Cleanup Methods for Contaminated Soils and Groundwater

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A Citizen's Guide to Activated Carbon Treatment

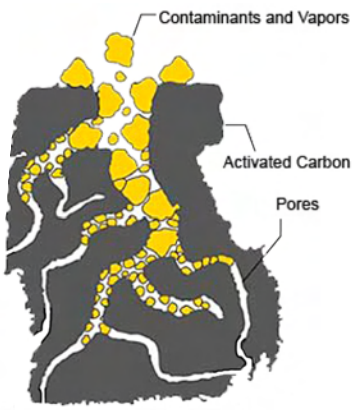
What Is Activated Carbon Treatment?

Activated carbon is a material used to filter harmful chemicals from contaminated water and air. It is composed of black granules of coal, wood, nutshells or other carbon-rich materials. As contaminated water or air flows through activated carbon, the contaminants sorb (stick) to the surface of the granules and are removed from the water or air. Granular activated carbon or "GAC" can treat a wide range of contaminant vapors including radon and contaminants dissolved in groundwater, such as fuel oil, solvents, polychlorinated biphenyls (PCBs), dioxins, and other industrial chemicals, as well as radon and other radioactive materials. It even removes low levels of some types of metals from groundwater.

How Does It Work?

Activated carbon treatment generally consists of one or more columns or tanks filled with GAC. Contaminated water or vapors are usually pumped through a column from the top down, but upward flow is possible. As the contaminated water or air flows through the GAC, the contaminants sorb to the outer and inner surfaces of the granules. The water and air exiting the container will be cleaner. Regular testing of exiting water or air is conducted to check contaminant levels. If testing shows that some contaminants remain, the water or air may need to be treated again to meet the treatment levels.

Activated carbon granules



Contaminants and vapors sorbed to activated carbon

The GAC will need to be replaced when the available surfaces on the granules are taken up by contaminants and additional contaminants can no longer sorb to them. The "spent" GAC may be replaced with fresh GAC or "regenerated" to remove the sorbed contaminants. To regenerate spent GAC, it is usually sent to an offsite facility where it is heated to very high temperatures to destroy the contaminants. If a lot of GAC needs to be regenerated, equipment to heat the GAC and remove the sorbed contaminants can be brought to the site.

Depending on the site, treated groundwater may be pumped into a nearby stream or river or back underground through injection wells or trenches. At some sites, a sprinkler system can distribute the water over the ground surface so that it seeps into soil. The water also may be discharged to the public sewer system for further treatment at a sewage treatment plant.

How Long Will It Take?

It only takes a few minutes for water or vapors to pass through an activated carbon filter. However, the time it takes to clean up a site with activated carbon treatment will depend on how long it takes to bring all the contaminated groundwater or contaminant vapors to the ground surface for treatment. This can take several months to many years. Treatment may take longer where:

- Contaminant concentrations are high or the source of dissolved contaminants has not been completely removed.
- The volume of contaminated groundwater or vapors is large.
- Treatment of groundwater or vapors involves several other cleanup methods.

These factors vary from site to site.

Is Activated Carbon Treatment Safe?

Activated carbon treatment is safe to use. Treated water is sampled and analyzed regularly to ensure that the carbon continues to adequately sorb contaminants. If concentrations start to increase in the treated water, the carbon is reactivated or replaced. The tanks are cleaned or replaced with care to avoid releasing contaminants. Larger filters are often preferred because they do not have to be replaced as often as small ones. When treatment is complete, the used carbon may contain hazardous contaminants that require special handling and disposal at a hazardous waste facility.

How Might It Affect Me?

Activated carbon treatment generally will not disrupt the surrounding community. Initial construction of systems to extract groundwater or contaminant vapors from the ground may involve the use of heavy equipment. This may cause a temporary increase truck traffic in the neighborhood as equipment is brought to the site or when carbon tanks are exchanged. However, the treatment system itself is not particularly noisy while running. Depending on the amount of groundwater or vapors that need to be treated, tanks of activated carbon can range in size from a 55-gallon drum to a tank that is 20 feet tall and 10 feet or more in diameter.

Why Use Activated Carbon Treatment?

Activated carbon is the most commonly used approach to treating groundwater in "pump and treat" systems (See *A Citizen's Guide to Pump and Treat* [EPA 542-F-12-017]). It is also used to treat contaminant vapors removed from contaminated soil and groundwater by soil vapor extraction and other cleanup methods. (See *A Citizen's Guide to Soil Vapor Extraction* [EPA 542-F-12-018].) Activated carbon units can be brought to the site and set up relatively quickly.

Large groundwater treatment system with five tanks of activated carbon.

Small groundwater treatment system with two tanks of activated carbon.

Example

Disposal of chemical wastes at the Conservation Chemical Company Superfund site in Missouri contaminated the soil and groundwater with solvents, waste oil, PCBs, and pesticides. A pump and treat system began operating in 1991 to keep the contaminated groundwater from moving offsite. The pumped water is being treated with a series of cleanup methods. One of the last treatment steps is the use of two columns of activated carbon to remove any remaining contaminants.

Water exiting the activated carbon columns is sampled weekly for metals and quarterly for PCBs, pesticides, and other contaminants to ensure the system is working. The columns are refilled with reactivated carbon when they can no longer remove contaminants adequately. The system uses about 240,000 pounds of activated carbon each year. Sampling of groundwater continues to show that the system is protecting human health and the environment, and the treated water is discharged to the nearby Missouri River.

For More Information

For more information on this and other technologies in the Citizen's Guide Series, contact:

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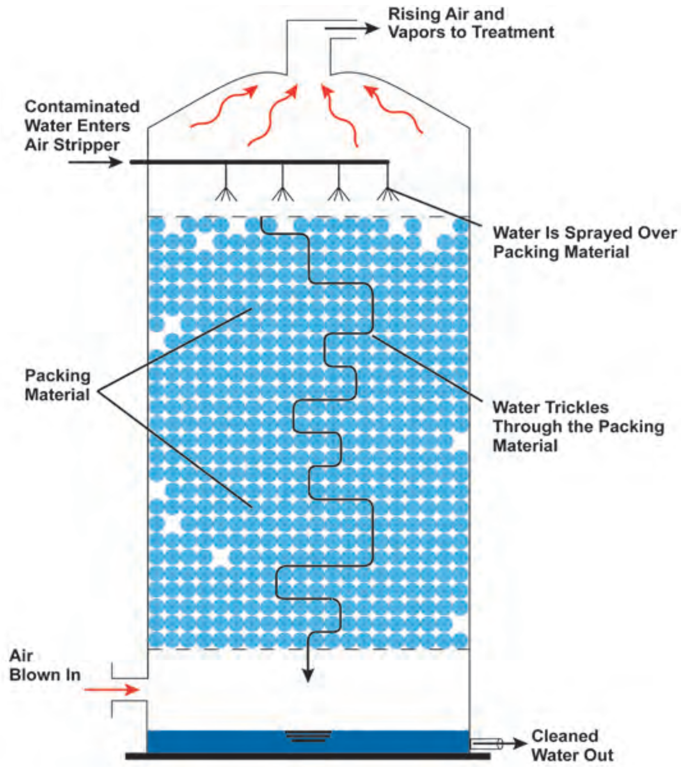
A Citizen's Guide to Air Stripping

What Is Air Stripping?

Air stripping is the process of moving air through contaminated groundwater or surface water in an above-ground treatment system. Air stripping removes chemicals called "volatile organic compounds" or "VOCs." VOCs are chemicals that easily evaporate, which means they can change from a liquid to a vapor (a gas). The air passing through contaminated water helps evaporate VOCs faster. After treating the water, the air and chemical vapors are collected, and the vapors are either removed or vented outside if VOC levels are low enough. Air stripping is commonly used to treat groundwater as part of the "pump and treat" cleanup method. (See *A Citizen's Guide to Pump and Treat* [EPA 542-12-017].)

How Does It Work?

Air stripping uses either an air stripper or aeration tank to force air through contaminated water and evaporate VOCs. The most common type of air stripper is a packed-column air stripper, which is a tall tank filled with pieces of plastic, steel, or ceramic packing material.



Packed-Column Air Stripper

Contaminated water is pumped above ground and into the top of the tank and sprayed over the top of the packing material. The water trickles downward through the spaces between the packing material, forming a thin film of water that increases its exposure to air blown in at the bottom of the tank. A sieve-tray air stripper is similar in design but contains several trays with small holes. As water flows across the trays, a fan at the bottom blows air upwards through the holes, increasing air exposure. Aeration tanks are another type of design that remove VOCs by bubbling air into a tank of contaminated water.

Rising air and vapors accumulate at the top of the air stripper or aeration tank where they are collected for release or treatment. Treated water flows to the bottom, where it is collected and tested to make sure it meets cleanup requirements. The water may be further treated, if necessary, to achieve required levels. Clean water may be pumped back underground, into local surface waters, or to the municipal wastewater treatment plant.

Aeration tanks are typically shorter than packed-column or sieve-tray air strippers. The size and type of air stripper used will depend on the types and amounts of contaminants as well as the quantity of water requiring treatment.

How Long Will It Take?

The flow of water through an air stripper or aeration tank may take only a few minutes, depending on the size of the device and the rate of water flow through it. However, cleanup of all the contaminated water at a site can take several months to years. The actual cleanup time will depend on several factors. For example, it will take longer where:

- Contaminant concentrations are high or the source of dissolved contaminants has not been completely removed.
- The amount of water requiring treatment is large.
- Groundwater cannot be pumped at a fast rate.
- Buildup of mineral deposits or algae on the packing material require frequent removal.

These factors vary from site to site.

Is Air Stripping Safe?

Air stripping is generally considered to be safe to use. Air strippers may be brought to the site so that contaminated water does not have to be transported to a cleanup facility. Contaminated water is contained throughout cleanup so that there is little chance for people to come into contact with it. The treated water usually may be returned to the groundwater or discharged to surface water. The chemical vapors produced by air stripping are treated, if necessary, to ensure unsafe levels of vapors are not released.

How Might It Affect Me?

Installation of the air stripper and treatment equipment may require use of heavy machinery, especially at large contaminated sites. Area neighborhoods may experience some increased truck traffic as the equipment is delivered. Large tanks or columns may be visible from the street and may need to operate for many years. However, care is taken to make sure the operation of air strippers is as quiet as possible.

Air stripper and treatment building

Why Use Air Stripping?

Air stripping is an effective way of removing VOCs from contaminated water and is commonly used as part of groundwater pump and treat systems at sites around the country. Air strippers can be brought to the site eliminating the need to pump contaminated water for offsite treatment.

Sample plastic packing material. (Photo from Mass Transfer, Ltd.)

Example

Air stripping is part of the treatment for four groundwater pump and treat systems operating at the North Indian Bend Wash Superfund site in Arizona. Groundwater at the site is contaminated with an industrial solvent called trichloroethene (TCE) and other VOCs. Contamination extends over an area of about 8 square miles and to depths over 100 feet.

The first pump and treat system began operating in 1994. The others were added later to improve cleanup. The packed-column air strippers remove VOC vapors, which are then treated with activated carbon and another method called "ultraviolet oxidation." Cleaned water is discharged to an area irrigation network and reservoir. As of 2011, over 40,000 pounds of TCE had been removed, and cleanup of some areas was nearly complete. The systems are expected to operate for another 40 to 70 years to clean up the entire site.

