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# An Overview of Underground Storage Tank Remediation Options

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## Contents

### Groundwater Remediation



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# Groundwater Remediation For UST Sites

## In Situ Air Sparging With Soil Vapor Extraction

*In situ air sparging with soil vapor extraction (SVE) is a technique for removing dissolved volatile contaminants from groundwater. The technique injects air into the saturated zone. The air forms bubbles that rise into the unsaturated zone, carrying trapped and dissolved contaminants. Extraction wells in the unsaturated zone capture sparged air. If necessary, the air can then be treated using a variety of vapor treatment options.*

*This technique is most effective in homogenous, permeable aquifers. Performance data for this technique are limited.*

*In situ air sparging with soil vapor extraction is a rapid remediation technique that can reduce contamination levels in six months. It is also able to quickly remove volatile organic compounds (VOCs) from below the groundwater table.*

### Petroleum Types And Constituents

- Gasoline and diesel
- Volatile organic compounds (VOCs) such as benzene, toluene, ethylbenzene, and xylene (BTEX)

# In Situ Air Sparging With Soil Vapor Extraction

| | |
|---|---|
| **Advantages** | • Rapidly reduces volatile organic compounds (VOCs) from below groundwater table<br>• Can enhance and accelerate effectiveness of soil vapor extraction (SVE) and downgradient pumping |
| **Limitations** | • Removes primarily volatile constituents<br>• Effectiveness is limited in low permeability or heterogeneous media<br>• Difficult to control air distribution in groundwater<br>• Can promote vapor and plume migration<br>• Limited performance data are available; contaminant levels may rebound over time |
| **System Components** | • Vertical or horizontal extraction and injection wells<br>• Trenches<br>• Vacuum pump, compressor, or blower<br>• Aboveground vapor treatment equipment (optional) |
| **Wastestream Treatment** | • Vapor treatment options (if needed):<br>  • *Vapor phase biofilter*<br>  • *Granulated activated carbon*<br>  • *Internal combustion engine*<br>  • *Catalytic oxidation unit*<br>  • *Thermal incinerator* |
| **Parameters to Monitor**[1] | • Vacuum/pressure monitoring at the wellhead, pump, compressor, blower, and observation points<br>• Airflow rate<br>• Vapor concentrations<br>• Dissolved oxygen<br>• Water levels<br>• Constituent concentrations in groundwater and soil |
| **Cleanup Levels and Timing**[2] | • Generally achieves maximum contaminant levels (MCLs) for volatile constituents<br>• For an ideal site[3], ~90% reduction in 6 months to 1 year<br>• For an average site[4], ~90% reduction in 6 months to 2 years |
| **Costs**[5] | • For an ideal site[3], $60,000 to $180,000<br>• For an average site[4], $120,000 to $200,000 |

[1] "Parameters to monitor" are for performance purposes only; compliance monitoring parameters vary by state.
[2] Cleanup standards are determined by the state.
[3] An "ideal site" assumes no delays in corrective action and a relatively homogenous, permeable subsurface.
[4] An "average site" assumes minimal delays in corrective action and a moderately heterogeneous and permeable subsurface.
[5] Costs include equipment, and operation and maintenance.

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5403W

EPA 510-F-93-018
October 1993

EPA

# Groundwater Remediation For UST Sites

## In Situ Bioremediation

*In situ* ***bioremediation*** *is a technique for removing biodegradable contaminants from groundwater. The technique relies on microorganisms and supplemental oxygen and nutrients to break down petroleum products in the groundwater.*

*In situ bioremediation offers the advantage of being able to treat contamination in place, without the need for pumping or the subsequent treatment of pumped groundwater. The technique is most effective in permeable aquifers.*

**Petroleum Types And Constituents**

- Fresh or weathered gasoline, diesel, jet fuel, kerosene, motor oil, heavy fuel oil, lubricating oils, and crude oils
- Volatile organic compounds (VOCs) such as benzene, toluene, ethylbenzene, and xylene (BTEX); residual semivolatile organic compounds (SVOCs) such as polynuclear aromatic hydrocarbons; and nonvolatile constituents

