# Chapter 10
# Air Sparging/Oxygen Enhancement With Air Sparging

## 10-1. General

The process of air sparging, its applications, and effectiveness are described in the chapter's first section. The second portion of the chapter is a hazard analysis with controls and control points listed.

## 10-2. Technology Description

*a. Air Sparging Methods.*

Groundwater air sparging involves the injection of air into the groundwater to achieve the following objectives:

- Increased oxygen supply to promote aerobic biodegradation of certain contaminants.
- Removal of volatile organic compounds (VOCs) by physical mechanisms (e.g., desorption and volatilization of compounds directly into the enhanced air stream).

A typical air sparging system consists of specially designed injection wells to inject air into the formation, typically accompanied by a properly designed soil vapor extraction (SVE) system to capture the contaminated off-gas. Air is injected into the subsurface under pressure, where it creates an inverted cone of partially aerated soils surrounding the injection point well. The air displaces pore water, volatilizes organics, and exits the saturated zone into the vadose zone. Off-gas is then captured by an SVE system installed in the unsaturated zone and treated prior to release. The sparged air also transfers dissolved oxygen into the groundwater, capillary fringe water, and soil moisture in the unsaturated zone.

Nutrients can be injected into the unsaturated zone in water or injected into the saturated zone, dissolved in water slugs, and moved through sparging points or secondary injection wells. Indigenous microbes use the injected oxygen and nutrients in enzyme reactions, resulting in the transformation or destruction of the contaminants. A schematic diagram of an air sparging system is presented in Figure 10-1.

*b. Applications.*

Air sparging is effective for removing substantial quantities of volatile hydrocarbons and chlorinated organics in certain geological settings. Air sparging can be enhanced by the use of oxygen, hydrogen peroxide, or ozone. Oxygen enhancement by the injected air can increase the oxygen content of the groundwater and soil gas, thus aiding bioremediation processes. Additions of ozone in sparging treatments can partially oxidize hard-to-treat organic compounds, such as chlorinated ethylene and complex aromatics, enhancing more traditional treatments by aerobic bioremediation and volatilization.