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A Citizen's Guide to Bioremediation

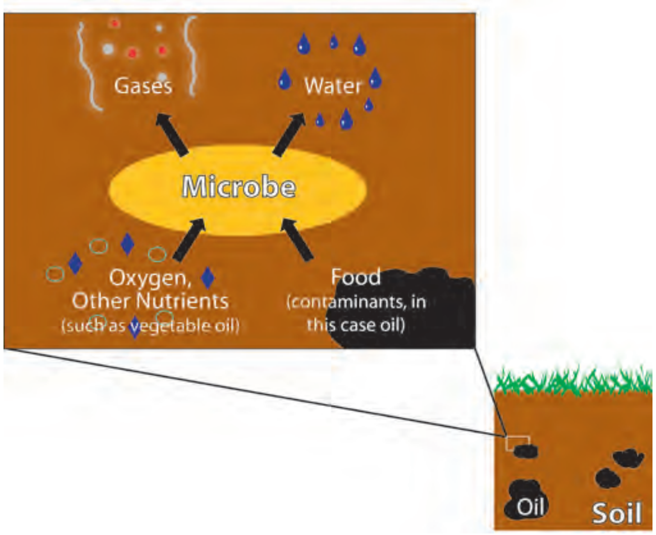
What Is Bioremediation?

Bioremediation is the use of microbes to clean up contaminated soil and groundwater. Microbes are very small organisms, such as bacteria, that live naturally in the environment. Bioremediation stimulates the growth of certain microbes that use contaminants as a source of food and energy. Contaminants treated using bioremediation include oil and other petroleum products, solvents, and pesticides.

How Does It Work?

Some types of microbes eat and digest contaminants, usually changing them into small amounts of water and harmless gases like carbon dioxide and ethene. If soil and groundwater do not have enough of the right microbes, they can be added in a process called "bioaugmentation."

For bioremediation to be effective, the right temperature, nutrients, and food also must be present. Proper conditions allow the right microbes to grow and multiply—and eat more contaminants. If conditions are not right, microbes grow too slowly or die, and contaminants are not cleaned up. Conditions may be improved by adding "amendments." Amendments range from household items like molasses and vegetable oil, to air and chemicals that produce oxygen. Amendments are often pumped underground through wells to treat soil and groundwater in situ (in place).



Microbe takes in oil, oxygen, and nutrients and releases gases and water.

The conditions necessary for bioremediation in soil cannot always be achieved in situ, however. At some sites, the climate may be too cold for microbes to be active, or the soil might be too dense to allow amendments to spread evenly underground. At such sites, EPA might dig up the soil to clean it "ex situ" (above ground) on a pad or in tanks. The soil may then be heated, stirred, or mixed with amendments to improve conditions.

Sometimes mixing soil can cause contaminants to evaporate before the microbes can eat them. To prevent the vapors from contaminating the air, the soil can be mixed inside a special tank or building where vapors from chemicals that evaporate may be collected and treated.

Is Oxygen Always Needed?

Some contaminants can only be bioremediated in an aerobic environment—one that contains oxygen. Others can only be bioremediated in an anaerobic environment without oxygen. Anaerobic microbes do not need oxygen to grow.

To clean up contaminated groundwater in situ, wells are drilled to pump some of the groundwater into above ground tanks. Here, the water is mixed with amendments before it is pumped back into the ground. The groundwater enriched with amendments allows microbes to bioremediate the rest of the contaminated groundwater underground. Groundwater also can be pumped into a "bioreactor" for ex situ treatment. Bioreactors are tanks in which groundwater is mixed with microbes and amendments for treatment. Depending on the site, the treated water may be pumped back to the ground or discharged to surface water or to a municipal wastewater system.

How Long Will It Take?

It may take a few months or even several years for microbes to clean up a site, depending on several factors. For example, bioremediation will take longer where:

- Contaminant concentrations are high, or contaminants are trapped in hard-to-reach areas, like rock fractures and dense soil.
- The contaminated area is large or deep.

- Conditions such as temperature, nutrients, and microbe population must be modified.
- Cleanup occurs ex situ.

Is Bioremediation Safe?

Bioremediation relies on microbes that live naturally in soil and groundwater. These microbes pose no threat to people at the site or in the community. Microbes added to the site for bioaugmentation typically die off once contamination and the conditions needed for bioremediation are gone. The chemicals added to stimulate bioremediation are safe. For example, the nutrients added to make microbes grow are commonly used on lawns and gardens, and only enough nutrients to promote bioremediation are added. To ensure that the treatment is working and to measure progress, samples of soil and groundwater are tested regularly.

How Might It Affect Me?

Bioremediation often occurs underground and does not cause much disruption to the site or surrounding community. Contaminated soil and groundwater stay onsite, reducing truck traffic, compared with some other cleanup methods. However, area residents and businesses may hear the operation of pumps, mixers, and other construction equipment used to add amendments or improve site conditions to begin the bioremediation process. Excavation and pumping also will occur for ex situ bioremediation. (See a *Citizen's Guide to Excavation of Contaminated Soil* [EPA 542-F-12-007].)

Why Use Bioremediation?

Bioremediation has the advantage of using natural processes to clean up sites. Because it may not require as much equipment, labor, or energy as some cleanup methods, it can be cheaper. Another advantage is that contaminated soil and groundwater are treated onsite without having to dig, pump, and transport them elsewhere for treatment. Because microbes change the harmful chemicals into small amounts of water and gases, few if any waste byproducts are created.

Bioremediation has successfully cleaned up many polluted sites and has been selected or is being used at over 100 Superfund sites across the country.

Injection of vegetable oil underground to improve conditions for bioremediation.

Example

Bioremediation is cleaning up groundwater contaminated with dry cleaning solvent at the Iceland Coin Laundry Superfund site in New Jersey. To improve the conditions at the site for bioremediation, amendments were added. A solution of vegetable oil and baking soda was injected into the groundwater in an area of particularly high contaminant concentrations. Bacteria also were added to increase the existing population of microbes. The treatment area is about 1800 feet long, 500 feet wide and extends 40 feet below ground.

Preliminary testing of the groundwater has shown that bioremediation is working and contaminant concentrations are decreasing. The objective is to continue to reduce the concentration of contaminants from 10 or more parts per billion to less than 1 part per billion.

For More Information

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A Citizen's Guide to Capping

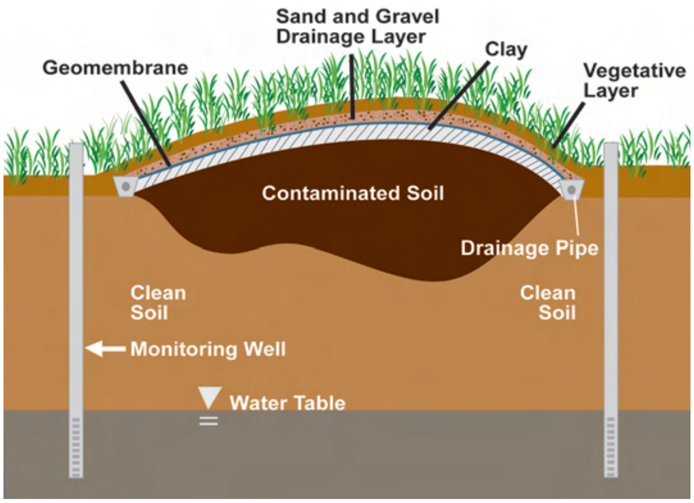
What Is Capping?

Capping involves placing a cover over contaminated material such as landfill waste or contaminated soil. Such covers are called "caps." Caps do not destroy or remove contaminants. Instead, they isolate them and keep them in place to avoid the spread of contamination. Caps prevent people and wildlife from coming in contact with contaminants.

How Does It Work?

A cap isolates and prevents the spread of contamination in several ways. For example, it can:

- Stop rain and snowmelt from seeping through the material and carrying contaminants to the groundwater.
- Keep storm water runoff from carrying contaminated material offsite or into lakes and streams.
- Prevent wind from blowing contaminated material offsite.
- Control releases of gas from wastes containing or producing "volatile" chemicals (those that evaporate).
- Keep people and wildlife from coming into contact with the hazardous material and tracking contaminants offsite.



Example of a cover with several layers.

The cap design selected for a site will depend on several factors, including the types and concentrations of contaminants present, the size of the site, the amount of rainfall the area receives, and the future use of the property. Construction of a cap can be as simple as placing a single layer of a material over lightly contaminated soil to placing several layers of different materials to isolate more highly contaminated wastes. For example, an asphalt cap might be selected to cover low levels of soil contamination on a property whose future reuse requires a parking lot. A cap for a hazardous waste landfill, however, might require several layers, including a vegetative layer, drainage layer, geomembrane, and clay layer. The following are some of the options for caps:

- **Asphalt or concrete:** A layer of these materials can serve as a parking lot or building slab foundation.
- **Vegetative layer:** A top layer of soil planted with grass or other vegetation can help prevent soil erosion and make the area look more natural and attractive. An evapotranspiration or "ET" cover is a vegetative cap in which the plants and underlying soil keep rain and snowmelt from soaking down into the contaminated area. (For more information, please see *A Citizen's Guide to Evapotranspiration Covers* [EPA 542-F-12-006.)
- **Drainage layer:** A layer of sand and gravel, often containing rows of slotted pipes, is built to collect and drain any water that makes it through the top layers of a cap.
- **Geomembrane:** A sheet of strong plastic-like material is used to prevent downward drainage of water and upward escape of gases.
- **Clay:** A layer of compacted clay also can help prevent the downward drainage of water.

Some landfill covers, such as those for municipal landfills, may also include collection and venting systems for methane and other gases that could build up underground.

How Long Will It Take?

Building a cap can take a few days up to several months. Construction may take longer when:

- The contaminated area is large.
- The design of the cap is thick or complex.
- Supplies of clean topsoil, clay, or other cap materials are not available locally.

Caps can be effective for many years when they are properly maintained. They are maintained for as long as the contaminated materials remain in place.

Is Capping Safe?

When properly built and maintained, a cap can safely keep contaminated material in place. A cap will continue to isolate contamination as long as it does not erode or develop cracks or holes that allow water to reach the contaminated material. Regular inspections are made to make sure that the weather, plant roots, and human activity have not damaged the cap and that plants on vegetative caps are still growing. Also, groundwater monitoring wells are placed around the capped area and sampled to help determine if leaks occur.

How Might It Affect Me?

Residents and businesses close to a site may see increased truck traffic as cap materials are brought to the site. Construction of the cap may involve bulldozers, backhoes, and other noisy equipment, and some soil may need to be excavated for use in the cap. Dust from excavation and construction can be controlled by spraying water or covering stockpiled materials with tarps.

Why Use Capping?

Capping is the traditional method for isolating landfill wastes and contaminants. It sometimes is used to address large volumes of soil or waste with low-levels of contamination. Caps made of asphalt or concrete, or even a layer of soil planted with grass, can allow some sites to be reused. Caps have been selected for use at many Superfund sites across the country.

Spring grasses grow on the cap of a hazardous waste landfill.

Example

Capping is one of several methods being used to protect people and the environment from contamination at the Roebling Steel Superfund site in New Jersey. Drums and other wastes were removed from one 5-acre area of the site. Two areas of soil that remained contained metals and other contaminants from steel manufacturing. In 2005, this soil was covered with two types of caps: asphalt and clean soil planted with grass. The purpose of these caps was to avoid the spread of contaminants and to prevent people from coming into contact with contaminated soil.

The caps also were designed with the future use of the site in mind. A station for New Jersey's light rail system was constructed on the property, and the asphalt cap serves as its parking lot. The grassy landscaping surrounds the remainder of the property. A plan is in place for the long-term maintenance and monitoring of the caps to ensure that they remain protective. Future excavation through the soil cap is not permitted.

For More Information

For more information on this and other technologies in the Citizen's Guide Series, contact:

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A Citizen's Guide to Ecological Revitalization

What Is Ecological Revitalization?

