Air Stripping (In Well)

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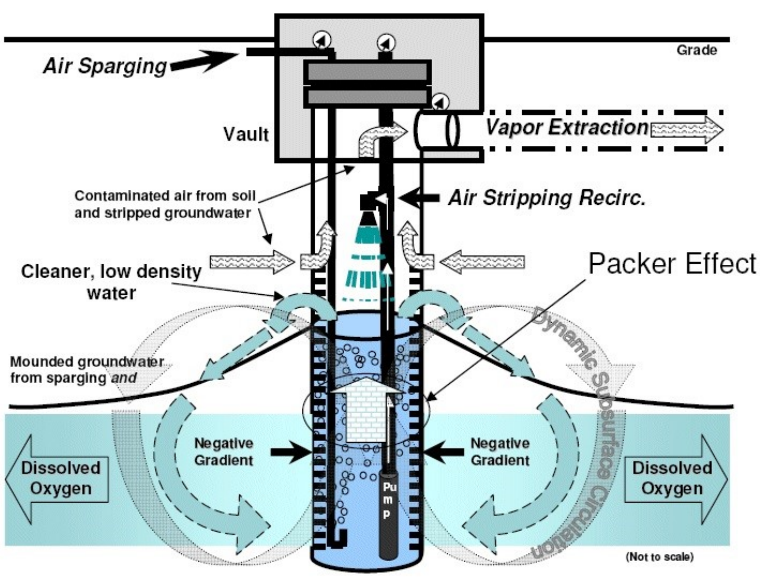
Schematic



Typical Air Stripping (Ex-Situ) Process Diagram

From Accelerated Remediation Technologies, Inc.

Introduction

In-well air stripping is an in situ remediation process that removes dissolved volatile organic compounds (VOCs) from groundwater by stripping the VOCs to the vapor phase within the well, without bringing groundwater to the ground surface. In-well stripping creates a groundwater circulation cell by injecting air into a double-screened well, lifting the water in the well and forcing it out the upper screen while additional water is drawn in the lower screen. Once in the well, some of the VOCs are transferred from the dissolved phase to the vapor phase by air stripping. The contaminated air rises in the well to the water surface where vapors are drawn off and treated by a vapor extraction system.

Other Technology Names

Groundwater Circulation Well (GCW)
In-Well Air Stripping
In-Well Vapor Stripping
In Situ Vapor Stripping
In Situ Air Stripping

Description

The in-well air stripping process consists of two concurrent actions within a single recirculation well – injection of air and extraction of vapors by creating a vacuum at the top of the well casing. These concurrent actions result in an in-well airlift pump effect that causes air sparging (AS) and groundwater flow into the bottom of the well screen. Negative pressure created from the concurrent soil vapor extraction (SVE) component of the system adds to the net reduction in head at the well location that further enhances groundwater flow into the bottom of the well screen. A submersible pump is placed at the bottom of the well to both draw in groundwater and recirculate it to a spray nozzle located near the top of the well screen. Recirculated groundwater sprayed from this nozzle contacts the upward airflow from the concurrent AS/SVE components, creating an air stripping effect that transfers dissolved phase volatile organic compounds (VOCs) from groundwater into the vapor phase for removal by the SVE component of the system and above-ground treatment. The atomized groundwater then discharges out of the top of the well screen back into the formation as a result of the "mounding" effect created within the well. In addition to the effects of sparging, stripping, and extracting volatile contaminants from the groundwater, in-well stripping establishes a circulation pattern of oxygen-saturated water in the aquifer that may also increase the aerobic biodegradation rate of petroleum compounds and other volatile contaminants in the subsurface. A variety of configurations of well screens, piping, and injection/extraction devices have been developed and marketed under various trade names. Some of these configurations include the injection of other types of oxidation and in situ biological treatment amendments.

