Chapter 7
Soil Vapor Extraction (In Situ), Bioventing, Biodegradation, Thermally Enhanced Soil Vapor Extraction, Electrical Resistivity Heating

7-1. General

The process of soil vapor extraction (SVE), SVE enhancements, bioventing, and in-situ groundwater bioremediation technology applications are included in this section. The second section of the chapter is a hazard analysis, including controls and control points.

7-2. Technology Description

a. Soil Vapor Extraction Methods.

SVE is the process of extracting soil gas from the vadose zone (the vertical soil zone between the ground surface and the groundwater surface) to convey volatile organic compound vapors (VOCs) to the surface for collection or destruction. The process, illustrated in Figure 7-1, generally consists of wells screened in the unsaturated, impacted zone above the water table. The wells are manifolded and connected to a vacuum blower capable of establishing a vacuum on the subsurface soils. The process relies on the combined effects of lowered soil gas pressure (partial vacuum) and soil gas mass flow (soil gas extraction) to enhance volatilization and mass removal of volatile compounds from soil and soil water. The process is dependent on the partitioning of VOCs into the soil gas from the water films and water table (Henry's Law) or from a separate phase on the pore space surfaces of the soils (Raoult's Law), or both.

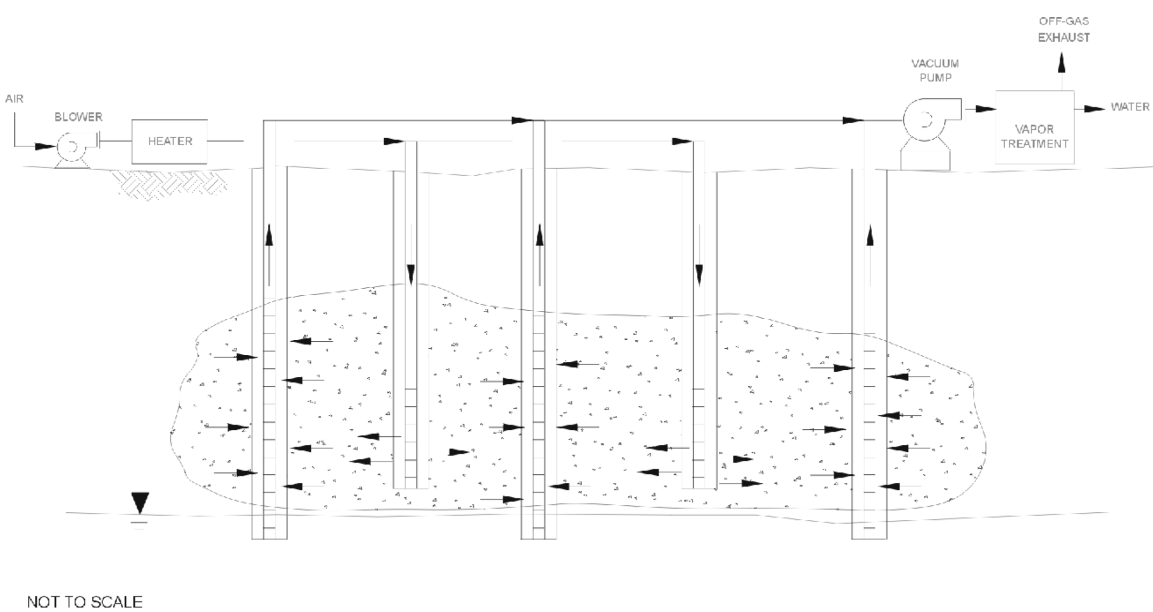

FIGURE 7-1. SVE (IN SITU)/THERMALLY ENHANCED SVE

Many VOCs of environmental concern have low water solubility and relatively high vapor pressures, so the SVE process extracts them readily. Ancillary equipment is used to protect the pump and to treat the extracted soil gas (typically using vapor phase granular activated carbon or catalytic oxidation). Fresh air can be introduced by installing infiltration, induction, or injection wells, or by general infiltration from the surface, or a combination of both.

b. SVE Thermal Enhancements.