Ecological revitalization is the process of returning a contaminated site to a natural environment, similar to the one that existed before the property was developed. The development of a property for industrial, commercial, and other uses can displace the plants and animals living there and disrupt the ecology (the ways these organisms interact with each other and their environment). Returning a meadow, forest, or wetlands to the property can restore the habitats and other natural characteristics of the area. This process can "revitalize" or give new life to a community with the creation of a new park, natural recreational area, or nature preserve.

How Does It Work?

Returning a site to a natural environment will involve different approaches, depending on the property and how it was altered during development and use. Ecological revitalization first requires an understanding of the plant and animal species, soil types, weather, and other characteristics of the site, both past and present. This may involve looking at old photographs and maps of the site, visiting nearby natural areas, and talking to local residents to get a better idea of what needs to be done. Ecological revitalization is most successful when considered during site cleanup. Common steps include:

- Demolition of buildings and other infrastructure.
- Regrading the ground surface to remove or create slopes.

- Bringing in fertile soil or adding nutrients and other natural materials, also known as "amendments," to existing soil to help plants grow.
- Creating or restoring wetlands and natural stream channels.
- Planting native trees, grasses, and other vegetation.
- Reestablishing wildlife.

The links between soil, plants, and wildlife, including birds, insects, and even microscopic organisms are an important part of ecological revitalization. For example, many native flowering plants in the United States rely on bees, bats, hummingbirds or other "pollinators" that feed on nectar to help them reproduce and spread.

The purpose of ecological revitalization is to provide an environment where both plants and animals can thrive.

Is Ecological Revitalization Safe?

When properly planned and managed, ecological revitalization is very safe. If there is any chance that contaminated soil or groundwater will remain at the site, EPA will combine revitalization with cleanup methods that isolate contaminants from people, plants, and wildlife. For instance a protective cap may be placed over contaminated soil or a vertical engineered barrier may be placed around the contaminated soil or groundwater. (See *A Citizen's Guide to Capping* [EPA 542-F-12-004] and *A Citizen's Guide to Vertical Engineered Barriers* [EPA 542-F-12-022].) Revitalization also can be conducted with methods that continue to actively clean up contamination.

How Long Will It Take?

An ecological revitalization project may take anywhere from a few months to several years. The time it takes to reestablish natural habitat will depend on several factors. For example, it may take longer where:

- Plants have a long life cycle and take longer to reach maturity.
- Unfavorable weather for seed germination or plant growth (such as drought) occurs.

- Plants that are eaten by animals or insects must be replaced.
- Stream channels must be restored or must be stabilized to prevent severe erosion, or if habitats, such as wetlands, need to be built from scratch.
- Soil conditions such as temperature, nutrient levels, and microorganism populations must be modified.

These factors vary from site to site.

How Might It Affect Me?

Generally, ecological revitalization does not cause much disruption to the surrounding community. Initial work may involve grading or tilling the soil with earth-moving equipment. Residents and businesses near the site may hear equipment noise or detect odor if the soil is mixed with natural amendments, such as compost, manure, and yard/wood waste. Airborne dust can be controlled by watering down the soil.

Why Use Ecological Revitalization?

Ecological revitalization is usually used with soil and groundwater cleanup methods to improve the condition of a contaminated site. It is most successful when the process starts during site cleanup. Ecological revitalization is often conducted to reclaim lost land and transform an eyesore into an attractive environmental resource for the community. It can help isolate or remove contamination from people and wildlife and can also reduce soil erosion. Revitalized sites help create wildlife habitats, improve air and water quality, and provide added green space for parks, recreation, and nature preserves. Returning contaminated sites to beneficial use can lead to increased property values, recreational centers, and protected open space in what are often densely developed areas.

Superfund site before and after ecological revitalization.

Example

Not long ago, the Army Creek Landfill in Delaware, was filled to capacity with tons of trash that contaminated nearby Army Creek and local water supply wells. After the site was cleaned up and a protective cap built over the remaining lightly contaminated soil, EPA planted grasses, wild flowers, and other native plants to provide resting and feeding habitats for migrating birds. Bird boxes were installed along the creek to encourage nesting, and gooseberry was planted as a food source.

The site is mowed once a year during the fall so that bird habitats are not disturbed during nesting season. The tall grass throughout the spring and summer provides shelter for birds and other small animals as well as seeds and an attractive habitat for insects, another source of food for birds. EPA also built wetlands to provide habitat for many species of plants, animals, and birds. Ecological revitalization transformed the site into a vibrant wildlife enhancement area for the commmunity.

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A Citizen's Guide to Evapotranspiration Covers

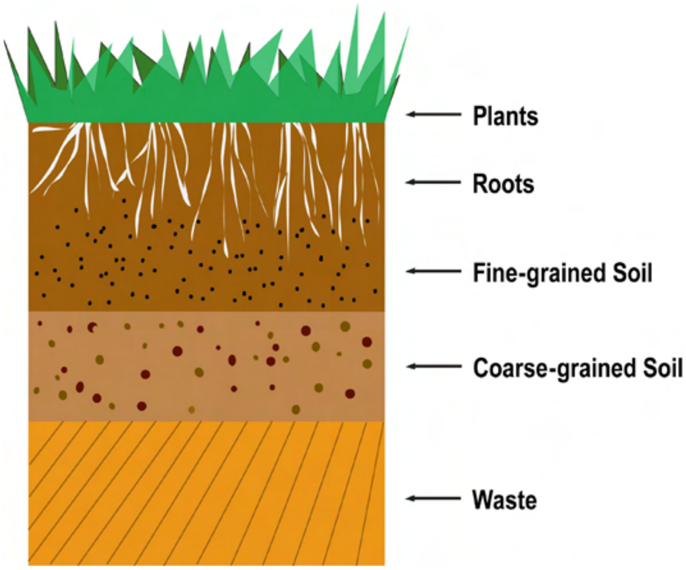
What Are Evapotranspiration Covers?

Evapotranspiration (ET) covers are a type of cap placed over contaminated material, such as soil, landfill waste, or mining tailings, to prevent water from reaching it. They differ from other types of caps (See *A Citizen's Guide to Capping* [EPA 542-F-12-004].) in the way they prevent water from seeping into the waste. ET covers store water from rainfall and snowmelt until drier or warmer weather evaporates the water, or until the water is taken in by plant roots and released to the air as water vapor through the leaves and stems. This process is called "transpiration."

Example of ET cover used at Operating Industries, Inc. Landfill Superfund site.

How Do They Work?

Like other caps, ET covers do not destroy or remove contaminants. Instead, they isolate them and keep them in place to prevent the spread of contamination and protect people and wildlife from the contaminated material. ET covers are constructed by placing a 2- to 10-foot-thick layer of fine-grained soil containing silt and clay over the contaminated material. The type of soil is chosen for its ability to store water and promote plant growth. The thickness of the cover depends on how much rainfall and snowmelt is expected in the area. Grass, shrubs, or small trees that form extensive root systems and survive the local climate are usually planted in the soil. Plants native to the area often work best.



The soil-plant layer of an ET cover slows the downward movement of rainwater and snowmelt and promotes storage of the water. The stored water will either evaporate or transpire. Together, evaporation and transpiration ("evapotranspiration") keep water from seeping into contaminated material and carrying contaminants downward into groundwater.

Construction of an ET cover sometimes involves placing the layer of fine-grained soil over a 1-to 2-foot-thick layer of coarse-grained soil, such as sand or gravel. This extra layer allows the fine-grained soil layer to hold more water through a process known as "capillary action." This type of cover usually needs a smaller amount of fine-grained soil to have the same water storage as a regular ET cover. Use of clean, locally-available soil for these layers will speed up construction and decrease costs.

How Long Does It Take?

Building an ET cover can take a few days to several months. Construction may take longer when:

- The contaminated area is large.
- A thick cover is needed.
- Supplies of clean soil, gravel, or other cap materials are not available locally.
- The growing time for the plants is long.

ET covers must be maintained for as long as the contaminated materials remain in place to ensure the plants and soil continue to keep water away from contamination.

Are They Safe?

When designed for local conditions, ET covers offer a very safe and effective way to isolate wastes. Regular inspections are made to ensure that the weather, plant roots, and animal activity have not damaged the soil cover and that any plants that are part of the cover are still growing. Also, groundwater wells around the covered area are sampled to ensure the cover is working and contaminants remain isolated.

How Might It Affect Me?

Residents and businesses close to a site may see increased truck traffic as materials are brought to the site. Construction of the cover may involve bulldozers, backhoes, and other noisy equipment, and some soil may need to be excavated for use in the cap. Any dust from excavation and construction can be controlled by spraying water or covering stockpiled materials with tarps.

Why Use ET Covers?

ET covers can be a quick, relatively inexpensive way to isolate landfill wastes and other buried contaminated materials. Like conventional caps, installing an ET cover can avoid the excavation of large amounts of soil or waste having low levels of contamination. ET covers can be designed to provide equal performance to conventional caps, and the plants can make the site more attractive. They are also less likely than conventional caps to be damaged by repeated freezing and thawing as seasons change. ET covers are more commonly used in dry climates where there is little rainfall.

Wheatgrasses, sage bush, pinyon and juniper are part of an ET cover at the Monticello Mill Tailings Superfund site in Utah.

Example

An ET cover was installed over wastes buried in the former Box Canyon Landfill, one of several contaminated areas at the Camp Pendleton Marine Corps Base Superfund site in California. The 28-acre landfill received municipal solid waste and commercial wastes from 1974 to 1984. In the 1990s, low concentrations of contaminants were found in groundwater and soil around the landfill.

Rather than excavating the wastes, in 2002 a 6-foot thick ET cover was constructed over the entire landfill. Quick-growing non-native plants were in the original plant mix to provide erosion control. These later were replaced with native grasses and brush to return the site to a natural coastal sage scrub habitat. The cover is inspected every six months to make sure the cover is in good condition and the plants are healthy.

For More Information

For more information on this and other technologies in the Citizen's Guide Series, contact:

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A Citizen's Guide to Excavation of Contaminated Soil

What Is the Excavation of Contaminated Soil?

Excavation of contaminated soil from a site involves digging it up for "ex situ" (above-ground) treatment or for disposal in a landfill. Excavation also may involve removing old drums of chemicals and other buried debris that might be contaminated. Removing these potential sources of contamination keeps people from coming into contact with contamination and helps speed the cleanup of contaminated groundwater that may be present.

How Does It Work?

Before excavation can begin, the contaminated areas must be identified. This requires researching past activities at the site to identify what contaminants may have been released and where. The soil is then tested to better define where contaminants are present.

Contaminated soil is excavated using standard construction equipment, like backhoes and excavator trackhoes. The equipment chosen depends on how large and deep the contaminated area is, and whether access is limited by the presence of buildings or other structures that cannot be moved. Long-arm excavators can reach as deep as 100 feet below ground, but excavations are generally limited to much shallower depths due to safety concerns and difficulty

Soil piles are covered with plastic tarps during excavation.

Worker collects soil samples to confirm that soil left onsite is clean.

keeping the hole open. Sometimes soil is excavated below the water table, which requires walling off the contaminated area and pumping out the water to keep dry during excavation.

If excavated soil will be disposed of in a landfill, it may be placed directly on a dump truck for transport. If it is to be disposed of elsewhere on the site or treated, it first may be stock piled on plastic tarps or in containers. The soil is then covered with tarps to prevent wind and rain from blowing or washing it away and to keep workers from coming into contact with contaminated soil. Excavation is complete when test results show that the remaining soil around the hole meets established cleanup levels.

The excavated soil may be cleaned using a mobile treatment facility brought to the site or disposed offsite. If the soil is treated onsite, treated soil may be used to fill in the excavated area. Clean soil obtained from other locations may be needed to fill in holes as well. After an excavation is filled in, the area may be landscaped to prevent soil erosion and make the site more attractive.

