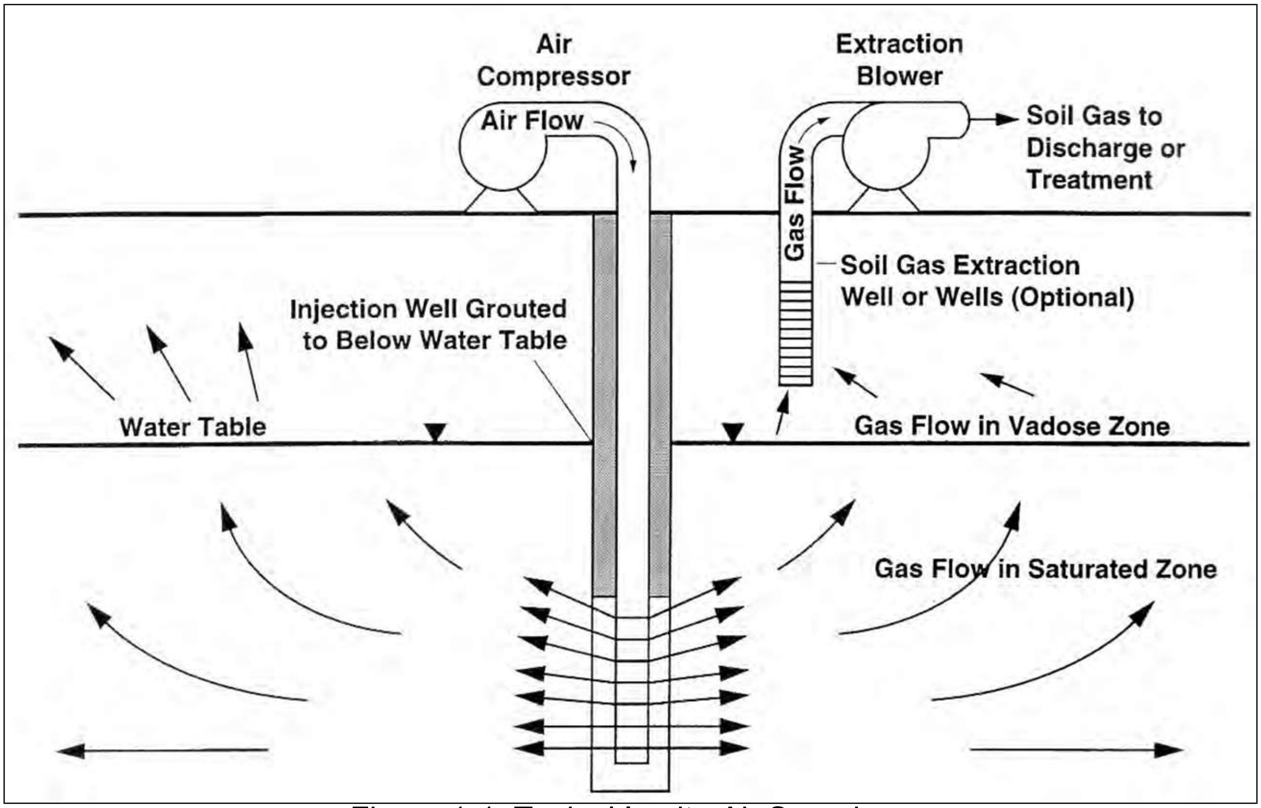

Figure 1-1. Typical In-situ Air Sparging.
The sparge well screen is situated vertically below a contaminated zone, such as a smear zone

1-7. Organization. This course is structured to show the progression from initial technology selection through testing, design, implementation, and closure. Chapter 2 provides a description of IAS, including its underlying physical processes. Recommendations for site characterization and technology evaluation are presented in Chapter 3. Strategy and guidance for pilot-scale testing are provided in Chapter 4 and design considerations are presented in Chapter 5. Issues associated with system operation and maintenance are discussed in Chapter 6 and system shutdown procedures are introduced in Chapter 7. Chapter 8 presents administrative issues associated with implementing IAS. Appendix A provides references cited in the document.
Appendix B provide a table of Henry's Law constants for selected organic compounds. Appendix C describes methods of calculating flow rates based on air velocity measurements.

CHAPTER 2

Technology Description and Underlying Physical Process

2-1. Introduction. This chapter provides an overview of air sparging, describes various applications of the technology, and discusses the underlying physical processes that occur during IAS.

2-2. Overview of Air Sparging.

a. Introduction. Air sparging is the process of injecting air into the saturated subsurface to treat contaminated soil and groundwater. Air sparging mechanisms include partitioning of volatile contaminants from the aqueous phase to the vapor phase (stripping), for their subsequent transfer to and removal from the unsaturated zone, and transfer of oxygen from the injected air to the aqueous phase to enhance aerobic microbial degradation of contaminants in the saturated zone, termed bio-sparging. Air sparging may be used for these diverse applications, which are addressed, in turn, in subparagraph 2-2*b*–*e*.

(1) Treat saturated zone contamination in a source area (although its effectiveness in remediating non-aqueous phase liquids [NAPL] is subject to some fundamental physical limitations, especially with respect to dense NAPL [DNAPL]).

(2) Treat dissolved phase contamination in a plume.

(3) Contain a dissolved-phase plume.

(4) Immobilize contaminants through chemical changes.

b. Treat Saturated Zone in a Source Area.

(1) Saturated zone contamination exists at many locations where fuel hydrocarbons or organic solvents have been released into the subsurface. Such "source" areas contain contaminants dissolved in the aqueous phase and also typically contain NAPL. Groundwater pump-and-treat, which until recently was often relied upon to treat such saturated zone contaminants, is a very slow remediation process and has been judged as having met with little success except as a containment tool (NRC 1994). With the dawning of this recognition, attention turned to alternative technologies. Although air-based remediation technologies, such as SVE and BV, gained favor for treatment of unsaturated zone contamination, they do not apply to the saturated zone. IAS, however, is an air-based technology that is meant to be applied within the saturated zone. The view was widely expressed by early practitioners that IAS can achieve site closure—implying treatment of both dissolved-phase and non-aqueous phase contaminants if present—much more rapidly than pump-and-treat (Brown and Fraxedas 1991, Marley 1992a,b, Angell 1992). As more experience was gleaned from applying IAS at numerous sites, these and other practitioners have