SVE systems can be installed with accompanying sparging or air injection processes to enhance the soil gas movement. Occasionally, the processes may also be enhanced in rate and extended to many semi-volatile organic compounds (SVOCs) by applying heat to the treatment zone. Most commonly, the air is heated before its injection, the soil is conductively heated through placement of down hole heaters, the soil is heated by passage of electrical current (Electrical Resistivity Heating [ERH]) through it between electrodes, or steam is injected into the subsurface. Because air has a much lower heat capacity than the soil and water it must heat, the rate of heating using air is generally slow. Steam can heat the soil much faster, but tends to flow upward from the injection point owing to buoyancy. Steam will preferentially travel through the more porous and permeable zone and, therefore, depends on conduction to heat less permeable zones. Heating using electric current passing through the soils (electrical resistivity heating) may more evenly heat the soil, but may result in undesirable voltages at the surface. Both steam injection and electrical resistivity heating can reach temperatures slightly above 100ºC, depending on the depth. Thermal conduction heating using down hole heaters results in quite uniform heating. Such thermal conduction heating can generate significantly higher temperatures than the other methods (greater than 400ºC near the heaters). Thermal enhancements may also alter the soil chemistry and structure, redistribute water in the soils, enhance mobilization of low solubility or low volatility contaminants, and thus (undesirably) mobilize them to the groundwater. Vapors from high volatility compounds may not be adequately controlled by the SVE system and may migrate to the surface or structures. The waste streams generated by these techniques are present in piping and equipment at high temperatures (boiling or above).

c. Bioventing (In-situ Biodegradation).

In-situ biodegradation, as related to SVE, is termed *bioventing* (Figure 7-2). Bioventing is the process of enhancing in-situ bioremediation of the contaminants in the soils by enhancing the availability of oxygen to the microbes by SVE-type venting processes. The primary parameters that can be altered are oxygen content of the pore water, nutrient (nitrogen and phosphorus) content of the soil and water, and pH.