How Long Will It Take?

Excavating contaminated soil may take as little as one day or as long as several years. The actual time it takes to excavate will depend on several factors. For example, it may take longer where:

- The contaminated area is large, very deep, or below the water table.

- Contaminant concentrations are high, requiring extra safety precautions.
- The contaminated soil contains a lot of rocks or debris.
- Buildings or site activities limit the movement of equipment.
- The site is remote, or the treatment and disposal facilities are far away.

These factors vary from site to site.

Is Excavation Safe?

Handling contaminated soil requires precautions to ensure safety. Site workers are trained to follow safety procedures while excavating soil to avoid contact with contaminants and prevent the spread of contamination offsite. Site workers typically wear protective clothing such as rubber gloves, boots, hard hats, and coveralls. These items are either washed or disposed of before leaving the site to keep workers from carrying contaminated soil offsite on their shoes and clothing. The tires and exteriors of trucks and other earth-moving equipment are also washed before leaving the site so that the soil is not tracked through neighboring streets.

Workers monitor the air to make sure dust and contaminant vapors are not present at levels that may pose a breathing risk, and monitors may be placed around the site to ensure that dust or vapors are not leaving it. Site workers close to the excavation may need to wear "respirators," which are face masks equipped with filters that remove dust and contaminants from the air. Contaminated soil is usually covered until it can be treated or disposed of to prevent airborne dust or being washed away with rainwater. Contaminant vapors may be suppressed with foams or other materials.

How Might It Affect Me?

Nearby residents and businesses may notice increased truck traffic during soil excavation and the noise of earth-moving equipment. Excavations are fenced off to prevent entry to the area until it is backfilled and covered with clean soil.

Why Excavate Contaminated Soil?

Excavation is commonly used where in situ cleanup methods will not work quickly enough or will be too expensive. Offsite disposal and ex situ treatment are often the fastest ways to deal with high levels of contamination that pose an immediate risk to people or the environment. Excavation is also a cost-effective approach for small amounts of contaminated soil.

Example

Soil excavation for offsite treatment and disposal was used to clean up the Federal Creosote Superfund site in New Jersey. Residential housing and a shopping mall had been built on the 50-acre property after a wood-treating facility closed in the 1950s. Creosote and waste chemicals that had been stored in lagoons were buried during construction.

Contamination was discovered in the 1990s. Between 2002 and 2008, soil was excavated from as deep as 35 feet near 93 homes. Some residents were relocated, and 18 homes were demolished to reach the contaminated soil beneath. A total of 275,000 tons of soil from this area was transported offsite for treatment and disposal. Another 177,000 tons were excavated from the mall property. Clean soil was used to fill in the excavations.

Throughout the work, workers monitored the air. Soil was covered with foam and plastic sheets to reduce odors from the creosote. Trucks were cleaned prior to leaving the property.

For More Information

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A Citizen's Guide to Fracturing for Site Cleanup

What Is Fracturing For Site Cleanup?

Fracturing creates or enlarges openings in bedrock or dense soil, such as clay, to help soil and groundwater cleanup methods work better. The openings, called "fractures," become pathways through which contaminants in soil and groundwater can be treated in situ (in place, underground) or removed for above-ground treatment. Although fractures can occur naturally in soil and rock, they are not always wide or long enough to easily reach underground contamination using cleanup methods. Fracturing can enlarge the cracks and create new ones to improve the speed and effectiveness of the cleanup. Fracturing is most commonly used with several in situ cleanup methods. (See A Citizen's Guide to Bioremediation [EPA 542-F-12-003], In Situ Chemical Oxidation [EPA 542-F-12-011], In Situ Chemical Reduction [EPA 542-F-12-012]), and Soil Vapor Extraction and Air Sparging [EPA 542-F-12-018]).

How Is Fracturing for Environmental Cleanup Different from Fracturing to Recover Oil and Gas?

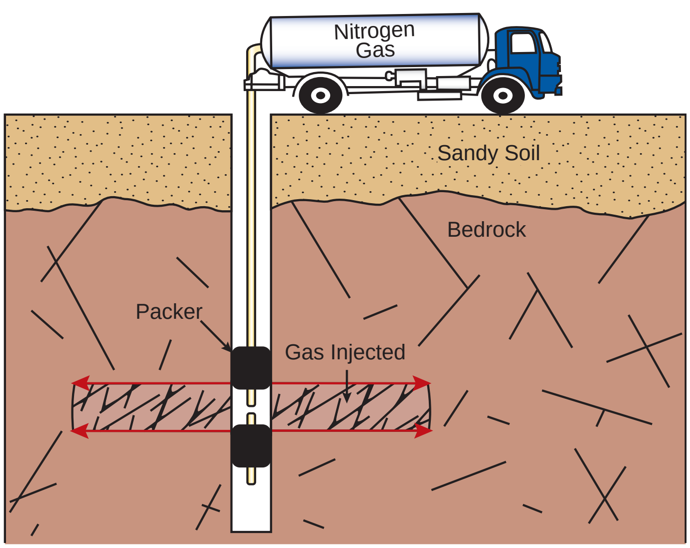
Oil and gas hydraulic fracturing is used to stimulate the recovery of oil or natural gas from underground geologic formations. Oil and gas hydraulic fracturing works by pumping a mixture of fluids and other substances into the target formation to create and enlarge fractures. Such operations are much larger, use different equipment and chemical additives, occur at greater depths, and use higher volumes of fluid than fracturing for site cleanup. Fracturing to clean up a contaminated site rarely exceeds a depth of 100 feet, and the affected area around the fracturing well usually is less than 100 feet in any direction. However, wells to extract oil and gas often are drilled hundreds or thousands of feet downward and sometimes horizontally into the oil- or gas-bearing rock. Fractures may extend over 500 feet from these wells.

How Does It Work?

There are three ways to fracture soil or rock:

- Hydraulic fracturing pumps water or a water-based fluid under pressure into holes drilled in the ground. The force of the water causes soil (or sometimes rock) to fracture. The water or fluid can be pumped with sand or other "propping agents." Propping agents help keep the fractures open during cleanup.
- Pneumatic fracturing injects air or other gases into the holes to fracture dense soil. Air forced into the soil also can promote evaporation of chemicals that change to gases quickly when exposed to air. The gases may be captured and treated above ground.
- Blast-enhanced fracturing uses explosives, such as dynamite, to fracture rock. The explosives are placed in holes and detonated. The main purpose is to create fractures for pump and treat cleanup.

Both pneumatic and hydraulic fracturing can direct pressure to specific underground zones, but blast-enhanced fracturing cannot.



Nitrogen gas is injected for pneumatic fracturing of bedrock.

How Long Will It Take?

Fracturing rock and soil does not take very long. It may only take a few days. However, even with the help of fracturing, actual cleanup may take months or years, depending on several factors. For example, it will take longer where:

- The contaminated area is large or deep.
- Contaminant concentrations are higher.
- Groundwater flow is slow.

Is Fracturing Safe?

When properly used, fracturing is a safe way to make cleanup methods faster and more efficient. Because fracturing affects the soil and bedrock, it is not typically used where it can affect building foundations and underground utilities. To be sure fracturing does not damage nearby structures, special monitoring equipment is used to measure any movement of the ground. When fracturing is conducted at shallow depths, the ground surface around the holes may rise as much as an inch, but will eventually settle back close to its original level if fractures are not propped open.

How Might It Affect Me?

Residents near the site may see increased truck traffic when fracturing equipment and materials needed for cleanup are delivered to the site. Residents also may hear noise from the detonation of explosives and from machines used to inject water or air underground.

Why Use Fracturing For Site Cleanup?

Fracturing is used to help reach contaminants in rock and dense soil so that they can be cleaned up faster and more completely. It offers a way of reaching contamination deep in the ground where it would be difficult or costly to excavate. Fracturing can reduce the number of wells needed for certain cleanup methods, which can save time and reduce cleanup costs. Fracturing has been used in cleanups at over 15 Superfund sites and many more sites throughout the country.

Pneumatic fracturing at the Hunters Point Naval Shipyard Superfund site

Example

Pneumatic fracturing was used to help clean up an area of the Hunters Point Naval Shipyard Superfund site in California. For years the site was used for ship building and maintenance, which contaminated groundwater with fuels, pesticides, heavy metals, industrial solvents, and other chemicals.

To clean up solvents from the groundwater, EPA needed to inject small particles of iron underground over an area larger than an acre to reach contaminants from 5 to 25 feet below ground. Pneumatic fracturing by high-pressure injection of nitrogen gas was used to create and widen fractures in soil. The fractures allowed the injected iron to spread more widely and evenly underground and treat more of the contaminated groundwater. After 12 weeks, solvent concentrations within the treatment areas decreased by an average of 87 to 99 percent. Additional monitoring is being conducted as part of the site-wide groundwater monitoring program.

For More Information

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A Citizen's Guide to Greener Cleanups

What Are Greener Cleanups?

The process of cleaning up a hazardous waste site uses energy, water, and other natural or material resources. This process places demands on the environment and creates an environmental "footprint" of its own. A greener cleanup looks at this footprint closely and finds ways to reduce it throughout the life of a project, while achieving cleanup goals and preserving site reuse options. Early consideration of the environmental footprint of a cleanup can help lead to sustainable reuse or redevelopment of the site.

Windmills power equipment to remove oil from contaminated groundwater.

How Does It Work?

A project team working toward a greener cleanup considers many techniques to reduce the footprint and compares their environmental advantages and disadvantages.

Because site conditions vary widely, so do the approaches and methods used to make a cleanup greener. To help find ways to reduce a cleanup's environmental footprint, possible environmental impacts are grouped into five core elements shown in the graphic. Here are just a few of the examples of activities under each core element that promote greener cleanups:

- **Energy** use can be reduced by assuring all cleanup equipment runs efficiently and is properly sized for the task. For example, a less efficient pump might be replaced by one that is more efficient and uses less electricity. Using fuel-efficient trucks could reduce use of diesel fuel. Greener cleanups also can find ways to use solar, wind, or other renewable energy to power equipment. The use of renewable energy reduces the electricity or natural gas needed from local utilities.
- Impacts on the **air and atmosphere** can be reduced by using less energy from utilities that rely heavily on burning fossil fuels, such as coal or oil. Air pollutants from site activities can be reduced by adding filters to the exhaust systems of heavy machinery and replacing machine engines with newer, cleaner models.
- **Water** used during the cleanup process can be recirculated and reused instead of using fresh water. Water quality could be protected by building soil barriers around a construction area to prevent stormwater runoff, which can carry topsoil to nearby streams and harm fish and other wildlife.
- Taking precautions to protect **land and ecosystems** in the cleanup area could involve relocating animals to safer areas or landscaping with native plants. Restricting truck traffic to paved roads or to defined pathways in unpaved areas avoids unnecessary land disturbance and can protect soil and habitats.
- **Materials and waste** management maximizes material reuse or recycling and minimizes waste. For example, saving concrete, wood, or other demolition materials for later construction activities can significantly reduce a cleanup's environmental footprint.

The core elements of an environmental footprint.

How Long Will It Take?

Taking the steps to assure a greener cleanup does not need to delay cleanup progress. Simple changes in field procedures such as setting a "no-idling" policy for machinery engines can be made within days. In comparison, changes such as installing a solar energy system could take a year to plan and months to construct while cleanup progresses. Planning for a greener cleanup at the beginning instead of the middle of a project can lead to the biggest reductions in a project's environmental footprint.

Simple changes in field procedures can reduce a site's environmental footprint.

How Might It Affect Me?