## In Situ Bioremediation

| | |
|---|---|
| **Advantages** | • Degrades contaminants in place<br>• Achieves lower concentration levels than pump and treat |
| **Limitations** | • Effectiveness is limited in low permeability or heterogeneous media<br>• Ability to transport nutrients and oxygen might be limited by soil and groundwater mineral content or pH<br>• Targets only biodegradable constituents |
| **System Components** | • Groundwater containment system<br>• Oxygen delivery equipment<br>• Nutrient delivery equipment<br>• Injection trenches<br>• Recovery walls or trenches<br>• Pumps<br>• Monitoring points |
| **Wastestream Treatment** | • Recirculated groundwater treatment options:<br>  • *Air stripping*<br>  • *Granulated activated carbon*<br>  • *Bioreactors* |
| **Parameters to Monitor**[1] | • Constituent concentrations in groundwater<br>• Microbial population in aquifer<br>• pH and total organic carbon<br>• Dissolved oxygen<br>• Nutrient concentration<br>• Flow rates |
| **Cleanup Levels and Timing**[2] | • Generally, can achieve maximum contaminant levels (MCLs)<br>• Achieves ≥ 90% reduction of biodegradable constituents<br>• For an ideal site[3], ~90% in 6 months to 1 year<br>• For an average site[4], ~90% in 6 months to 4 years<br>• Longer time required to degrade heavier hydrocarbons |
| **Costs**[5] | • For an ideal site[3], $150,000 to $250,000<br>• For an average site[4], $200,000 to $500,000 |

[1] "Parameters to monitor" are for performance purposes only; compliance monitoring parameters vary by state.
[2] Cleanup standards are determined by the state.
[3] An "ideal site" assumes no delays in corrective action and a relatively homogeneous, permeable subsurface.
[4] An "average site" assumes minimal delays in corrective action and a moderately heterogeneous and permeable surface.
[5] Costs include equipment, and operation and maintenance.

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Solid Waste and Emergency Response 5403W
EPA 510-F-93-019
October 1993

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# Groundwater Remediation For UST Sites

## In Situ Bioventing Combined With Low Flow Air Sparging (Biosparging)

*In situ bioventing combined with low flow air sparging (biosparging) stimulates the aerobic biodegradation of organic contaminants in groundwater by delivering oxygen to the saturated and unsaturated zones. The oxygen is delivered at a slow rate to encourage biodegradation rather than volatilization.*

*Biosparging degrades volatile organic compounds (VOCs) in place, reducing the need for subsequent vapor treatment and the costs of remediation. This technique is most effective in permeable aquifers.*

### Petroleum Types And Constituents

- Fresh or weathered gasoline, diesel, jet fuel, kerosene, motor oil, fuel oil, lubricating oils, and crude oils
- Volatile organic compounds (VOCs) such as benzene, toluene, ethylbenzene, and xylene (BTEX); and residual semivolatile organic compounds (SVOCs) such as polynuclear aromatic hydrocarbons

# In Situ Bioventing Combined With Low Flow Air Sparging (Biosparging)

| | |
|---|---|
| **Advantages** | • Degrades volatile organic compounds (VOCs) in place<br>• Reduces air emissions and subsequent need for vapor treatment |
| **Limitations** | • Effectiveness is limited in low permeability or heterogeneous media<br>• Difficult to control air distribution in groundwater<br>• Limited performance data available |
| **System Components** | • Vertical or horizontal extraction and injection wells<br>• Vacuum pump, compressor, or blower<br>• Aboveground vapor treatment (optional) |
| **Wastestream Treatment** | • Vapor treatment options (might be needed for high concentrations of contaminants):<br>  • *Vapor phase biofilters*<br>  • *Granulated activated carbon*<br>  • *Internal combustion engine*<br>  • *Catalytic oxidation unit*<br>  • *Thermal incinerator* |
| **Parameters to Monitor**[1] | • Vacuum/pressure monitoring at the pump, compressor, blower, and observation points<br>• Airflow rate<br>• Dissolved oxygen<br>• Water levels<br>• Constituent concentrations in groundwater |
| **Cleanup Levels and Timing**[2] | • Generally achieves maximum contaminant levels (MCLs) for volatile constituents<br>• New application; to date, few sites have been fully remediated |
| **Costs**[3] | • Estimates for an ideal site[4], $60,000 to $180,000<br>• Estimates for an average site[5], $120,000 to $200,000<br>• Costs vary depending on vapor treatment costs and treatment time |

[1] "Parameters to monitor" are for performance purposes only; compliance monitoring parameters vary by state.
[2] Cleanup standards are determined by the state.
[3] Costs include equipment, and operation and maintenance.
[4] An "ideal site" assumes no delays in corrective action and a relatively homogenous, permeable subsurface.
[5] An "average site" assumes minimal delays in corrective action and a moderately heterogeneous and permeable subsurface.