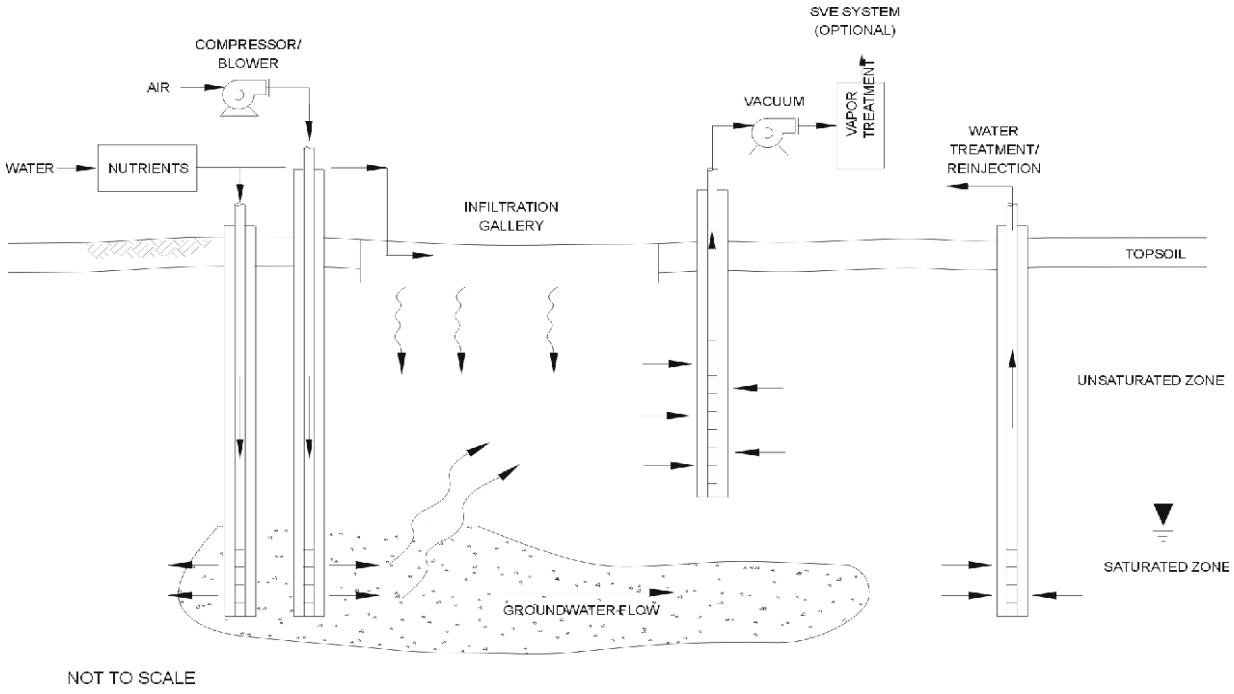


**FIGURE 10-1. AIR SPARGING/BIOSPARGING**

*c. Effectiveness.*

The effectiveness of air sparging depends on the geological characteristics of the site, especially the ease of transmission of air through the soil pore structure. Groundwater air sparging occasionally requires groundwater pump-and-treat systems as well, since sparging effectively creates groundwater mounding around the sparge points, causing radial flow away from the points, and thus the potential to spread groundwater contamination.

## 10-3. Hazard Analysis

Principal unique hazards associated with air sparging/oxygen enhancement, methods for control, and control points are described below.

*a. Physical Hazards.*

(1) *Fire and Explosion Hazards (Drilling).*
*Description.* Soil boring using hollow-stemmed augers may cause a fire or explosion during drilling into soils saturated with flammable or combustible materials in unusual or extraordinary conditions. Sparks generated when a metal auger bit strikes against rocks, metal, or other underground objects may ignite a flammable atmosphere inside the bore hole.

Fire or explosion may also result from drilling into soil contaminated with readily flammable/combustible wastes such as carbon disulfide, gasoline, or explosives such as metal fulminates.

*Control.* Controls for fire/explosion hazards include:

- Train the operators in the hazards of drilling into or through flammable liquids or materials.
- Train the operators in emergency procedures in case of a catastrophic event, in life saving first aid procedures including extinguishing flames or neutralizing chemical reactions, extracting, extinguishing and stabilizing victims, and in emergency drill system isolation and shutdown procedures.
- Use mud or water rotary drilling methods, which add moisture to the cutting area.
- Fill bore holes to prevent vapor accumulation.
- Have adequate fire fighting equipment always at hand to extinguish any fires generated.

**CONTROL POINT**: Construction, Maintenance

(2) *Utility Contact Hazard.*
*Description.* Fire, explosion, or electrocution hazards may exist when using hollow-stemmed auger drilling methods if the rotating auger contacts or ruptures underground utilities such as electrical and gas lines or contacts overhead electric lines.

*Control.* Controls for utility contact hazards include:

- Train the operators in the hazards of drilling in the vicinity of underground or overhead utilities.
- Train the operators in emergency procedures in case of a catastrophic event, in life saving first aid procedures for electrocutions burns, and extinguishing flames, extracting, extinguishing and stabilizing victims, and in emergency drill system isolation and shutdown procedures.
- Contact local utilities and public works authorities to determine the locations of all utilities. When there is any doubt or uncertainty, conduct a utility survey, probe with a metal rod prior to excavation, or hand excavate to determine the exact location of utilities prior to drilling. Once utilities are located, careful excavation by backhoe may be allowed.
- Post an observer to the side to guide when raising a drill mast.
- Do not move the drilling rig with the mast raised.

**CONTROL POINT**: Design, Construction, Maintenance

(3) *Fire (Oxygen Enhancement).*
*Description.* Owing to the presence of high levels of oxygen in an enhanced air sparge system, there may be an increased risk of starting a fire.