Development Status and Availability

The following checklist provides a summary of the development and implementation status of in-well air stripping:

- ☐ At the laboratory/bench scale and shows promise
- ☐ In pilot studies
- ☒ At full scale
- ☒ To remediate an entire site (source and plume)
- ☐ To remediate a source only
- ☒ As part of a technology train
- ☐ As the final remedy at multiple sites
- ☐ To successfully attain cleanup goals in multiple sites

In-well stripping is available through the following vendors:

- ☐ Commercially available nationwide
- ☒ Commercially available through limited vendors because of licensing or specialized equipment

☐ Research organizations and academia

Applicability

Contaminant Class Applicability Rating for In-Well Air Stripping

(Rating codes: ● Demonstrated Effectiveness, ◐ Limited Effectiveness, ○ No Demonstrated Effectiveness,
◊ Level of Effectiveness dependent upon specific contaminant and its application/design, I/D Insufficient Data)

Nonhalogenated VOC	Halogenated VOC	Nonhalogenated SVOC	Halogenated SVOC	Fuels	Inorganics	Radionuclides	Munitions	Emerging Contaminants
◐	◐	◐	○	◐	○	○	○	I/D

In-well air stripping is used primarily to treat halogenated and hydrocarbon VOCs dissolved in groundwater (EPA, 1997). Recirculation wells can be used to either provide downgradient plume migration control or treat the entire extent of a plume. This technology can also be used to concurrently treat VOCs in both the vadose zone and dissolved in groundwater. Typically, in-well air stripping systems are more cost-effective for remediating VOC-contaminated groundwater at sites with deep water tables because the water does not need to be brought to the surface. In-well air stripping also avoids the need to install, operate, and maintain above-ground treatment systems if only VOC removal is required. The technology can be difficult to apply to shallow groundwater where a limited unsaturated zone above the contaminated groundwater does not allow for adequate recirculation. This process has been found to be applicable to aquifers with horizontal conductivities greater than 10-3 cm/sec and a ratio of horizontal to vertical conductivities between 3 and 10. A ratio of less than 3 indicates a small radius of influence. If the ratio is greater than 10, the circulation time may be unacceptably long. Literature searches have not identified any sites that have attained regulatory site closure using this technology.

Cost

A site-specific cost analysis performed in 2002 estimated a modest cost savings (approximately 3 percent) for the installed in-well stripping system compared to a hypothetical, equivalent pump-and-treat system (ESTCP, 1998). Savings compared to traditional pump-and-treat systems are realized by the absence of an above-groundwater water treatment system and no treated water discharge infrastructure or fees. At sites where these factors have a larger impact on costs, in situ well stripping may result in more savings when compared to traditional pump-and-treat. For instance, at sites where treated water must be pumped long distances to a discharge point, where discharge fees are high, or where suitable discharge points are not available, in situ well stripping may be more cost effective and implementable. As with all in situ technologies, application costs vary according to site, contaminants, and requirements for above-ground treatment for recovered vapor. Major cost drivers include:

Upfront Costs

- Area and depth of contaminants requiring treatment, which impact the number of wells, the drilling depths required, and the type and size of air injection equipment needed
- Aquifer hydrogeology and plume size, which will dictate the radius of influence and corresponding well spacing and total number of wells needed
- Need to perform mathematical groundwater flow and contaminant transport modeling to demonstrate effectiveness and optimize the design

Operation and Maintenance Costs

- Volatility of the contaminants and susceptibility to air stripping
- Starting concentrations of contaminants, which affects operational time
- Percentage of fine-grained soil within the treatment zone, which tends to sorb contaminants and release them slowly, resulting in longer operational time

The list above highlights those cost dependencies specific to in-well air stripping and does not consider the dependencies that are general to most in situ remediation technologies. Click here for a general discussion on costing which includes definitions and repetitive costs for remediation technologies. A project-specific cost estimate can be obtained using an integrated cost-estimating application such as RACER® or consulting with a subject matter expert.