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# Groundwater Remediation For UST Sites

## Vacuum Enhanced Pump And Treat

*__Vacuum enhanced pump and treat__ is a technique that uses a surface-mounted vacuum pump to remove contaminated soil vapors and groundwater simultaneously. This method increases the rate of pumping, reducing remediation time. The pumped water and soil vapors can then be treated with a number of techniques.*

*Vacuum enhanced pump and treat is most effective when used in aquifers with medium to low permeability (silts and clays).*

*This method offers pumping rates that are 3 to 10 times greater than conventional pump and treat rates. Increased pumping rates result in decreased remediation time.*

### Petroleum Types And Constituents

- Dissolved gasoline and diesel, jet fuel, and kerosene
- Dissolved constituents such as benzene, toluene, ethylbenzene, and xylene (BTEX)

# Vacuum Enhanced Pump And Treat

| | |
|---|---|
| **Advantages** | • Controls contaminant plume migration and reduces plume concentrations<br>• Increases recovery rate of pumping by 3 to 10 times, reducing remediation time<br>• Effective in aquifers with low permeability<br>• Can remove residuals from dewatered aquifer soils |
| **Limitations** | • Can require treatment of vapors from vacuum pump<br>• Generates larger volume of water for treatment in a shorter time than conventional pump and treat<br>• Requires control of water table fluctuation to minimize smearing contaminants<br>• High iron content/hardness can affect water treatment |
| **System Components** | • Vertical or horizontal extraction wells<br>• Trenches<br>• Vacuum blower or pump<br>• Water pumps<br>• Aboveground air/water treatment systems |
| **Wastestream Treatment** | • Vapor treatment options:<br>  • *Vapor phase biofilter*<br>  • *Granulated activated carbon*<br>  • *Internal combustion engine*<br>  • *Catalytic oxidation unit*<br>  • *Thermal incinerator*<br>• Water treatment options:<br>  • *Air stripping*<br>  • *Granulated activated carbon*<br>  • *Bioreactors* |
| **Parameters to Monitor**[1] | • Vacuum/pressure monitoring at well head, pump, blower<br>• Airflow rate<br>• Water discharge rate<br>• Water levels<br>• Constituent concentrations in groundwater<br>• Influent and effluent concentrations from water treatment system |
| **Cleanup Levels and Timing**[2] | • Might not achieve maximum contaminant levels (MCLs)<br>• For an ideal site[3], 6 months to 1 year<br>• For an average site[4], 6 months to 2 years |
| **Costs**[5] | • For an ideal site[3], $80,000 to $120,000<br>• For an average site[4], $100,000 to $180,000<br>• Higher initial costs than some alternatives, but shorter remediation time might lower total cost |

[1] "Parameters to monitor" are for performance purposes only; compliance monitoring parameters vary by state.
[2] Cleanup standards are determined by the state.
[3] An "ideal site" assumes no delays in corrective action and a relatively homogenous, permeable subsurface.
[4] An "average site" assumes minimal delays in corrective action and a moderately heterogeneous and permeable subsurface.
[5] Costs include equipment, and operation and maintenance.

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# Groundwater Remediation For UST Sites

## Pump And Treat

***Pump and treat** is a technique that brings contaminated groundwater above the ground through the use of extraction wells. The water is then treated, normally using one of three processes: granulated activated carbon, air stripping, or bioremediation.*

*This technique is most effective in permeable aquifers. It also can be used with in situ vapor extraction (SVE) to enhance removal of volatile contaminants from the zone of water table fluctuation.*

*A limitation of pump and treat is that it can take a long time to achieve complete remediation, sometimes as long as seven years even for an ideal site. In addition, this method is subject to fluctuations of the water table that can smear contaminants and complicate cleanups.*

**Petroleum Types And Constituents**

- Dissolved gasoline and diesel, jet fuel, and kerosene
- Dissolved constituents such as benzene, toluene, ethylbenzene, and xylene (BTEX)

## Pump And Treat

| | |
|---|---|
| **Advantages** | • Controls contaminant plume migration and reduces plume concentration |
| **Limitations** | • Not very effective in aquifers with low permeability<br>• Can require expensive and lengthy long-term pumping and treating<br>• High iron content/hardness can affect water treatment<br>• Requires control of water table fluctuation to minimize smearing contaminants<br>• Might require off-site discharge permits |
| **System Components** | • Vertical or horizontal extraction wells<br>• Trenches<br>• Water pumps<br>• Aboveground water handling and/or treatment systems |
| **Wastestream Treatment** | • Wastestream treatment options:<br>  • *Air stripping*<br>  • *Granulated activated carbon*<br>  • *Bioreactors* |
| **Parameters to Monitor**[1] | • Constituent concentrations in groundwater<br>• Influent and effluent concentrations from water treatment system<br>• Water discharge rate<br>• Water levels |
| **Cleanup Levels and Timing**[2] | • Might not meet cleanup standards or maximum contaminant levels (MCLs)<br>• For an ideal site[3], 3 to 7 years<br>• For an average site[4], 3 to 10 years or longer |
| **Costs**[5] | • For an ideal site[3], $150,000 to $200,000<br>• For an average site[4], $250,000 to $300,000 |

[1]"Parameters to monitor" are for performance purposes only; compliance monitoring parameters vary by state.
[2]Cleanup standards are determined by the state.
[3]An "ideal site" assumes no delays in corrective action and a relatively homogenous, permeable subsurface.
[4]An "average site" assumes minimal delays in corrective action and a moderately heterogeneous and permeable subsurface.
[5]Costs include equipment, and operation and maintenance.