All steps of a greener cleanup are meant to improve long-term health of a community by protecting the environment in which we live. Many steps may go unnoticed outside of the project team. Some may result in direct benefits to a community, such as reduced traffic and noise due to fewer waste-hauling trucks on the roads. Other greener cleanup methods could offer ways for individuals to become more involved, such as finding local uses for uncontaminated scrap metal, lumber, or demolition material.

Why Use A Greener Cleanup Strategy?

As a nation, we value land as a natural, cultural, and economic resource. Using a greener strategy is often a smarter way to clean up contaminated land. Greener cleanups can help decrease the use of fossil fuels such as oil and coal. A greener strategy also could lower cleanup costs by reducing the amount of electricity and materials that are used. In general, a greener strategy started during the early stages of a cleanup could set the stage for sustainable reuse or redevelopment of the site.

Heavy machinery used to remove contaminated soil can run on ultra-low sulfur diesel.

Example

Owners of the Apache Nitrogen Products, Inc., Superfund site in Arizona, cleaned up contaminated soil and groundwater with many green features.

- A wetland system was constructed to remove contaminants from groundwater through natural processes. The hillside location of the wetland allows water to flow through the system without using pumps.
- Renewable energy powers the equipment that recirculates water through the wetland.
- Treated groundwater is pumped back underground to replenish clean groundwater supplies rather than releasing it to creeks or ponds.
- Clay for the soil cap was obtained locally, minimizing transportation impacts.

These features help make a cleanup greener by avoiding chemicals sometimes used to treat contaminants, reducing the energy needed to operate cleanup equipment, and increasing the supply of clean groundwater.

For More Information

For more information on this and other technologies in the Citizen's Guide Series, contact:

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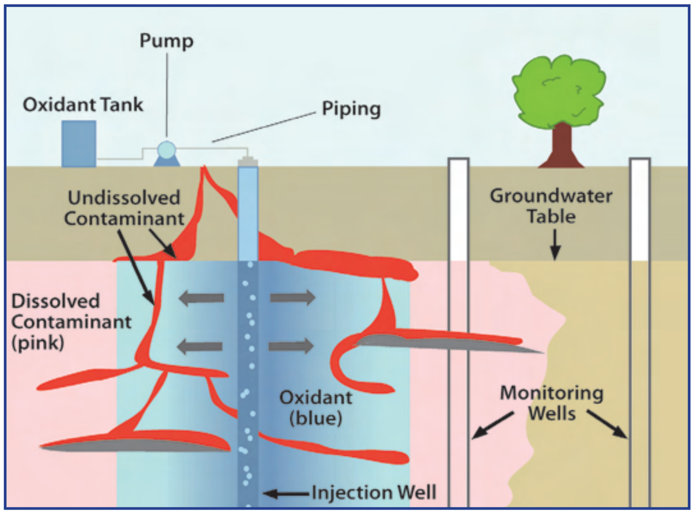
A Citizen's Guide to In Situ Chemical Oxidation

What Is In Situ Chemical Oxidation?

Chemical oxidation uses chemicals called "oxidants" to help change harmful contaminants into less toxic ones. It is commonly described as "in situ" because it is conducted in place, without having to excavate soil or pump out groundwater for aboveground cleanup. In situ chemical oxidation, or "ISCO," can be used to treat many types of contaminants like fuels, solvents, and pesticides. ISCO is usually used to treat soil and groundwater contamination in the source area where contaminants were originally released. The source area may contain contaminants that have not yet dissolved into groundwater. Following ISCO, other cleanup methods, such as pump and treat or monitored natural attenuation, are often used to clean up the smaller amounts of contaminants left behind. (See *A Citizen's Guide to Pump and Treat* [EPA 542-F-12-017] and *A Citizen's Guide to Monitored Natural Attenuation* [EPA 542-F-12-014].)

How Does It Work?

When oxidants are added to contaminated soil and groundwater, a chemical reaction occurs that destroys contaminants and produces harmless byproducts. To treat soil and groundwater in situ, the oxidants are typically injected underground by pumping them into wells. The wells are installed at different depths in the source area to reach as much dissolved and undissolved contamination as possible. Once the oxidant is pumped down the wells, it spreads into the surrounding soil and groundwater where it mixes and reacts with contaminants.



To improve mixing, the groundwater and oxidants may be recirculated between wells. This involves pumping oxidants down one well and then pumping the groundwater mixed with oxidants out another well. After the mixture is pumped out, more oxidant is added, and it is pumped back (recirculated) down the first well. Recirculation helps treat a larger area faster. Another option is to inject and mix oxidants using mechanical augers or excavation equipment. This may be particularly helpful for clay soil.

The four major oxidants used for ISCO are permanganate, persulfate, hydrogen peroxide and ozone. The first three oxidants are typically injected as liquids. Although ozone is a strong oxidant, it is a gas, which can be more difficult to use. As a result, it is used less often.

Catalysts are sometimes used with certain oxidants. A catalyst is a substance that increases the speed of a chemical reaction. For instance, if hydrogen peroxide is added with an iron catalyst, the mixture becomes more reactive and destroys more contaminants than hydrogen peroxide alone.

Following treatment, if contaminant concentrations begin to climb back up or "rebound," a second or third injection may be needed. Concentrations will rebound if the injected oxidants did not reach all of the contamination, or if the oxidant is used up before all the contamination is treated. It may take several weeks to months for the contamination to reach monitoring wells and to determine if rebound is occurring.

ISCO may produce enough heat underground to cause the contaminants in soil and groundwater to evaporate and rise to the ground surface. Controlling the amount of oxidant helps avoid excessive heat, and if significant gases are produced, they can be captured and treated.

How Long Will It Take?

ISCO works relatively quickly to clean up a source area. Cleanup may take a few months or years, rather than several years or decades. The actual cleanup time depends on several factors that vary site to site. For example, ISCO will take longer where:

- The source area is large.
- Contaminants are trapped in hard-to-reach areas like fractures or clay.
- The soil or rock does not allow the oxidant to spread quickly and evenly.
- Groundwater flow is slow.
- The oxidant does not last long underground.

Is ISCO Safe?

The use of ISCO poses little risk to the surrounding community. Workers wear protective clothing when handling oxidants, and when handled properly, these chemicals are not harmful to the environment or people. Because contaminated soil and groundwater are cleaned up underground, ISCO does not expose workers or others at the site to contamination. Workers test soil and groundwater regularly to make sure ISCO is working.

How Might It Affect Me?

Nearby residents and businesses may see drilling rigs and tanker trucks with oxidants and supplies as they are driven to the site. Residents may also hear the operation of drilling rigs, pumps, and other equipment leading up to and during the injection period. Following an injection, however, the cleanup process occurs underground with little aboveground disruption. Workers may visit the site to collect soil and groundwater samples to monitor cleanup progress.

Why Use ISCO?

ISCO is usually selected to clean up a source area, where it destroys the bulk of contaminants in situ without having to dig up soil or pump out groundwater for aboveground treatment. This can save time and money. ISCO has successfully cleaned up many contaminated sites and has been selected or is being used at around 40 Superfund sites and many other sites across the country.

ISCO system installed behind a small drycleaning facility.

Example

Groundwater near a former wastewater treatment plant at the Naval Air Station Pensacola in Florida was contaminated with solvents and acids from painting and electroplating. A groundwater pump and treat system had operated for more than 10 years to control migration of contaminated groundwater. However, it did not do much to lower the concentrations of contaminants. ISCO using hydrogen peroxide with an iron catalyst was chosen to reduce contaminant concentrations in the source area enough to allow monitored natural attenuation to complete the cleanup.

The natural chemistry of the site's groundwater was found to limit the effectiveness of the first phase of injections. In the second phase, a chemical was added to the reagent mix to stabilize the oxidant mixture. Contaminant levels fell substantially. The successful use of ISCO at this site was estimated to save several million dollars compared with continued pump and treat.

For More Information

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A Citizen's Guide to In Situ Chemical Reduction

What Is In Situ Chemical Reduction?

In situ chemical reduction, or "ISCR," uses chemicals called "reducing agents" to help change contaminants into less toxic or less mobile forms. It is described as "in situ" because it is conducted in place, without having to excavate soil or pump groundwater above ground for cleanup. ISCR can clean up several types of contaminants dissolved in groundwater. It can also be used to clean up contaminants known as "dense non-aqueous phase liquids" or "DNAPLs," which do not dissolve easily in groundwater and can be a source of contamination for a long time. ISCR is most often used to clean up the metal chromium and the industrial solvent trichloroethene, or "TCE," which is a DNAPL.

How Does It Work?

When reducing agents are added to contaminated soil and groundwater, a chemical reaction occurs that changes contaminants into other forms. For example, a very toxic form of chromium called "hexavalent chromium," or "chrome 6," can be changed to chrome 3 when reducing agents are injected into contaminated groundwater. Chrome 3 is a much less toxic form of the metal. Chrome 3 is also less mobile because it does not dissolve as easily in water.

Common reducing agents include zero valent metals, which are metals in their pure form. The most common metal used in ISCR is zero valent iron, or "ZVI." ZVI must be ground up into small granules for use in ISCR. In some cases, micro- or nano-scale (extremely small) particles are used. The smaller particle size increases the amount of iron available to react with contaminants. Other common reducing agents include polysulfides, sodium dithionite, ferrous iron, and bimetallic materials, which are made up of two different metals. The most common bimetallic material used in ISCR is iron coated with a thin layer of palladium or silver.

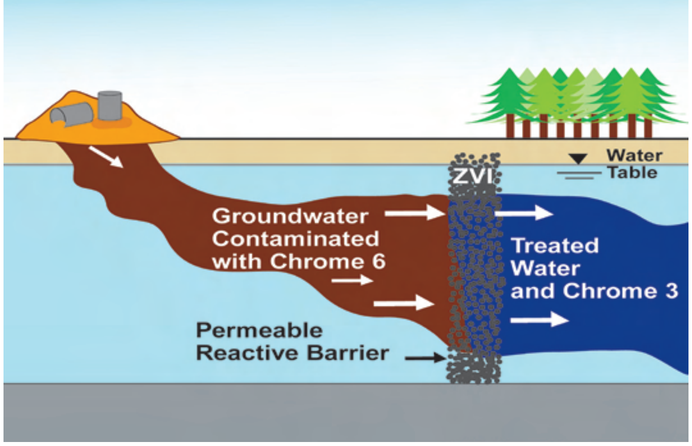

Illustration of the treatment of contaminated water with a PRB made of ZVI.

There are two ways of bringing reducing agents into contact with contaminated soil and groundwater: direct injection and construction of a permeable reactive barrier, or "PRB."

Direct injection involves mixing the reducing agent with water (or sometimes vegetable oil) to create a slurry, which is pumped down holes drilled directly into the contaminated soil and groundwater. This method is often used to treat highly contaminated source areas, including DNAPLs. Nano-scale ZVI is usually used when injecting iron underground, but micro-scale ZVI also is used.

A **PRB** is a wall built below ground, usually by digging a trench and filling it with a reducing agent. Iron filings, which are larger granules of ZVI, are commonly used. Because the wall is permeable, groundwater flows through the PRB allowing contaminants to react with the reducing agent; treated water flows out the other side. A PRB is used to treat contaminants dissolved in groundwater. It will only treat the water that flows through it. (See *A Citizen's Guide to Permeable Reactive Barriers* [EPA 542-12-015].)

How Long Will It Take?

ISCR may take as little as a few months to clean up a source area using direct injection, and PRBs may take several years. The actual cleanup time will depend on several factors that vary from site to site. For example, ISCR will take longer where:

- The source area is large, or contaminants are trapped in hard-to reach areas like fractures or clay.
- The soil or rock does not allow the reducing agent to spread quickly and evenly or reach contaminants easily.
- Groundwater flow is slow.