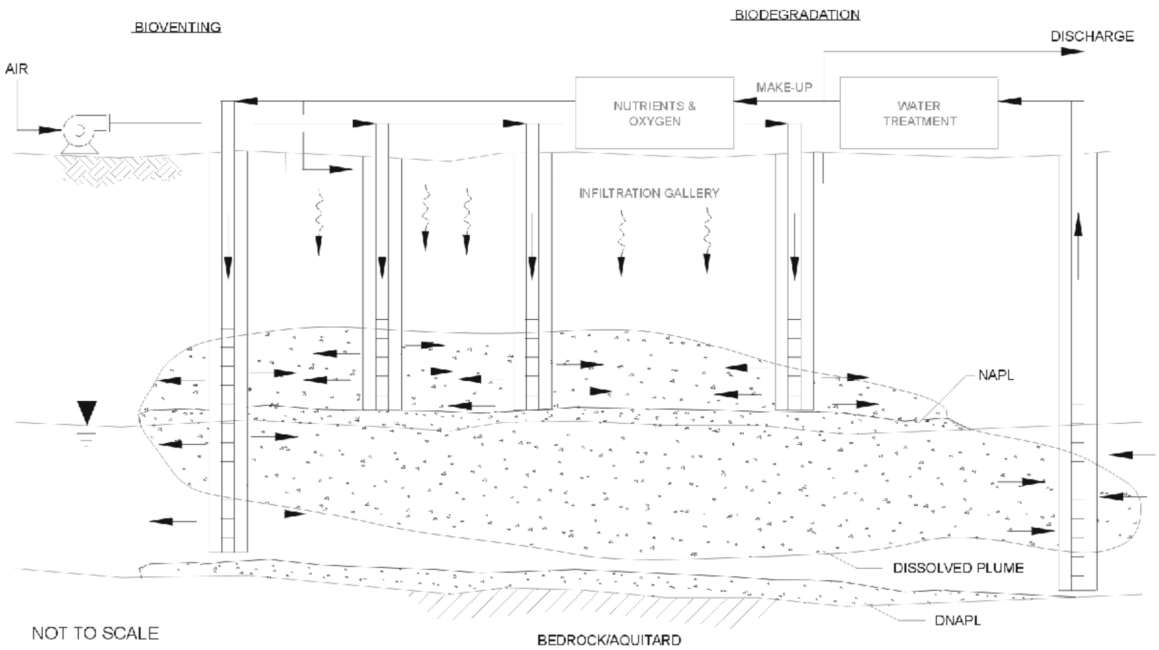

FIGURE 7-2. BIOVENTING/BIODEGRADATION

During bioventing, air drawn or injected into the subsurface provides oxygen to aerobic microorganisms that degrade the VOCs and SVOCs. Because the objective is to provide sufficient oxygen to microbes rather than to use air as a mass remover of VOCs, the rate of air flow is usually lower than with SVE; only the rate needed to sustain biological activity is required. Occasionally, nutrients and water may be added to the subsurface using infiltration galleries to optimize the biodegradation rate or in some cases these can be delivered via air into the treatment zone. The degradation process produces carbon dioxide, water, and incompletely digested organic intermediates as the reaction products with the intermediate products subject to further microbial digestion.

d. Bioventing Enhancements.

These venting processes can be enhanced by active injection of air or by induction of air during active air extraction. The latter approach provides for better control of the off-gas as active injection of air can cause contaminated soil gas to exit the soil surface, and radially flow uncontrolled through the soil.

e. In-situ Groundwater Bioremediation.

In-situ bioremediation (ISB) of groundwater usually involves injection of an organic substrate (i.e., electron donor), such as molasses, sodium lactate, or hydrogen release compound. Electron donor solutions can be introduced via injection wells or direct push injection points. Addition of electron donors can be used to stimulate reductive de-chlorination of some types of chlorinated solvents such as TCE. Biodegradation of nitrate and perchlorate can also be stimulated through electron donor injection. In some instances nutrients or buffering compounds are also injected. Examples of nutrient-containing compounds include ammonium nitrate and ammonium phosphate.

Biofouling of injection or extraction wells often occurs during ISB. Well rehabilitation procedures may involve use of acid, sodium hypochlorite, or hydrogen peroxide solutions. Incomplete degradation of contaminants during in-situ bioremediation can produce intermediates (i.e., TCE may be transformed into DCE and vinyl chloride). Electron donor injection can also produce hydrogen sulfide or methane. If the aquifer is relatively shallow, then there may be an increased risk of hydrogen sulfide or methane migrating into basements and above ground structures.

f. Applications.

The processes will remove or biologically alter the chemical structure of many VOCs and SVOCs. Because they are in-situ processes, they minimize exposure to these compounds during the remediation. However, they require longer times to implement than soil removal technologies.

SVE effectively treats fuel component VOCs and chlorinated organic VOCs as well; bioventing effectively treats fuel, VOCs, and some SVOCs. Thermal enhancements can extend the range of treatable organics to compounds with higher boiling points and viscosities and may allow treatment of volatile metals such as mercury. Chlorinated compounds treated with SVE are treated at rates commensurate with their volatilities and solubilities. The conventional bioventing process is not very effective for treating most types of chlorinated VOCs. However, a variation on the bioventing process (i.e., co-metabolic bioventing) was developed to treat of some types of chlorinated VOCs. Co-metabolic bioventing involves injection of air and a co-metabolite, such as methane or propane.

7-3. Hazard Analysis

The principal unique hazards associated with soil vapor extraction (in-situ) bioventing, biodegradation, and thermally enhanced soil vapor extraction, methods for control, and control points are described below.

a. Physical Hazards.

(1) *Heat Stress*.
Description. Workers may be exposed to elevated temperatures while installing the wells and from excessive heating by blowers and other process equipment during operation of the extraction system. The 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. Require frequent body fluid replacement and frequent work breaks in shaded locations.
- 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

(2) *High Temperatures*.
Description. Operation of the thermal enhanced treatment systems, such as the injection of steam into the subsurface or in using ERH system electrodes and metal wells adjacent to the heat application points, can increase the subsurface temperatures to the boiling point of groundwater. Following shutdown, it may take several days or weeks for the equipment to cool down, including casings. Severe burns can result from contact with components without proper personal protection equipment (PPE).