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Emergency Response
5403W

October 1993

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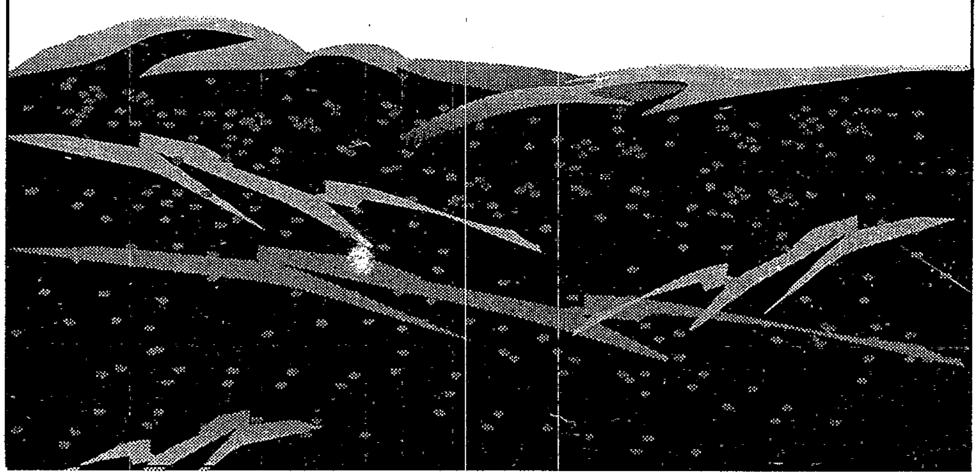
# An Overview Of Underground Storage Tank Remediation Options

## Contents

### Soil Remediation





United States Environmental Protection Agency
Solid Waste and Emergency Response 5403W
EPA 510-F-93-021
October 1993

EPA

# Soil Remediation For UST Sites

## In Situ Soil Vapor Extraction

*In situ soil vapor extraction (SVE) is a technique for removing contaminants from unsaturated soils. The technique draws fresh air into the ground with a vacuum pump. The air brings the contaminants to the surface, where they can be treated and safely discharged.*

*In situ soil vapor extraction is most effective in coarse-grained soils such as sand and gravel. It requires a minimum 5-foot-thick unsaturated zone of soil. This technique can be used in conjunction with air sparging, groundwater pumping, or bioremediation systems.*

*This technique is able to treat large volumes of soil effectively and with minimal disruption to business operations. It also can remove contamination from near or under fixed structures.*

### Petroleum Types And Constituents

- Fresh and weathered gasoline and diesel
- Volatile organic compounds (VOCs) such as benzene, toluene, ethylbenzene, and xylene (BTEX); and semivolatile organic compounds (SVOCs)

# In Situ Soil Vapor Extraction

| | |
|---|---|
| **Advantages** | • Effectively treats large volumes (>1,000 cu yd) of soil<br>• Removes contamination near or under fixed structures<br>• Causes minimal disruption to business operations<br>• Removes volatile contaminants from the zone of water table fluctuation |
| **Limitations** | • Effectiveness limited in heterogeneous soils or soils with high clay or organic content<br>• Airflow may not contact all parts of soil<br>• Leaves residual constituents in soil<br>• Might require air discharge permits |
| **System Components** | • Vertical or horizontal extraction wells<br>• Trenches<br>• Vacuum blower or pump<br>• Injection and passive inlet wells<br>• Aboveground vapor treatment equipment (optional) |
| **Wastestream Treatment** | • Vapor treatment options (if needed):<br>  • *Vapor phase biofilter*<br>  • *Granulated activated carbon*<br>  • *Internal combustion engine*<br>  • *Catalytic oxidation unit*<br>  • *Thermal incinerator* |
| **Parameters to Monitor**[1] | • Vapor concentration<br>• Airflow rate |
| **Cleanup Levels and Timing**[2] | • Can remove 90% of volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs)<br>• For an ideal site[3], 90% in 6 months to 1 year<br>• For an average site[4], 90% in 6 months to 3 years<br>• Longer time required for heterogeneous soils and less volatile constituents |
| **Costs**[5] | • For an ideal site[3], $40,000 to $120,000<br>• For an average site[4], $100,000 to $150,000<br>• Vapor treatment costs can drastically affect total costs |

[1] "Parameters to monitor" are for performance purposes only; compliance monitoring parameters vary by state.
[2] Cleanup standards are determined by the state.
[3] An "ideal site" assumes no delays in corrective action and a relatively homogeneous, permeable subsurface.
[4] An "average site" assumes minimal delays in corrective action and a moderately heterogeneous and permeable subsurface.
[5] Costs include equipment, and operation and maintenance.