Is In Situ Chemical Reduction Safe?

The use of ISCR poses little risk to the surrounding community. Workers wear protective clothing while handling reducing agents, and when handled properly, these chemicals are not harmful to the environment or to people. Because contaminated soil and groundwater are cleaned up underground, ISCR does not expose workers or others at the site to contamination. If contaminated soil is encountered when digging the PRB trench, workers will need to wear protective clothing. They also cover any loose contaminated soil to keep dust and contaminants out of the air before disposing of it. Groundwater and soil are tested regularly to make sure ISCR is working.

How Might It Affect Me?

Residents and businesses near the site may see increased truck traffic when drilling rigs, earth-moving equipment, and reducing agents are delivered to the site. Residents also may hear the operation of equipment during injections or installation of PRBs. However, when injections and PRB installations are complete, ISCR requires no noisy equipment. Cleanup workers will occasionally visit the site to collect soil and groundwater samples to make sure ISCR is working.

Why Use In Situ Chemical Reduction?

ISCR can treat some types of contaminants including DNAPLs that are difficult to clean up using other methods. It can destroy most of the contamination in situ without having to pump groundwater for treatment or dig up soil for transport to a landfill or treatment facility. This can save time and money. In addition, no energy is needed to operate a PRB because it relies on the natural flow of groundwater. ISCR is a relatively new method for cleaning up hazardous waste sites, but is seeing increased use at Superfund sites across the country.

Injection of reducing agent into a hole drilled underground.

Example

ISCR was used to treat soil and groundwater contaminated with chrome 6 at the Macalloy Corporation Superfund site in South Carolina. Leaks and disposal of wastes at the former iron-chrome alloy manufacturing plant contaminated the groundwater, which flows into a nearby creek.

In December 2005, five PRBs (and later another four) were constructed to contain and treat groundwater before it could enter the creek. Soil excavated from trenches was mixed with gravel and a blend of ferrous iron and sodium dithionite. The mixture was placed back in the trenches to form the PRBs.

A 2010 review showed that concentrations of chrome 6 and the extent of contamination are decreasing at the site. Cleanup goals are being met in most of the wells sampled. The PRBs are expected to continue to reduce chrome 6 over the next five years.

For More Information

For more information on this and other technologies in the Citizen's Guide Series, contact:

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A Citizen's Guide to In Situ Thermal Treatment

What is In Situ Thermal Treatment?

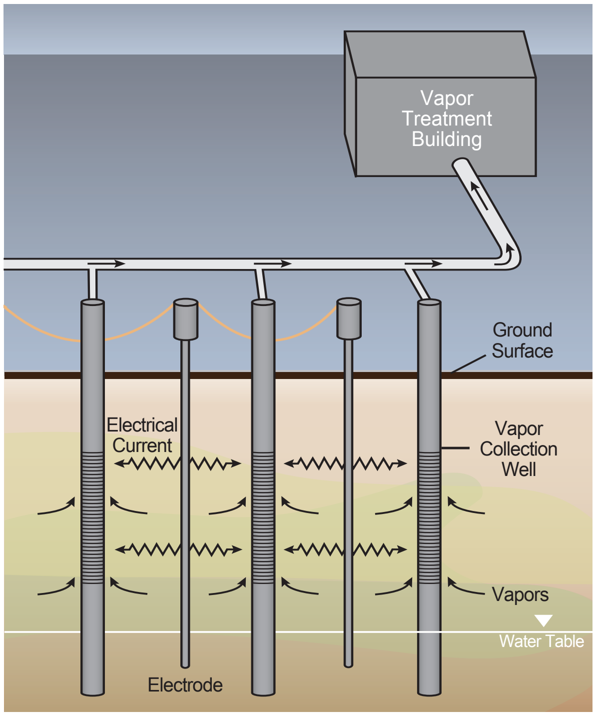
In situ thermal treatment methods move or "mobilize" harmful chemicals in soil and groundwater using heat. The chemicals move through soil and groundwater toward wells where they are collected and piped to the ground surface to be treated using other cleanup methods. Some chemicals are destroyed underground during the heating process. Thermal treatment is described as "in situ" because the heat is applied underground directly to the contaminated area. It can be particularly useful for chemicals called "non-aqueous phase liquids" or "NAPLs," which do not dissolve readily in groundwater and can be a source of groundwater contamination for a long time if not treated. Examples of NAPLs include solvents, petroleum, and creosote (a wood preservative).

How Does It Work?

In situ thermal treatment methods heat contaminated soil, and sometimes nearby groundwater, to very high temperatures. The heat vaporizes (evaporates) the chemicals and water changing them into gases. These gases, also referred to as "vapors," can move more easily through soil. The heating process can make it easier to remove NAPLs from both soil and groundwater. High temperatures also can destroy some chemicals in the area being heated.

In situ thermal methods generate heat in different ways:

- **Electrical resistance heating (ERH)** delivers an electrical current between metal rods called "electrodes" installed underground. The heat generated as movement of the current meets resistance from soil converts groundwater and water in soil into steam, vaporizing contaminants.
- **Steam enhanced extraction (SEE)** injects steam underground by pumping it through wells drilled in the contaminated area. The steam heats the area and mobilizes and evaporates contaminants.
- **Thermal conduction heating (TCH)** uses heaters placed in underground steel pipes. TCH can heat the contaminated area hot enough to destroy some chemicals.



The chemical and water vapors are pulled to collection wells and brought to the ground surface by applying a vacuum. (See *A Citizen's Guide to Soil Vapor Extraction and Air Sparging* [EPA 542-12-018] for information on how this is done.) The vapors are then treated above ground using one of several cleanup methods available. Or, if concentrations are high, the vapors can be condensed back to liquid chemicals and reused.

How Long Will It Take?

In situ thermal treatment might take a few months to a few years to clean up a site. The actual cleanup time will depend on several factors. For example, it might take longer where:

- Contaminant concentrations are high.
- The contaminated area is large or deep.
- A variety of soil types are present, causing the ground to heat unevenly.
- The soil has a lot of organic matter, which causes chemicals to stick to the soil and not evaporate easily.

These factors vary from site to site.

Are In Situ Thermal Treatment Methods Safe?

In situ thermal treatment methods do not pose a threat to site workers or the community when properly operated. For instance, when using ERH, the electrical current is prevented from traveling outside of the treatment area or to aboveground structures by using common electrical grounding techniques. A thermal treatment area is usually covered with an impermeable surface cover (such as concrete, asphalt, or a heavy-duty tarp) to keep the heat and steam underground. Such seals also help prevent the release of chemical vapors to the air. In addition, workers test air samples to make sure that vapors are being captured.

How Might It Affect Me?

In situ thermal treatment requires the use of drilling equipment and other heavy machinery to install wells or electrodes and to collect and treat vapors. Neighborhoods near the site may experience some increased truck traffic as the equipment is delivered and later removed. Nearby residents and businesses also may hear operating equipment.

Why Use In Situ Thermal Treatment?

In situ thermal treatment methods speed the cleanup of many types of chemicals, and are among the few in situ methods that can clean up NAPLs. Thermal treatment can be used in silty or clayey soil where other cleanup methods do not perform well. They also can reach contamination deep underground or beneath buildings, which would otherwise be difficult or costly to dig up to treat above ground. In situ thermal treatment has been selected or is being used in cleanups of at least 12 Superfund sites as well as dozens of other sites across the country.

ERH system cleans up contaminated soil and groundwater.

Example

SEE was used to speed clean up of the Southern California Edison Co., Visalia Pole Yard Superfund site in California. Use of chemicals to treat wooden utility poles contaminated soil and groundwater at the facility. Conventional "pump and treat," begun in 1984, did not show much progress in meeting cleanup objectives. In 1997, 14 steam injection wells were installed around the contaminated area. Steam was injected into the ground at depths of 80-100 feet, vaporizing the chemicals and forcing them toward the collection wells.

Initially, about 13,000 pounds of contaminants were pumped from the collection wells every day. SEE was stopped after three years when the wells began collecting less than 4 pounds per day, indicating that most of the chemicals had been removed. The pump and treat system was turned off in 2004. Overall, about 1.3 million pounds of contaminants were removed, and groundwater contaminant concentrations were reduced to below drinking water standards. By using SEE as part of the cleanup effort, the overall site cleanup was reduced from an estimated 120 years to 20 years.

For More Information

For more information on this and other technologies in the Citizen's Guide Series, contact:

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A Citizen's Guide to Incineration

EPA

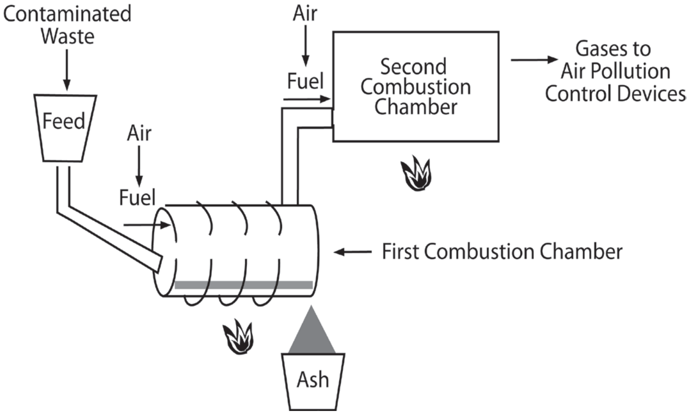
What is Incineration?

Incineration is the process of burning hazardous materials at temperatures high enough to destroy contaminants. Incineration is conducted in an "incinerator," which is a type of furnace designed for burning hazardous materials in a combustion chamber. Many different types of hazardous materials can be treated by incineration, including soil, sludge, liquids, and gases. Although it destroys many kinds of harmful chemicals, such as solvents, PCBs (polychlorinated biphenyls), and pesticides, incineration does not destroy metals, such as lead and chromium.

How Does It Work?

Hazardous materials must be excavated or pumped into containers before incineration. They may require further preparation, such as grinding or removing large rocks and debris, or removing excess water. The materials are then placed in the combustion chamber of an incinerator where they are heated to an extremely high temperature for a specified period of time. The temperature and length of time depend on the types of wastes and contaminants present. Air or pure oxygen may be added to the chamber to supply the oxygen needed for burning. The destruction of contaminants will depend on:

- Reaching the target temperature: Depending on the contaminants present, the target temperature may range from 1,600 to 2,500°F.



How an incinerator converts waste into ash and gases.

- The length of time the waste is heated in the combustion chamber: Typically, solid wastes must be heated for 30 to 90 minutes, while liquid and gaseous wastes may only require 2 seconds.
- Mixing of the waste material. Mixing helps all of the waste to be heated to the proper temperature.

As the wastes heat up, the contaminants volatilize (change into gases) and most are destroyed. Gases that are not destroyed pass through a secondary combustion chamber for further heating and destruction. The resulting gases then pass though air pollution control equipment, which removes particulate matter (extremely small particles or liquid droplets) and "acid gases." Acid gases such as sulfur dioxide are very corrosive.

Incinerators can be constructed for temporary use at the site. However, in recent years, it has been more common for the wastes to be loaded onto trucks for transport to a permanent offsite facility. EPA requires that an incinerator can destroy and remove at least 99.99 percent of each harmful chemical in the waste it processes. When some extremely harmful chemicals are present, EPA requires that an incinerator show it can destroy and remove at least 99.9999 percent of contaminants in the waste. Ash remaining at the bottom of the combustion chambers likely will require disposal in a hazardous waste landfill. However, the amount of material that requires disposal after incineration is much less than the initial amount of waste that was burned.