*Control.* Controls for fire due to oxygen enhancement include:

- Train the operators in the hazards of handling and operating with pure oxygen and in the nature and likely sources of static electricity buildup within the enhanced air sparge system.
- Inspect oxygen delivery systems regularly for leaks and the elimination of all sources of ignition.

**CONTROL POINT**: Operations, Maintenance

(4) *Fire and Explosion (Flammable Gas).*
*Description.* Fires and explosions may occur because of emissions of flammable VOCs at the surface or in the SVE collection system. Sparks, heat sources, and static electricity may ignite explosive gases, causing rupture of the collection system.

*Control.* Controls for fire/explosion due to flammable gas include:

- Train the operators in the hazards unique to the SVE collection system, including the reactivity of the contaminants extracted, and the sources of ignition, including static electricity.
- Train the operators in emergency procedures in case of a catastrophic event, in life saving first aid procedures including extinguishing flames or neutralizing chemical reactions, extracting, extinguishing and stabilizing victims, and in emergency SVE system isolation and shutdown procedures.
- Verify that the hazardous area classifications, as defined in NFPA 70, Chapter 5, 500.1 through 500.10, are indicated on the drawings.
- Use all controls, wiring, and equipment in gas collection that complies with EM 385-1-1, Section 11, and NFPA 70 for the identified hazard areas.
- Use grounded equipment or equipment with ground fault circuit interrupter (GFCI) protection if required by EM 385-1-1, Section 11, or NFPA 70.
- Inspect systems regularly for leaks.
- Control all sources of ignition.
- Ventilate areas adequately to help prevent the accumulation of flammable gases.

**CONTROL POINT**: Design, Construction, Operations, Maintenance

(5) *Equipment Hazards (Drilling).*
*Description.* The rotating drilling auger poses a hazard to workers as loose clothing may become entangled with the auger.

*Control.* Controls for equipment hazards during drilling include:

- Prohibit the use of loose clothing.
- Drill rigs will be level and blocked wherever soil conditions warrant.
- Use low-profile auger pins.
- Use long-handled shovels to remove soil cuttings from the borehole.

**CONTROL POINT**: Construction, Maintenance

(6) *Blower Hazards.*
*Description.* Blowers may be equipped with unguarded pulleys that may cause entanglement of body parts or loose clothing.

*Control.* Controls for blower hazards include:
- Use guarded pulleys and guarded moving or rotating mechanical devices on blowers.
- Inform workers that guards must be in place for equipment operation.
- Do not allow work in the vicinity of unguarded pulleys or moving machinery.

**CONTROL POINT**: Design, Operations, Maintenance

(7) *Noise Hazards.*
*Description.* The air sparging and SVE collection systems may expose workers to elevated noise levels in the work areas owing to the operation of air blowers and vacuum pumps. The noise level may interfere with safe and effective communications and promote hearing loss.

*Control.* Controls for noise hazards include:
- Train workers in the use of hearing protection and establish a hearing protection program (see 29 CFR 1910.95).
- Use personal electronic communications devices, such as a dual ear headset with speaker microphone, to overcome ambient noise in areas where noise is prevalent and effective communication is critical for operation and worker safety. The device reduces ambient noise levels while enhancing communication. Avoid using hearing protectors that overprotect against ambient noise and in this way effectively prevent necessary communication.
- Establish noise-free areas during operations to provide breaks from the noise, which can cause fatigue and inattention.

**CONTROL POINT**: Design, Operations

(8) *Fire Hazard (Piping Systems).*
*Description.* Piping systems that become plugged may induce failure of the vacuum pump causing an electrical fire. Also, pipes or joints may burst from excessive pressure.

*Control.* Controls for fire due to piping systems include:
- Train the operators in the hazards unique to the piping system, including the tendency to plug, reactivity of the contaminants, and the sources of ignition, including electrical fires caused by overloaded electrical machinery and equipment.
- Train the operators in emergency procedures in case of a catastrophic failure of the piping system, in life saving first aid procedures including extinguishing flames or neutralizing chemical reactions, shutting down electrical power, extracting, extinguishing and stabilizing victims, and in emergency piping system isolation and shutdown procedures.