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Solid Waste and
Emergency Response
5403W

EPA 510-F-93-022
October 1993

EPA

# Soil Remediation For UST Sites

## In Situ Bioremediation: Bioventing

*In situ bioremediation—bioventing—is a technique for removing biodegradable contaminants from unsaturated soils. The technique injects oxygen into contaminated soil. The oxygen stimulates the aerobic biodegradation of the organic contaminants in the soil. Oxygen is delivered at a low rate to encourage biodegradation rather than volatilization.*

*Bioventing is most effective in coarse-grained soils such as sand and gravel. It requires a minimum 5-foot-thick unsaturated zone. This technique can be used in conjunction with air sparging or groundwater pumping systems.*

*This technique is able to treat large volumes of soil effectively and with minimal disruption to business operations. It also can remove contamination from near or under fixed structures. Bioventing also reduces the need for aboveground treatment because it works to degrade contaminants in place.*

### Petroleum Types And Constituents

- Fresh or weathered gasoline, diesel, jet fuel, kerosene, motor oil, heavy fuel oil, lubricating oils, and crude oils
- Volatile organic compounds (VOCs) such as benzene, toluene, ethylbenzene, and xylene (BTEX); residual semivolatile organic compounds (SVOCs) such as polynuclear aromatic hydrocarbons; and nonvolatile constituents

# In Situ Bioremediation: Bioventing

| | |
|---|---|
| **Advantages** | • Degrades semivolatile organic compounds (SVOCs) and nonvolatile organic compounds<br>• Effectively treats large volumes (>1,000 cu yd) of soil<br>• Causes minimal disruption to business operations<br>• Degrades contaminants near or under fixed structures<br>• Degrades volatile organic compounds (VOCs) in place, which reduces air emissions and subsequent need for treatment |
| **Limitations** | • Targets only biodegradable constituents<br>• Is a relatively slow process<br>• Requires sufficient nutrients, moisture, active indigenous microbial population, and pH of 6-9 to degrade contaminants<br>• Effectiveness limited in heterogeneous soils |
| **System Components** | • Vertical or horizontal extraction wells<br>• Trenches<br>• Vacuum blower or pump<br>• Injection and passive inlet wells<br>• Vapor treatment (optional)<br>• Nutrient delivery equipment (optional) |
| **Wastestream Treatment** | • Vapor treatment options (might be needed for high concentrations of contaminants):<br>  • *Vapor phase biofilter*<br>  • *Granulated activated carbon*<br>  • *Internal combustion engine*<br>  • *Catalytic oxidation unit*<br>  • *Thermal incinerator* |
| **Parameters to Monitor[1]** | • Vapor concentration<br>• Airflow rate<br>• In situ respiration rate (oxygen consumption and carbon dioxide production)<br>• Soil contaminant concentration<br>• Microbial population<br>• Soil pH, moisture, and nutrients |
| **Cleanup Levels and Timing[2]** | • Treats ≥ 90% of biodegradable constituents<br>• For an ideal site[3], ~90% in 1 to 2 years<br>• For an average site[4], ~90% in 1 to 4 years<br>• Longer time required to degrade heavier hydrocarbons |
| **Costs[5]** | • For an ideal site[3], $40,000 to $120,000<br>• For an average site[4], $100,000 to $150,000<br>• Vapor treatment and longer treatment times increase costs |

[1] "Parameters to monitor" are for performance purposes only; compliance monitoring parameters vary by state.
[2] Cleanup standards are determined by the state.
[3] An "ideal site" assumes no delays in corrective action and a relatively homogenous, permeable subsurface.
[4] An "average site" assumes minimal delays in corrective action and a moderately heterogeneous and permeable subsurface.
[5] Costs include equipment, and operation and maintenance.