How Long Will it Take?

Incineration of all waste at a site might take a few weeks to several years. The actual cleanup time will depend on several factors. For example, it may take longer where:

- The amount of waste is large, requiring more time to excavate or pump out.
- The waste contains large rocks or debris that must be removed before incineration.
- The capacity of the incinerator is small.

These factors vary from site to site.

Is Incineration Safe?

An incinerator that is properly designed and operated can safely destroy harmful chemicals. Proper temperatures must be maintained for complete incineration, and air pollution control equipment must be monitored to ensure all contaminants are removed from the offgases. Hazardous materials transported to offsite incinerators are covered or contained to prevent their release.

How Might It Affect Me?

Residents and businesses near the site may see and hear large earth-moving equipment such as backhoes that may be needed to excavate wastes for incineration. They will notice increased truck traffic if wastes must be transported to an offsite incinerator. Odors, smoke, and dust are not typically issues with modern incinerators, though residents may occasionally see harmless white steam that disappears quickly into the air.

Why Use Incineration?

Incineration can destroy a wide range of highly contaminated wastes and greatly reduce the amount of material that must be disposed of in a landfill. For small contaminated areas, excavation and transport to an offsite incinerator can be a quick cleanup approach. A faster cleanup may be important when a site must be cleaned up quickly to prevent immediate harm to people or the environment.

Although incinerators require a lot of fuel for their operation, the heat generated sometimes can be used to generate electric power in a process called "waste to energy."

Offsite incineration has been selected or is being used at over a hundred Superfund sites, while onsite incineration has been selected or is being used at over 40 Superfund sites across the country.

Example of offsite incinerator.

Example

Incineration was used as part of the cleanup effort at the MOTCO, Inc. Superfund site in Texas. From the 1950s through 1970s, the site was contaminated with tar- and petroleum-related chemicals from tar recycling activities. Investigation of the site in the 1980s found seven unlined waste disposal pits containing 7 million gallons of PCB-contaminated liquid and 18 thousand cubic yards of sludge and tar. These wastes had to be removed to prevent further contamination of soil and groundwater.

From 1993 to 1996, the liquid, sludge, and tar were excavated and transported about 280 miles to an incinerator in Louisiana. The remaining contaminated soil beneath these wastes was covered with a cap and surrounded by underground slurry walls to prevent release of any contaminants that remained. Removal of the contaminant sources was expected to speed up the cleanup of groundwater.

For More Information

For more information on this and other technologies in the Citizen's Guide Series, contact:

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A Citizen's Guide to Monitored Natural Attenuation

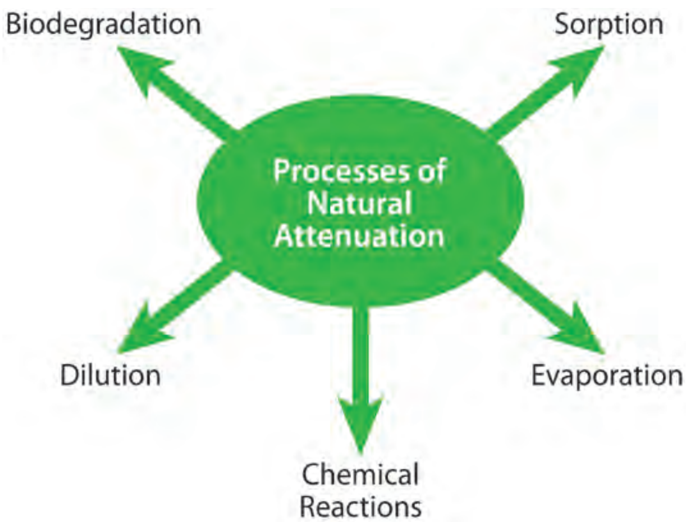
What Is Monitored Natural Attenuation?

Natural attenuation relies on natural processes to decrease or "attenuate" concentrations of contaminants in soil and groundwater. Scientists monitor these conditions to make sure natural attenuation is working. Monitoring typically involves collecting soil and groundwater samples to analyze them for the presence of contaminants and other site characteristics. The entire process is called "monitored natural attenuation" or "MNA." Natural attenuation occurs at most contaminated sites. However, the right conditions must exist underground to clean sites properly and quickly enough. Regular monitoring must be conducted to ensure that MNA continues to work.

How Does It Work?

When the environment is contaminated with harmful chemicals, nature may work in five ways to clean it up:

- *Biodegradation* occurs when very small organisms, known as "microbes," eat contaminants and change them into small amounts of water and gases during digestion. Microbes live in soil and groundwater and some microbes use contaminants for food and energy. (*A Citizen's Guide to Bioremediation* [EPA 542-F-12-003] describes how microbes work.)



- *Sorption* causes contaminants to stick to soil particles. Sorption does not destroy the contaminants, but it keeps them from moving deeper underground or from leaving the site with groundwater flow.
- *Dilution* decreases the concentrations of contaminants as they move through and mix with clean groundwater.
- *Evaporation* causes some contaminants, like gasoline and industrial solvents, to change from liquids to gases within the soil. If these gases escape to the air at the ground surface, air will dilute them and sunlight may destroy them.
- *Chemical reactions* with natural substances underground may convert contaminants into less harmful forms. For example, in low-oxygen environments underground, the highly toxic "chromium 6" can be converted to a much less toxic and mobile form called "chromium 3" when it reacts with naturally occurring iron and water.

MNA works best where the source of contamination has been removed. For instance, any waste buried underground must be dug up and disposed of properly, or removed using other available cleanup methods. When the source is no longer present, natural processes may be able to remove the remaining, smaller amount of contaminants in the soil or groundwater. The site is monitored regularly to make sure that contaminants attenuate fast enough to meet site cleanup objectives and that contaminants are not spreading.

How Long Will It Take?

MNA may take several years to decades to clean up a site. The actual cleanup time will depend on several factors. For example, cleanup will take longer when:

- Contaminant concentrations are higher.
- The contaminated area is large.
- Site conditions (such as temperature, groundwater flow, soil type) provide a less favorable environment for biodegradation, sorption or dilution.

These factors vary from site to site.

Is It Safe?

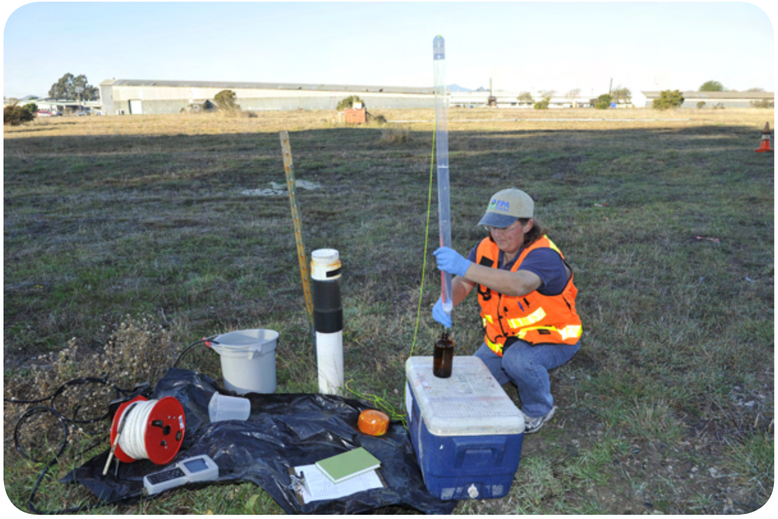
MNA does not pose a threat to the community or to site workers. MNA does not involve excavating soil or pumping groundwater to the surface for above ground treatment, so the potential to contact contaminants is limited. Long-term, regular monitoring is conducted to make sure contamination does not leave the site and that it is being attenuated at a rate that's consistent with cleanup goals for the site. This ensures that people and the environment are protected during the cleanup process.

How Might It Affect Me?

Generally, MNA does not cause much disruption to the surrounding community since no heavy machinery or other equipment is required during the MNA process. Residents and businesses near the site may initially see and hear drilling rigs when wells to monitor groundwater quality are installed. Once installed, workers will need to visit the site to collect samples of groundwater, soil or sediment to ensure MNA is working properly and is protective of human health and the environment. At those times, residents may hear the pumps and generators often used to collect groundwater samples from the wells.

Why Use Monitored Natural Attenuation?

MNA is selected when any contaminant source has been removed and only low concentrations of contaminants remain in soil or groundwater. The anticipated cleanup time for MNA must be reasonable compared to that of other more active cleanup methods. MNA requires less equipment and labor than most methods, which decreases cleanup costs. However, the cost of many years of monitoring can be high. MNA has been selected or is being used at over 100 Superfund sites across the country.



Monitoring natural attenuation at the site by collecting a groundwater sample.

Example

MNA is being used to complete groundwater cleanup at a former landfill on the Kings Bay Naval Submarine Base, Georgia. From 1993 to 2001, other cleanup methods were used to contain and treat the source of solvents in the groundwater. The goal was to reduce solvent concentrations to a level at which MNA would ensure safe concentrations at the property boundary, and unsafe levels of solvents would no longer flow beneath nearby housing. MNA was considered an efficient final treatment because of the right conditions for bioremediation to occur.

Monitoring for natural attenuation has been occurring monthly since 1998. Groundwater is being sampled for solvents and other conditions that indicate MNA is working. The long-term objective is to reduce contaminant concentrations across the site to below Maximum Contaminant Levels (MCLs). Concentrations have decreased at most wells, but the groundwater in the former source area is still expected to take decades to reach MCLs.

For More Information

For more information on this and other technologies in the Citizen's Guide Series, contact:

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A Citizen's Guide to Permeable Reactive Barriers

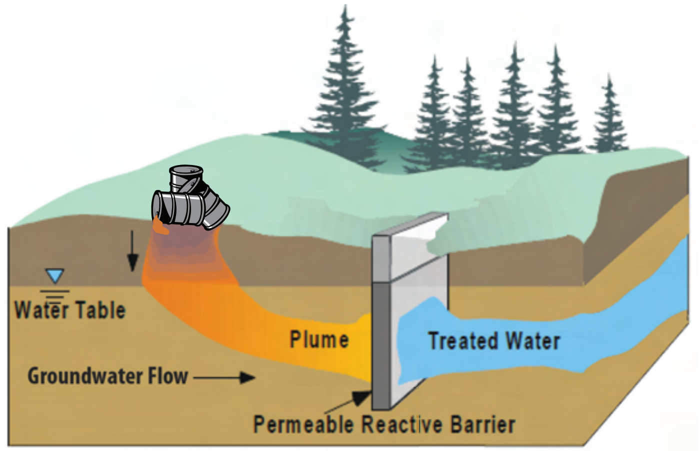
What Are Permeable Reactive Barriers?

A permeable reactive barrier, or "PRB," is a wall created below ground to clean up contaminated groundwater. The wall is "permeable," which means that groundwater can flow through it. Water must flow through the PRB to be treated. The "reactive" materials that make up the wall either trap harmful contaminants or make them less harmful. The treated groundwater flows out the other side of the wall.

How Do They Work?

A PRB is usually built by digging a long, narrow trench in the path of contaminated groundwater flow. The trench is filled with a reactive material, such as iron, limestone, carbon, or mulch, to clean up contamination. Due to limitations of excavation equipment, walls typically can be no deeper than 50 feet. However, a deeper but usually shorter PRB can be built by drilling a row of large-diameter holes or by using fracturing (See *A Citizen's Guide to Fracturing* [EPA 542-12-008]) and other new techniques.

The reactive material selected for the PRB will depend on the types of contaminants present in the groundwater. The material may be mixed with sand to make the wall more permeable so that it is easier for groundwater to flow through it, rather than around it. Side walls filled with an impermeable material such as clay may be constructed at an angle to the PRB to help funnel the flow of contaminated groundwater toward the reactive materials. The filled trench is covered with soil, and is not usually visible at the ground surface.