- Inspect and clean piping systems periodically to help prevent blockage by material buildup.

**CONTROL POINT**: Design, Operations, Maintenance

(9) *Heat Stress.*
*Description.* Workers may be exposed to elevated temperatures because of excessive heating of blowers and other process equipment. The work exposure may induce heat stress.

*Control.* Controls for heat stress include:
- Use the correctly sized blowers, motors, and other equipment to prevent overheating.
- Vigorously train workers in the signs and symptoms of heat stress.
- Use the Buddy System and provide easy access to water.
- Monitor for heat stress using the physiological or Wet Bulb Globe Temperature (WBGT) Index protocol provided in the most recent publication of the American Conference of Governmental Industrial Hygienists (ACGIH) "TLVs and BEIs: Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices."

**CONTROL POINT**: Design, Operations, Maintenance

(10) *Steam Pressure Washing.*
*Description.* Steam pressure washing of equipment may expose workers to thermal, burn or injection hazards, eye hazards from flying projectiles dislodged during pressure washing, slip hazards from wet surfaces, and noise hazards.

*Control.* Controls for steam pressure washing include:
- Use insulated gloves (e.g., silica fabric gloves) and keep all body parts away from the ejection point of the steam pressure discharge nozzle.
- Wear safety goggles and hearing protection.
- Equip washers with deadman or kill switch if not provided by manufacturer.
- Wear slip-resistant boots.
- Drain water away from the decontamination operation into a tank or pit.
- Drain walking surfaces and keep free of standing liquids or mud.

**CONTROL POINT**: Construction, Operations, Maintenance

(11) *Muscle Injuries.*
*Description.* Manual lifting of heavy objects may expose workers to back, arm, and shoulder injuries.

*Control.* Controls for muscle injuries include:
- Do not require workers to lift heavy loads manually.

- Use proper lifting techniques including stretching, bending at the knees, and bringing the load close to the body prior to lifting (see EM 385-1-1, Section 14). Utilize more than one worker to manage loads.
- Use mechanical lifting equipment to lift or to move loads.

**CONTROL POINT**: Design, Construction, Operations, Maintenance

(12) *Emergency Wash Equipment.*
*Description.* Emergency shower/eye wash equipment required per 29 CFR 1910.151 is not always provided with adequate floor drains, thereby creating potential electrical hazards and walking surface hazards during required testing and use.

*Control.* A control for emergency wash equipment includes:
- See American National Standards Institute ANSI Z 358.1 – 1998: "Emergency Eyewash and Shower Equipment" for design requirements.
- Equip showers/eye wash equipment with accompanying functional drains to isolate and collect the shower/eye washwater from unprotected electrical equipment and walking surfaces that, when wet, create slipping and electrical hazards.

(12) *Design Field Activities.*
*Description.* Design field activities associated with subsequent construction may include surveying, biological surveys, soil gas surveys, geophysical surveys, trenching, drilling, stockpiling, contaminated groundwater sampling, and other activities. Each of these field activities may expose the survey personnel to physical, chemical, radiological, and biological hazards.

*Control.* Controls for hazards resulting from design field activities include:
- Prepare an activity hazard analysis for design field survey activities. EM 385-1-1, Section 1, provides guidance on developing an activity hazard analysis.
- Train workers in hazards identified.

**CONTROL POINT**: Design

*b. Chemical Hazards.*

(1) *Toxic Ozone Exposure.*
*Description.* The use of oxygen or ozone enhancement may create an increased flammability potential or toxic (ozone) exposure.

*Control.* Controls for toxic (ozone) exposure include:
- Ventilate the affected area adequately.

- Inspect piping systems regularly for leaks.
- Monitor for ozone and train workers in ozone hazards and recognition including odor identification.