United States
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Solid Waste and
Emergency Response
5403W

EPA 510-F-93-023
October 1993

EPA

# Soil Remediation For UST Sites

## Ex Situ Bioremediation: Biomounding

*Ex situ **bioremediation—biomounding**—is a technique for removing biodegradable contaminants from excavated mounds of soil. Nutrients are added to the soil mounds, which are often several feet high, to facilitate bioremediation. Aeration conduits and irrigation systems are constructed in the mound.*

*Biomounding is most appropriate for shallow contamination sites that cover a large horizontal area. This is a low-maintenance technique that requires a relatively short treatment time. Biomounding also provides better control over aeration, moisture, nutrient levels, and soil texture than other methods.*

### Petroleum Types And Constituents

- Fresh or weathered gasoline, diesel, jet fuel, kerosene, motor oil, heavy fuel oil, lubricating oils, and crude oils
- Volatile organic compounds (VOCs) such as benzene, toluene, ethylbenzene, and xylene (BTEX); residual semivolatile organic compounds (SVOCs) such as polynuclear aromatic hydrocarbons; and nonvolatile constituents

# Ex Situ Bioremediation: Biomounding

| | |
|---|---|
| **Advantages** | • Degrades semivolatile organic compounds (SVOCs) and nonvolatile organic compounds<br>• Requires low maintenance<br>• Entails a relatively short treatment time<br>• Enhances control and management of aeration, moisture, nutrients, and soil texture<br>• Can use treated soil as backfill |
| **Limitations** | • Targets only biodegradable constituents<br>• Must excavate soil and remove debris<br>• Requires sufficient nutrients, moisture, active indigenous microbial population, and pH of 6-9 to degrade contaminants |
| **System Components** | • Plastic liner<br>• Gravel and slotted pipe to provide air to mound<br>• Nutrients<br>• Blower<br>• Soil vapor sampling probes<br>• Irrigation system (optional)<br>• Plastic cover (optional)<br>• Vapor treatment equipment (optional) |
| **Wastestream Treatment** | • Vapor treatment options (might be needed for high concentrations of contaminants):<br>  • *Granulated activated carbon*<br>  • *Internal combustion engine*<br>  • *Catalytic oxidation unit*<br>  • *Thermal incinerator* |
| **Parameters to Monitor**[1] | • Vapor concentration<br>• Airflow rate<br>• Soil contaminant concentration<br>• Microbial population<br>• Soil pH, moisture, and nutrients<br>• Leachate analysis (optional) |
| **Cleanup Levels and Timing**[2] | • Treats ≥ 90% of biodegradable constituents<br>• For an ideal site[3], ~90% in 6 months to 18 months<br>• For an average site[4], ~90% in 6 months to 2 years<br>• Longer time required to degrade heavier hydrocarbons |
| **Costs**[5] | • For an average site[4], $80,000 to $125,000 ($80 to $125/cu yd)<br>• Unit costs generally decrease as soil volume increases |

[1]"Parameters to monitor" are for performance purposes only; compliance monitoring parameters vary by state.
[2]Cleanup standards are determined by the state.
[3]An "ideal site" assumes no delays in corrective action and a relatively homogeneous, permeable subsurface.
[4]An "average site" assumes minimal delays in corrective action and a moderately heterogeneous and permeable subsurface.
[5]Costs include equipment, and operation and maintenance.

United States Environmental Protection Agency
Solid Waste and Emergency Response 5403W
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October 1993

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# Soil Remediation For UST Sites

## On-Site Low Temperature Thermal Desorption

**Low temperature thermal desorption** *is a technique for removing contaminants from large volumes (greater than 1,000 cubic yards) of soil. The technique heats contaminated soil to relatively low temperatures (200-1,000°F). The heat causes contaminants to vaporize so that they can be treated with air emissions treatment systems.*

*On-site thermal treatment is most effective on soil that contains high levels of hydrocarbons. It requires less time than bioremediation or soil vapor extraction (SVE). On-site thermal treatment can be implemented rapidly and works quickly—within six to eight weeks—at a relatively low cost.*

### Petroleum Types And Constituents

- All types of petroleum products

## On-Site Low Temperature Thermal Desorption

| | |
|---|---|
| **Advantages** | • Rapid to implement<br>• Minimizes long-term liability<br>• Can reuse some types of soil for backfill |
| **Limitations** | • Expensive for soil with high moisture or clay content<br>• Might require air discharge permits |
| **System Components** | • Excavation equipment<br>• Sorting and sizing equipment<br>• Rotary kiln<br>• Offgas treatment equipment |
| **Wastestream Treatment** | • Air emissions equipment |
| **Parameters to Monitor[1]** | • Contaminant concentrations in pre- and post-treatment soil |
| **Cleanup Levels and Timing[2]** | • Can excavate to cleanup standards<br>• >99% removal efficiency<br>• Typically completed in 6 to 8 weeks |
| **Costs[3]** | • For an average site[4], $60,000 to $100,000 ($60 to $100/cu yd) |

[1] "Parameters to monitor" are for performance purposes only; compliance monitoring parameters vary by state.
[2] Cleanup standards are determined by the state.
[3] Costs include equipment, and operation and maintenance.
[4] An "average site" assumes minimal delays in corrective action and a moderately heterogeneous and permeable subsurface.