Control. Controls for high temperatures include:

- Verify through temperature probes that the equipment, such as metal casings used in conjunction with the heat treatment, is cooled below 140ºF for safe handling.
- Provide proper PPE for burn hazards, such as insulated gloves for handling well attachments and electrodes.
- Vigorously train personnel in working around equipment heated to extreme temperatures for sampling during active heating and for several weeks following shutdown.
- Use the Buddy System for the symptoms of heat stress, and provide easy access to water. Require frequent body fluid replacement and frequent work breaks in shaded locations.
- 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: Operations, Maintenance

(2) *Equipment Hazards (Excavation).*
Description. During drilling of wells or excavation of trenches when installing horizontal piping systems, workers may be seriously injured or killed by heavy equipment such as drill rigs or front-end loaders and scrapers operating in their work areas. This equipment may also generate excessive noise during operation.

Control. Controls for equipment hazards include:

- Use heavy equipment with a backup alarm to alert workers.
- Provide workers and spotters in the vicinity of operating heavy equipment with fluorescent orange or lime green traffic vests.
- Approach operating equipment from the front and within view of the operator, preferably making eye contact.
- Wear hearing protection and establish a hearing conservation program.

CONTROL POINT: Construction, Operations, Maintenance

(3) *Utility Contact Hazards*.
Description. Fire or explosion hazards may exist if excavation equipment ruptures an underground utility (electrical or gas lines) during installation of the system.

Control. Controls for utility hazards include:

- Train the operators in the hazards of excavating 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 excavation isolation procedures.
- Identify the location of all below- and above-ground utilities by contacting local utilities and public works authorities. When there is any doubt or uncertainty, perform a utility survey, probe with a metal rod, or hand excavate to determine the exact location of utilities prior to drilling. Once utilities are located, careful excavation by backhoe may be allowed.

CONTROL POINT: Design, Construction

(4) *Fire and Explosion Hazards (Gas Transfer).*
Description. During the transfer of flammable gas from the extraction wells or subsurface piping systems to the treatment unit, a fire or explosion hazard may exist. The gas may be ignited by improperly selected or installed equipment.

Control. Controls for fire and explosion hazards during gas transfer include:

- Train the operators in the hazards of the gas collection system, including the reactivity of the contaminants extracted, and the sources of ignition, including static electricity.
- Perform a Process Hazard Analysis (PHA) prior to startup and correct all deficiencies found.
- Train the operators in emergency procedures in case of a catastrophic event, in life saving first aid procedures including extinguishing flames, extracting, extinguishing and stabilizing victims, and in emergency gas recovery system isolation and shutdown procedures.
- Verify that the hazardous area classifications, as defined in NFPA 70 Chapter 5, sections 500.1 through 500.10, are indicated on the drawings.
- Use controls, wiring, and equipment in conformance with the requirements of EM 385-1-1, Section 11, and NFPA 70 for the identified hazard areas.
- Perform all electrical work according to code and under the supervision of a state licensed master electrician.
- Use grounded equipment or equipment with ground fault circuit interrupter (GFCI) protection if required by EM 385-1-1, Section 11, or NFPA 70.
- Monitor the atmosphere periodically around the area with a combustible-gas monitor. If the concentration of explosive gas reaches 10% of the Lower Explosive Level (LEL) or greater, inspect the system for leaks and emission points.
- Control all sources of VOC emissions to prevent the release of flammable gas.
- Install a permanent explosion level meter or alarm if necessary.

CONTROL POINT: Design, Construction

(5) *Explosion Hazards (Steam Generator).*
Description. Thermally enhanced SVE systems may incorporate steam to heat soils. Pressure caused by plugged steam lines may cause a rupture or an explosion in the system.

Control. Controls for explosion due to steam generators include:

- Train the operators in the hazards of operating the steam generators, including the operating parameters that would lead to plugged lines and catastrophic pipe failure and steam release.
- Perform a Process Hazard Analysis (PHA) prior to startup and correct all deficiencies found.
- Train the operators in emergency procedures in case of a catastrophic event, in life saving first aid procedures including emergency burn treatment, extracting, and stabilizing victims, and in emergency recovery system isolation and shutdown procedures.