**CONTROL POINT**: Design, Operations, Maintenance

(2) *Contaminants (Well Installation).*
*Description.* During well installation, workers may be exposed to contaminants, such as VOCs, dusts, and metals in soil and development water through the inhalation/ingestion/dermal contact routes.

*Control.* Controls for contaminants include:

- Apply water or an amended water solution to the area during well installation to help control the generation of airborne dusts, particulates, contaminated with VOCs.
- Use respiratory protection including approved filter/cartridges such as N, R or P95 particulate air filters, OV cartridges for vapors, or combination filter/cartridges for dual protection.
- Analyze work tasks and potential for chemical exposure to determine the correct PPE or respirator cartridges. The analysis should include a chemical profile on the waste materials to help ensure the equipment specified will be appropriate for the respective chemical hazards.

**CONTROL POINT**: Construction, Maintenance

(3) *Chemical Materials and Byproducts (Operation).*
*Description.* During operation of the system equipment, workers may be exposed to chemical materials, such as hydrogen sulfide, VOCs, carbon dioxide, and intermediate byproducts by the inhalation/ingestion/dermal contact exposure routes.

*Control.* Controls for chemical exposure include:

- Use proper ventilation.
- Wear appropriate personal protection equipment (PPE) (e.g., an air-purifying respirator with organic vapor cartridges (air-purifying respirators for $H_2S$ exposure are for escape only) or supplied-air respirators where the contaminants exhibit poor warning properties such as $H_2S$).
- Check closed systems, such as SVE, routinely for leaks with PIDs, air samples, oxygen meters, leak detection fluids, explosive gas meters, or specific gas tests such as Draeger-type tubes. Repair leaks immediately.
- Use vent stack heights that are adequate to disperse off-gas above and beyond the breathing zone of the workers.
- Designers: anticipate byproducts and products and make certain that the technology for off-gas treatment (e.g., activated carbon, condensation, catalytic oxidation) is effective and safe.

**CONTROL POINT**: Design, Operations, Maintenance

(4) *Ozone Exposure*.
*Description.* Ozone exposure may occur via the inhalation route from leaks in equipment used to generate ozone. Ozone is an irritant to skin, eyes and mucous membrane systems.

*Control.* Controls for ozone exposure include:
- Use closed delivery systems for the addition of ozone to help minimize worker exposure.
- Test the equipment used to generate ozone for leaks prior to use.
- Perform regular maintenance and leak tests according to the manufacturer's instructions.
- Train workers in ozone hazard recognition.
- Provide emergency use chemical cartridge, gas canister or supplied air respirators.

**CONTROL POINT**: Design, Operations, Maintenance

(5) *Hydrogen Peroxide Exposure*.
*Description.* During handling of hydrogen peroxide, workers may be exposed to liquid hydrogen peroxide via the inhalation/ingestion/dermal contact exposure routes. Hydrogen peroxide is an irritant to the skin, eyes, and mucous membranes.

*Control.* Controls for hydrogen peroxide exposure include:
- Use closed delivery systems for the addition of hydrogen peroxide to help minimize worker exposure.
- Test the system for leaks prior to use.
- Perform regular maintenance and leak tests according to the manufacturer's instructions.
- Train workers in hydrogen peroxide hazard recognition.
- Provide emergency use supplied air respirators.

**CONTROL POINT**: Design, Operations, Maintenance

(6) *VOC Migration*.
*Description.* Injection (sparging) wells may cause migration of VOCs into subsurface structures, such as basements and sewers. The VOCs may be toxic or flammable, resulting in chemical exposure or the potential for a fire or explosion.

*Control.* Controls for VOC migration include:
- The designer must determine the pressure range of the system and install hazard warning alarms to prevent over-pressurization.
- Periodically test air in basements and other areas where VOCs may migrate to ensure safe levels.

- Train workers in the air sparging VOC dispersion patterns to expect and the potential hazard of accumulating VOCs in subsurface structures and low-lying areas in the vicinity of the air sparging systems.