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5403W

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October 1993

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# Soil Remediation For UST Sites

## Ex Situ Bioremediation: Land Farming

***Ex situ bioremediation—land farming (or land treatment)***—*is a technique for removing biodegradable contaminants from excavated soil. The excavated soil and added nutrients are spread over a lined treatment area. The area is periodically tilled to facilitate the natural release of volatile organic compounds (VOCs) and the biodegradation of contaminants.*

*Land farming is effective on many soil types and a variety of contaminants. It is also easy and inexpensive to design, operate, and maintain.*

### Petroleum Types And Constituents

- Fresh or weathered gasoline, diesel, jet fuel, kerosene, motor oil, heavy fuel oil, lubricating oils, and crude oils
- Volatile organic compounds (VOCs) such as benzene, toluene, ethylbenzene, and xylene (BTEX); residual semivolatile organic compounds (SVOCs) such as polynuclear aromatic hydrocarbons; and nonvolatile constituents

| Ex Situ Bioremediation: Land Farming | |
|---|---|
| **Advantages** | • Simple and inexpensive to design, operate, and maintain<br>• Effective on many soil types with a variety of contaminants |
| **Limitations** | • Targets only biodegradable constituents<br>• Requires substantial space |
| **System Components** | • Nutrients (fertilizer)<br>• Lined treatment cell with berms around the perimeter<br>• Tilling equipment<br>• Lime (needed for low pH)<br>• Irrigation equipment (optional) |
| **Wastestream Treatment** | • Might need to treat or dispose of collected rainwater or leachate |
| **Parameters to Monitor[1]** | • Soil contaminant concentration<br>• Microbial population in soil<br>• Soil pH, moisture, and nutrients<br>• Leachate analysis (optional) |
| **Cleanup Levels and Timing[2]** | • Treats ≥ 90% of biodegradable constituents<br>• For an ideal site[3], ~90% in 6 months to 2 years<br>• For an average site[4], ~90% in 6 months to 3 years<br>• Longer time required to degrade heavier hydrocarbons |
| **Costs[5]** | • For an average site[4], \$20,000 to \$70,000 (\$20 to \$70/cu yd)<br>• Costs vary with the amount of soil to be treated and the design of the containment cell |

[1] "Parameters to monitor" are for performance purposes only; compliance monitoring parameters vary by state.
[2] Cleanup levels are determined by the state.
[3] An "ideal site" assumes no delays in corrective action and a relatively homogeneous, permeable subsurface.
[4] An "average site" assumes minimal delays in corrective action and a moderately heterogeneous and permeable subsurface.
[5] Costs include equipment, and operation and maintenance.

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# Soil Remediation For UST Sites

## In Situ Passive Biodegradation (Natural Attenuation)

***In situ passive biodegradation (natural attenuation)** is an approach for removing biodegradable contaminants from soil. This method of remediation relies on microorganisms to break down petroleum products in the soil. It does not require the addition of oxygen or nutrients to facilitate the process.*

*In situ passive biodegradation is extremely slow. It is most appropriate when expedient remediation is not needed and nearby receptors will not be affected by contaminated soil. To date, few sites have been fully remediated using this approach.*

*This technique offers low cost and minimal disruption to business operations. In addition, this method generates no wastestreams.*

### Petroleum Types And Constituents

- Fresh or weathered gasoline, diesel, jet fuel, kerosene
- Volatile organic compounds (VOCs) such as benzene, toluene, ethylbenzene, and xylene (BTEX); residual semivolatile organic compounds (SVOCs) such as polynuclear aromatic hydrocarbons; and nonvolatile constituents

| In Situ Passive Biodegradation (Natural Attenuation) | |
|---|---|
| **Advantages** | • Costs substantially less than other methods<br>• Eventually degrades volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and nonvolatile organic compounds<br>• Causes minimal disruption to business operations<br>• Generates no wastestreams<br>• Reduces potential for human contact with contaminated soil or soil vapor |
| **Limitations** | • Targets only biodegradable constituents<br>• Is an extremely slow process<br>• Requires sufficient nutrients, moisture, active indigenous microbial population, and pH of 6-9 to degrade contaminants<br>• To date, few sites have been fully remediated |
| **System Components** | • Monitoring wells<br>• Soil borings<br>• Soil vapor probes |
| **Wastestream Treatment** | • None |
| **Parameters to Monitor**[1] | • Soil and groundwater contaminant concentrations<br>• Oxygen and carbon dioxide |
| **Cleanup Levels and Timing**[2] | • Can achieve risk-based cleanup levels<br>• Computer models project average remediation times of 50 to 200 years<br>• Longer time required to degrade heavier hydrocarbons |
| **Costs**[3] | • Costs vary depending on monitoring frequency and risk assessments<br>• Average risk assessment costs: $10,000 to $50,000<br>• Average monitoring and reporting costs: $10,000 to $60,000 |