- Operate the steam generator within its design parameters and use emergency pressure relief valves.
- Flush steam lines periodically to remove any accumulated scale or deposits.

CONTROL POINT: Design, Operations, Maintenance

(6) *Burn (Steam) and Freezing Hazards.*
Description. The surface temperature of uninsulated steam generators and piping systems may reach several hundred degrees and pose a burn hazard to workers. Steam will be generated in the subsurface during operation of the ERH system. The steam will be present throughout the treatment area, and in the vapor recovery wells in the vicinity of the treatment area as well as at the condenser and within the condenser. Steam may be generated under positive pressure. Catalytic oxidation system components can be hot, and also pose a burn hazard. Cryogenic systems, associated with O_2 delivery systems, can have very cold surfaces and pose a contact-freezing hazard.

Control. Controls for burn and freezing hazards include:

- Train the operators in the hazards of operating high temperature steam generators, including the surface operating temperatures of equipment.
- Properly insulate surfaces exposed to operators.
- Avoid exposing workers to the sources of steam.
- Provide PPE including face shields, gloves, and heat resistant rain clothing for protection against burns when opening or working around wells, piping, or system components containing steam.
- Include high temperature hazard warning signs on the equipment.
- Provide physical covers and barriers to prevent contact.

CONTROL POINT: Design, Construction, Operations, Maintenance

(7) *Noise Hazards*.
Description. High levels of noise may be generated by blowers and compressors and may result in hearing loss.

Control. Controls for noise hazards include:

- Use insulated materials, barriers, and properly lubricate and maintain equipment.
- Establish a hearing protection program (see 29 CFR 1926.52). Require personal hearing protection when working in areas of elevated noise levels.

CONTROL POINT: Design, Operations

(8) *Unguarded Moving Equipment*.
Description. Unprotected blowers and fans may entangle workers' clothing and cause injury.

Control. Controls for moving equipment include:

- Guard all moving and rotating equipment.
- Inform workers that all such equipment must be operated with guards in place.
- Train workers in the entanglement hazards.
- Disallow the wearing of loose-fitting clothing.

CONTROL POINT: Design, Operations

(9) *Equipment Hazards (Drilling).*
Description. During drilling and direct push operations, heavy equipment such as augers and pipes are periodically raised overhead and placed above or into the well. Workers may be exposed to swinging equipment during lifting or may be exposed to crushing hazards if the equipment falls. Cables used to rise and lower equipment may also become entangled in loose clothing or other equipment. Direct push drilling methods using hydraulic pressure to advance a soil boring may pose a crushing hazard to hands or feet.

Control. Controls for equipment hazards during drilling include:

- Train workers in heavy equipment lifting hazards, including properly securing the loads, establish and practice the Buddy System for all lifts, and maintain a constant line of sight between all members of the ground crew and the lift operator.
- Stabilize drill rig by leveling or blocking whenever soil conditions dictate.
- Post a spotter to the side to supervise when raising a drill mast.
- Do not move the drilling rig with the mast raised.
- Secure all loose clothing, use low-profile auger pins, and use long-handled shovels to remove soil cuttings from the borehole.
- Use cable systems with caution and inspect regularly for loose strands or frayed wires that may become entangled in loose clothing.

CONTROL POINT: Design, Maintenance

(10) *Electrocution/Fire Hazards (Overhead Lines or Piping Systems).*
Description. Electrocution or fire hazards may exist when using hollow-stemmed auger, direct push, or other drilling methods if the drilling mast contacts overhead electric lines or piping systems containing flammable chemicals.

Control. Controls for electrocution include:

- Train the operators in the hazards of drilling in the vicinity of 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.
- Inform all workers as to the location of overhead utilities.
- Drill in an alternative location if possible.
- Keep all lifting equipment (cranes, forklifts, and drilling rigs) at least 10 feet from the power line according to Occupational Safety and Health Administration (OSHA) regulation 29 CFR 1926.550 and EM 385-1-1, Section 11.
- Post a worker to observe and supervise when raising a drill mast.
- Operate the mast at its lowest height; different drill rigs have different mast elevations and may be operated at different heights.