**CONTROL POINT**: Design, Operations, Maintenance

(7) *Confined Space Chemical Hazards*.
*Description.* During entry into confined space, such as a manhole to collect condensate samples, workers may be exposed to airborne chemical hazards if the atmosphere in the confined space contains a toxic chemical or is oxygen deficient.

*Control.* Controls for confined space chemical hazards include:
- Train workers in confined space hazards and on safety procedures to employ in confined space entry.
- Design the confined space to maximize natural ventilation, accessibility with adequately sized access doors, and space for easy sample collection.
- Develop a pre-entry confined space permit. Implement a confined-space entry program to assess hazards including air testing the space's interior both prior to and throughout the work planned (see 29 CFR 1926.21).
- Ventilate confined spaced if a hazardous atmosphere exists.

**CONTROL POINT**: Operations

(8) *Toxic Intermediate Products*.
*Description.* Biological degradation of certain chlorinated organic compounds may produce toxic intermediate products, including vinyl chloride. Vinyl chloride exists as a gas and may accumulate to higher levels in boreholes or in the system. Workers may be exposed to intermediate products during operation or maintenance of the system.

*Control.* Controls for toxic intermediate products include:
- Ventilate the affected area.
- Select the proper respirator according to 29 CFR 1910.1017 or 29 CFR 1910.134 for other intermediate products if exposures are not less than the Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL).
- Check with the respirator manufacturer to verify use in atmospheres containing vinyl chloride.

**CONTROL POINT**: Design, Operations, Maintenance

*c. Radiological Hazards.*

*Radon Exposure*.
*Description.* In some geological settings, workers may be exposed to naturally occurring radon gas. The gas is drawn from the soil in the SVE stream. Radon gas and radon progeny do not present a significant external hazard. While breakdown products

of radon (progeny) may present an inhalation/ingestion hazard, quantities of radon progeny normally present would not pose a significant exposure hazard.

*Control.* Controls for radon exposure include:

- Check for proper operation of emission control technologies to limit exposure to acceptable levels.
- Consult a qualified health physicist if excessive levels are suspected or encountered.

**CONTROL POINT**: Design, Operations, Maintenance

*d. Biological Hazards.*

(1) Biological Contaminants.

*Description.* At those sites involving medical wastes or sewage sludge, microorganisms in the soil may pose exposure hazards during system installation activities. Workers may be exposed to inhalation/ingestion/dermal contact with pathogens such as *Coccidioides sp.*, *Histoplasma sp.*, and *Mycobacterium sp.* if contaminated dusts become airborne.

*Control.* Controls for biological contaminants include:

- Reduce the generation of airborne microbe-contaminated dust with the periodic application of water, surfactant amended water, or emission-suppressing foams to the active excavation/drilling areas. The addition of foam to control vapors may also create a slip and fall hazard. Workers should not walk on areas where foam has been applied.
- Erect windscreens and use portable surface covers.
- Use the proper types of PPE: an air-purifying respirator with N, R, or P100 or N, R or P95 particulate air filters approved for microbial inhalation hazards, and appropriate gloves.
- Use experienced workers, repeated health and safety meetings, decontamination stations, and other standard procedures.

**CONTROL POINT**: Construction, Maintenance

(2) *Pests*.

*Description.* Workers may be exposed to a wide array of biological hazards, including snakes, bees, wasps, ticks, hornets, and rodents during any phase of remediation. The symptoms of exposure vary from mild irritation to anaphylactic shock and death. Deer ticks may cause Lyme disease. Rodents can transmit Hanta virus. Mosquitoes can transmit the West Nile Virus.

*Control.* Controls for pests include:

- Periodically inspect the site to identify stinging insects and to check for snakes and rodents.
- Use professional exterminating companies if necessary.

- Use tick and insect repellents with N,N-diethyl-m-toluamide (DEET) 25% as the active ingredient for exposure control. Clothing may be treated with permethrin clothing repellent BEFORE donning, for added protection. Workers should check their skin and clothing for ticks periodically.

**CONTROL POINT**: Construction, Operations, Maintenance