[1] "Parameters to monitor" are for performance purposes only; compliance monitoring parameters vary by state.
[2] Cleanup standards are determined by the state.
[3] Costs include equipment, and operation and maintenance.

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# Soil Remediation For UST Sites

## Excavation And Off-Site Treatment

***Excavation and off-site treatment** is a method for removing contaminants from small volumes (less than 1,000 cubic yards) of soil that cannot be treated effectively on site. Contaminated soil is excavated and then treated. Typical treatment facilities include:*

- *Low temperature thermal desorption facilities*
- *Asphalt plants*
- *Incinerators*

*This technique can be used with many different kinds of soils and contaminants. It offers the benefit of actually destroying contaminants rather than simply moving them from one location to another.*

### Petroleum Types And Constituents

- All types of petroleum products

# Excavation And Off-Site Treatment

| | |
|---|---|
| **Advantages** | • Easy and rapid to implement<br>• Destroys contaminants<br>• Minimizes long-term liability<br>• Can reuse some types of soil for backfill<br>• Effective on soils with varying concentrations and constituents |
| **Limitations** | • Expensive for large volumes of soil with low contaminant concentrations, high moisture, or clay content<br>• Transportation costs can be high |
| **System Components** | • System components can include:<br>  • *Excavation equipment*<br>  • *Trucking equipment*<br>  • *Equipment for sorting and sizing*<br>  • *Rotary dryer or kiln*<br>  • *Thermal screw*<br>  • *Offgas treatment equipment* |
| **Wastestream Treatment** | • Air emissions equipment |
| **Parameters to Monitor[1]** | • Contaminant concentrations in pre- and post-treatment soil |
| **Cleanup Levels and Timing[2]** | • Can excavate to cleanup standards<br>• >99% removal efficiency<br>• Typically completed in 1 to 3 days |
| **Costs[3]** | • For an average site[4], $70,000 to $180,000 ($70 to $180/cu yd) |

[1]"Parameters to monitor" are for performance purposes only; compliance monitoring parameters vary by state.
[2]Cleanup standards are determined by the state.
[3]Costs include equipment, and operation and maintenance.
[4]An "average site" assumes minimal delays in corrective action and a moderately heterogeneous and permeable subsurface.

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# Soil Remediation For UST Sites

## Excavation With Off-Site Landfill Disposal

*__Excavation with off-site landfill disposal__ involves removing small volumes (less than 1,000 cubic yards) of soil with high concentrations of contaminants. Contaminated soil is excavated and trucked to a landfill for disposal.*

*A limitation of this method is that it simply moves contaminants to a landfill without treating or destroying them. The technique also is subject to extensive land disposal restrictions, which can vary between states and counties. It is also subject to constraints in landfill capacity.*

**Petroleum Types And Constituents**

- All types of petroleum products

| Excavation With Off-Site Landfill Disposal | |
|---|---|
| **Advantages** | • Easy and rapid to implement for small volumes of soil |
| **Limitations** | • Simply moves contaminants; does not treat<br>• Not cost-effective for large soil volumes or soil with low contaminant concentrations<br>• Cannot remove soil from under buildings or structures<br>• Might need to meet landfill acceptance criteria or address landfill capacity constraints<br>• Can pose long-term liability |
| **System Components** | • Excavation equipment<br>• Trucking equipment |
| **Wastestream Treatment** | • Land disposal restrictions in some states/counties |
| **Parameters to Monitor[1]** | • Confirmatory soil sampling after excavation |
| **Cleanup Levels and Timing[2]** | • Can excavate to cleanup standards<br>• Concentrations will persist in landfill<br>• Typically completed in 1 to 3 days |
| **Costs[3]** | • For an average site[4], $45,000 to $200,000 ($45 to $200/cu yd) |

[1]"Parameters to monitor" are for performance purposes only; compliance monitoring parameters vary by state.
[2]Cleanup standards are determined by the state.
[3]Costs include equipment, and operation and maintenance.
[4]An "average site" assumes minimal delays in corrective action and a moderately heterogeneous, permeable subsurface.