Duration

The duration of in-well air stripping is controlled by the same mass transfer limitations as pump and treat systems, which are most commonly medium- to long-term, dependent on the following conditions:

- Cleanup goals
- Volume of groundwater requiring treatment
- Contaminant concentrations and distribution
- Aquifer characteristics, including permeability, and heterogeneity/anisotropy
- Henry's law constants of the contaminants present at the site
- Radius of influence and the groundwater flow regime

Implementability Considerations

The following factors are key considerations associated with implementing in-well air stripping:

- Since this technology involves groundwater recirculation and flushing, effective implementation is typically limited to more homogeneous groundwater units with higher transmissivities. Heterogeneous and lower permeability groundwater units could result in non-uniform re-circulation and flushing of contaminants, or distribution of oxygen or other delivered amendments. This results in preferential pathways, non-uniform contact and treatment of the groundwater unit, and susceptibility to matrix diffusion rebound.
- The driving force for groundwater recirculation results in a smaller radius of influence than typical pump and treat extraction wells, so more wells are typically required to cover a plume.
- Primary contaminant removal mechanism is groundwater flushing/desorption, which is the same as a typical groundwater extraction system. As a result, the same mass transfer limitations can cause slow mass removal, low mass removal rates, and an inability to reach remediation goals in a reasonable timeframe. Application of the technology to petroleum contaminants, which are susceptible to aerobic biodegradation, or use of recirculation wells to deliver other in situ amendments, could improve contaminant degradation/removal rates and improve the treatment duration.
- Chemical precipitates or biological growth may form when air is circulated through the subsurface, causing clogging of the well screens.

- Shallow aquifers with limited vadose zone height above the contaminated saturated zone may not allow for sufficient area for in-well recirculation.
- Treatment is localized and is limited by the pumping capacity and radius of influence of each well.
- The contaminant plume must be adequately delineated for accurate well construction to prevent the spreading of the contamination.
- This process is not suited for sites containing non-aqueous phase liquids (NAPLs) because of the likely smearing of contaminants in the vadose zone.

Resources

EPA. Clu-In In-well Vapor Stripping Technology Overview Report (1997)
Technology summary report provides an overview of in-well vapor stripping including general principles and techniques and applicability of the technology.

EPA. Field Applications of In Situ Remediation Technologies: Ground-Water Circulation Wells (1998)
This document describes field applications in sites managed by the Department of Defense, Department of Energy, EPA, and commercial sector using ground-water circulation well systems for the remediation of saturated soils and ground water.

EPA. Clu-In In-well Vapor Stripping Technology Innovative Technology Summary Report (2002)
This technology summary report was prepared for the U.S. Department of Energy, and provides information needed to assess whether in-well vapor stripping might apply to a particular environmental management problem.

ESTCP. Groundwater Circulating Well Technology Assessment (1999)
The objective of this report was to complete a survey of groundwater circulation well technology based on demonstrations at a number of federal and public sites documenting the successes and shortcomings of system performance. In addition, a guideline was developed for the use of the technology with recommendations for additional data requirements to either support or argues against the use of this technology for particular contaminant and hydrogeologic applications. One conclusion of this document is "The wide-scale use of GCW seems limited by a general uncertainty and skepticism about the technology's true performance. In the absence of well documented

examples of successful demonstrations, the use of GCW technology will likely continue to be limited, at least on federal sites."

SERDP. Bioenhanced In-Well Vapor Stripping (BEHIVS) to Treat Trichloroethylene (2003)
This project tested the combination of in-well vapor stripping and in situ aerobic cometabolic bioremediation to remediate a trichloroethene source area.

USGS. Using Oxygen to Enhance Biodegradation of Contaminants - Lessons Learned (2016)
This USGS website summarizes the site remediation approach of adding oxygen to ground water contaminated by gasoline spills or leaking underground storage. Additional references and other relevant information is provided.