CONTROL POINT: Design, Construction, Maintenance

(11) *Electrical Equipment Hazards*.
Description. Operation of temporary and permanent electrical equipment, such as lights, generators, and heated SVE system components, such as ERH electrodes, may cause electrical hazards.

Control. Controls for electrical equipment include:

- Train workers in recognizing electrical hazards and in the controls specified in NFPA 70 and EM 385-1-1.
- Verify that the hazardous area classifications as defined in NFPA 70 Chapter 5, sections 500.1 through 500.10, are indicated on the drawings.
- Perform all electrical work according to code and under the supervision of a state licensed master electrician.
- Use all controls, wiring, and equipment in conformance with the requirements of EM 385-1-1, Section 11, and NFPA 70 for the identified hazardous areas.
- Use grounded equipment or equipment provided with ground fault circuit interrupter (GFCI) protection if required by EM 385-1-1, Section 11, or NFPA 70 requirements.
- Startup and initial unattended operations of ERH power control units must be performed only with Site Startup Checklist completed and signed by appropriate thermal operations personnel.
- Establish an exclusion zone around the electrode field of an ERH system when voltage is initially applied to electrodes, typically with a chain link security fence, plastic fencing or barrier tape, depending on environs. Locate fencing to maintain less than or equal to step-

touch potential not to exceed 15 volts. If surface voltages are verified less than 15 volts throughout the electrode field, the exclusion zone can be reclassified to general remediation hazard area. Identify all metal objects within 100 feet of the electrodes prior to startup. If startup indicates hazardous voltages developing outside the exclusion zone, improve grounding systems by reorienting the surface grid area, or adding grounding rods, otherwise breaking the conducting path outside the exclusion zone or increasing the size of the exclusion zone.

- Maintain strict access control to the exclusion zone, electrodes, and equipment.
- Establish and maintain rigorous lock-out/tag-out procedures implemented by only authorized personnel.

CONTROL POINT: Design, Construction, Operations, Maintenance

(12) *Explosion Hazards (Gas Storage).*
Description. Improper storage and use of cylinders of compressed gases in some in-situ bioremediation systems may cause explosive or projectile hazards.

*Control***.** Controls for explosion attributable to gas storage include:

- Train the workers in the hazards of handling compressed gases in cylinders and in safe handling requirements (see 29CFR 1910.101, Compressed Gas Association Pamphlet P-1-1965, and Compressed Gas Association Pamphlets S-1.1-1963 and 1965 addenda and S-1.2-1963).
- Train the operators in emergency procedures in case of a catastrophic event, in life saving first aid procedures including emergency burn treatment, toxic gas exposure treatment, extracting, and stabilizing victims, and in emergency isolation procedures.
- Store cylinders of compressed gases upright, capped, and secured to prevent movement or tipping.
- Avoid extreme temperatures.

CONTROL POINT: Design, Operations

(13) *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 a 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

(14) *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). Some loads may require two people.
- Use mechanical lifting equipment to lift or to move loads.

CONTROL POINT: Design, Construction, Operations, Maintenance

(15) *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) *Degradation Products*.
Description. Biological degradation of certain organic compounds may produce toxic intermediate products. As an example, degradation of trichloroethylene (TCE) can produce trichloroethylene (DCE) and vinyl chloride (VC). Vinyl chloride exists as a gas and may accumulate to

higher levels in boreholes or in the system. Workers may be exposed to the degradation products during operation or maintenance of the system.

Control. Controls for degradation products include:

- Install vapor extraction wells to prevent emissions from reaching basements, above-ground work areas, and enclosed structures.
- Ventilate the area to minimize exposure.
- Require air-supplied respiratory protection if supported by air monitoring results. (Note: air-purifying respirators are not recommended for vinyl chloride.)
- Remediation designers must understand and anticipate the generation and management of general and specific process products, such as carbon dioxide, hydrogen sulfide, methane, and vinyl chloride (CO, H_2S, CH_4, VC), and design for their management.

CONTROL POINT: Design, Operations, Maintenance

(2) *Waste Chemicals and VOC Exposure*.
Description. During installation of the wells and system operations and maintenance, workers may be exposed to dermal or inhalation hazards associated with waste chemicals, such as airborne dusts, particulates, and VOC emissions resulting from off gassing or leaks.

Control. Controls for waste chemicals and VOCS include:

- Apply water or surfactant amended water solution to the area during installation to help control airborne dusts, particulates, and VOCs.
- Use proper ventilation during installation and operation.
- Use personal protective equipment (PPE) that eliminates exposure hazards (e.g., an air-purifying respirator with organic vapor cartridges).
- Check closed systems, such as SVE, routinely for leaks of the off-gas treatment system with PIDs, air samples, oxygen meters, leak detection fluids, explosive gas meters, or specific gas tests with chemical-specific detector tubes.
- Repair leaks immediately.
- Make vent stack heights adequate to disperse off-gas.
- Designers must anticipate byproducts and products and be certain that technologies selected for treatment (e.g., activated carbon, condensation, catalytic oxidation) of off-gas residuals are both effective and safe.

CONTROL POINT: Design, Construction, Operations, Maintenance

(3) *VOC Migration*.
Description. Air injection may cause the migration of VOCs to low areas, such as basements and sewers. The accumulated, flammable VOCs can cause chemical exposure or an explosion to the occupants. In addi-

tion to VOCs, other types of gasses may accumulate such as hydrogen sulfide and methane.

Control. Controls for VOC migration include:

- Train workers in the hazards of accumulating dense flammable contaminants, such as VOCs generated during the extraction process, in low areas and spaces, such as basements, sewers, and manholes.
- Install vapor extraction wells to prevent emissions from reaching basements, above-ground work areas, and enclosed structures.
- Operate building heating/ventilation/air-conditioning systems under positive pressure to reduce intrusion of emissions from the subsurface.
- Train workers in emergency procedures in case of a catastrophic event, such as a gas explosion, in life saving first aid procedures including emergency burn treatment, extracting, and stabilizing victims, and in emergency SVE shutdown procedures.
- Test air periodically to ensure safe levels in basements and other areas where VOCs may migrate.

CONTROL POINT: Design, Operations, Maintenance

(4) *VOC Exposure (Vents).*
Description. Workers may be exposed to VOCs as they are discharged from the blower vent.

Control. Controls for VOC migration include:

- Install emission controls, such as activated carbon canisters, on the blower vent discharge.
- Monitor periodically for efficiency.

CONTROL POINT: Design, Operations, Maintenance

(5) *Chemical Release*.
Description. Fire or explosion or chemical release (inhalation/ingestion/asphyxiation) hazards may exist when using a hollow-stemmed auger, direct push, or other drilling methods if the drilling bit or bucket ruptures underground utilities, tanks, or piping systems (overhead chemical feed lines) containing hazardous chemicals.

Control. Controls for accidental chemical release include:

- Train workers in the hazards of drilling in the vicinity of underground utilities.
- Train workers in emergency procedures in case of a catastrophic event, such as a gas explosion or electrocution, in life saving first aid procedures including emergency burn treatment, extracting, and stabilizing victims, and in emergency SVE or drilling shutdown procedures.

- Identify location of all below ground utilities by contacting local utilities during design phase.
- Perform a utility survey, probe with a metal rod prior to excavation, or hand excavate to determine the exact location of underground lines prior to drilling.
- Locate overhead hazards and design so that installations using erect equipment are not necessary in that area, if possible.

CONTROL POINT: Design, Construction

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:

- Operate emission control technologies properly to limit exposure to acceptable levels.
- Consult a qualified health physicist if excessive levels are encountered or suspected.

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 cause 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 particulate air filters approved for microbial inhalation hazards and rubber 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 insect nests and to check for snakes and rodents.
- Use professional exterminating companies if necessary.
- Use tick and insect repellents containing the active ingredient N,N-diethyl-m-toluamide (DEET) 25% 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