PRB treats a plume of groundwater contaminants.

Depending on the reactive material, contaminants are removed through different processes:

- Contaminants *sorb* (stick) to the surface of the reactive material. For example, carbon particles have a surface onto which contaminants, such as petroleum products, sorb as groundwater passes through.
- Metals dissolved in groundwater *precipitate*, which means they settle out of the groundwater by forming solid particles that get trapped in the wall. For example, limestone and shell fragments can cause dissolved lead and copper to precipitate in a PRB.
- Contaminants *react* with the reactive material to form less harmful ones. For example, reactions between iron particles and certain industrial cleaning solvents can convert the solvents to less toxic or even harmless chemicals.
- Contaminants are *biodegraded* by microbes in the PRB. Microbes are very small organisms that live in soil and groundwater and eat certain contaminants. When microbes digest the contaminants, they change them into water and gases, such as carbon dioxide. (*A Citizen's Guide to Bioremediation* [EPA 542-F-12-003] describes how microbes work.) Organic mulch frequently is used as reactive media in this type of PRB. Mulch barriers consist of plant-based materials, such as compost or wood chips, and naturally contain many different microbes. Groundwater flow through the PRB also releases organic carbon from the mulch wall, creating another reactive zone for contaminants just beyond the wall.

Over time, reactive materials will fill up with contaminants or treatment products and become less effective at cleaning groundwater. When this occurs the contaminated reactive material may be excavated for disposal and replaced with fresh material.

How Long Will It Take?

PRBs may take many years to clean up contaminated groundwater. The cleanup time will depend on factors that vary from site to site. For example, cleanup may take longer where:

- The source of dissolved contaminants (for instance, a leaking drum of solvent) has not been removed.
- The contaminants remain in place because they are not easily dissolved by groundwater.
- Groundwater flow is slow.

Are PRBs Safe?

The reactive materials placed in PRBs are not harmful to groundwater or people. Contaminated groundwater is cleaned up underground so treatment does not expose workers or others onsite to contamination. Because some contaminated soil may be encountered when digging the trench, workers wear protective clothing. Workers also cover loose contaminated soil to keep dust and vapors out of the air before disposing of it. Groundwater is tested regularly to make sure the PRB is working.

How Might It Affect Me?

During construction of the PRB, nearby residents may see increased truck traffic when materials are hauled to the site or hear earth-moving equipment. However, when complete, PRBs require no noisy equipment. Cleanup workers will occasionally visit the site to collect groundwater and soil samples to ensure that the PRB is working. When the reactive materials need to be replaced, the old materials will have to be excavated and hauled to a landfill.

Why Use PRBs?

PRBs are a relatively inexpensive way to clean up groundwater. No energy is needed because PRBs rely on the natural flow of groundwater. The use of some materials, such as limestone, shell fragments, and mulch, can be very inexpensive, if locally available. No equipment needs to be above ground, so the property may continue its normal use, once the PRB is installed.

Construction of a PRB in Sunnyvale, CA

PRBs have been selected or are being used at more than 30 Superfund sites across the country.

Example

A PRB with iron as the reactive material was installed in 1995 to clean up groundwater at a former semiconductor manufacturing site in Sunnyvale, California. Concentrations of industrial solvents in the groundwater plume were extremely high.

Due to changing groundwater flow directions, low-permeability walls were installed below ground and perpendicular to the PRB to direct the flow of contaminated groundwater toward the PRB. The PRB itself is about 8-feet wide, 40-feet long and 20-feet deep. The objective of the PRB is to reduce solvent concentrations to below the cleanup standards set by the State of California. As of 2009, solvent concentrations in groundwater samples collected within the treatment zone remain below the cleanup standards. Use of a PRB has allowed the metals machining facility currently at the site to continue operating during cleanup.

For More Information

For more information on this and other technologies in the Citizen's Guide Series, contact:

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Or visit:
http://www.cluin.org/prb

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A Citizen's Guide to Phytoremediation

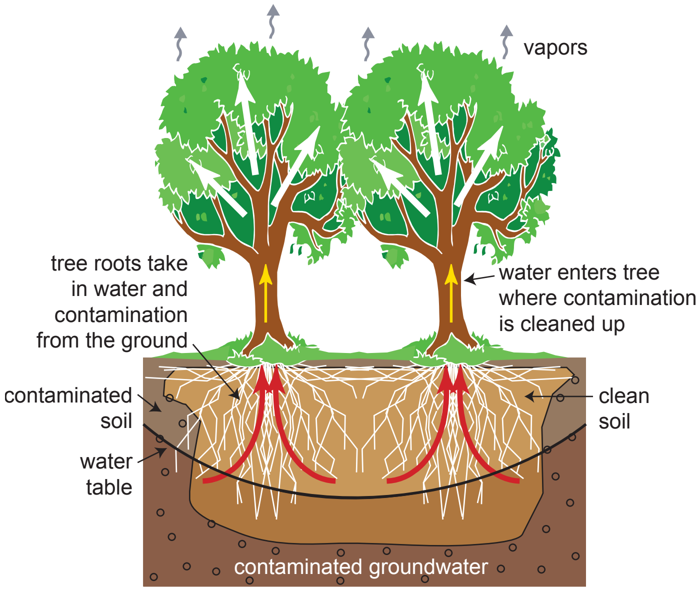
What Is Phytoremediation?

Phytoremediation uses plants to clean up contaminated environments. Plants can help clean up many types of contaminants including metals, pesticides, explosives, and oil. However, they work best where contaminant levels are low because high concentrations may limit plant growth and take too long to clean up. Plants also help prevent wind, rain, and groundwater flow from carrying contaminants away from the site to surrounding areas or deeper underground.

How Does It Work?

Certain plants are able to remove or break down harmful chemicals from the ground when their roots take in water and nutrients from the contaminated soil, sediment, or groundwater. Plants can help clean up contaminants as deep as their roots can reach using natural processes to:

- Store the contaminants in the roots, stems, or leaves.
- Convert them to less harmful chemicals within the plant or, more commonly, the root zone.
- Convert them to vapors, which are released into the air.
- Sorb (stick) contaminants onto their roots where very small organisms called "microbes" (such as bacteria) that live in the soil break down the sorbed contaminants to less harmful chemicals. (See *A Citizen's Guide to Bioremediation* [EPA 542-F-12-003].)



Phytoremediation often is used to slow the movement of contaminated groundwater. Trees act like a pump, drawing the groundwater up through their roots to keep it from moving. This method of phytoremediation is called "hydraulic control." It reduces the movement of contaminated groundwater toward clean areas offsite.

Constructed wetlands are another form of phytoremediation. A wetland may be created at a site to treat acid mine drainage that flows through it or as a final treatment step for water discharged from other treatment systems. Water treated with constructed wetlands generally has very low concentrations of contaminants that need to be removed before it may be discharged into a lake or stream. The construction of wetlands may involve some excavation or regrading of soil at the site in order for water to flow through it without pumping. The area is planted with grasses and other vegetation typical of naturally occurring wetlands in the area.

Certain plants are better at removing contaminants than others. Plants used for phytoremediation must be able to tolerate the types and concentrations of contaminants present. They also must be able to grow and survive in the local climate. Depth of contamination is another factor. Small plants like ferns and grasses have been used where contamination is shallow. Because tree roots grow deeper, trees such as poplars and willows are used for hydraulic control or to clean up deeper soil contamination and contaminated groundwater.

How Long Will It Take?

Phytoremediation may take several years to clean up a site. The cleanup time will depend on several factors. For example, phytoremediation will take longer where:

- Contaminant concentrations are high.
- The contaminated area is large or deep.
- Plants that have a long growing time are used.
- The growing season is short.

These factors vary from site to site. Plants may have to be replaced if they are damaged by extreme weather, pests, or animals. This also will add time to the cleanup.

Is Phytoremediation Safe?

Phytoremediation is a low-risk and attractive cleanup method. Fences and other barriers are constructed to keep wildlife from feeding on contaminated plants. In certain instances, plants may release chemical vapors into the air in a process called "phytovolatilization." When this occurs, workers sample the air to make sure the plants are not releasing harmful amounts of vapors.

How Might It Affect Me?

Phytoremediation cleanups cause little disruption to the site or surrounding community. Initial work may involve grading or tilling of the soil with earth-moving equipment, and backhoes may be needed to plant trees and large shrubs. Residents and businesses near the site may hear equipment noise or detect an odor if fertilizer is added to the soil. Any airborne dust can be minimized by watering down the soil.

Plants used for phytoremediation can make a site more attractive. The use of native plants is encouraged since they are better adapted to the area's conditions and less likely to attract nuisance animals or pests.

Why Use Phytoremediation?

EPA uses phytoremediation for many reasons. It takes advantage of natural plant processes and requires less equipment and labor than other methods since plants do most of the work. Also, the site can be cleaned up without digging up and hauling soil or pumping groundwater, which saves energy. Trees and smaller plants used in phytoremediation help control soil erosion, make a site more attractive, reduce noise, and improve surrounding air quality.

Phytoremediation has been successfully used at many sites, including at least 10 Superfund sites across the country.

Poplar trees at a phytoremediation site.

Example

Phytoremediation is being used to clean up contaminated groundwater near a former disposal area at the Aberdeen Proving Ground in Maryland. This area was used for disposal and burning of industrial and warfare chemicals from 1940 through the 1970s. Chemicals used as industrial degreasers and solvents were found to be a particular problem in the groundwater.

In the spring of 1996, 183 poplar trees were planted in a one-acre area. The trees draw in contaminated groundwater and break down contaminants in the root zone. The groundwater levels near the trees show that they are keeping the plume of contaminants from moving to clean areas. EPA estimates that within 30 years of the start of cleanup, the contaminants in groundwater at the site may be reduced by up to 85 percent.

For More Information

For more information on this and other technologies in the Citizen's Guide Series, contact:

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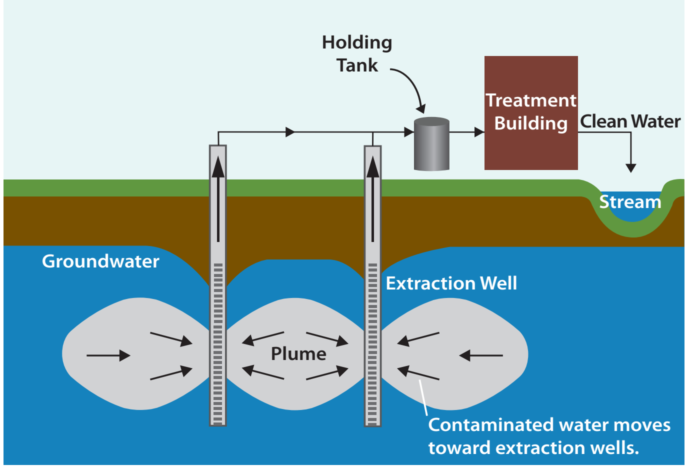
A Citizen's Guide to Pump and Treat

What Is Pump And Treat?

Pump and treat is a common method for cleaning up groundwater contaminated with dissolved chemicals, including industrial solvents, metals, and fuel oil. Groundwater is pumped from wells to an above-ground treatment system that removes the contaminants. Pump and treat systems also are used to "contain" the contaminant plume. Containment of the plume keeps it from spreading by pumping contaminated water toward the wells. This pumping helps keep contaminants from reaching drinking water wells, wetlands, streams, and other natural resources.

How Does It Work?

Pump and treat methods may involve installing one or more wells to extract the contaminated groundwater. Groundwater is pumped from these "extraction wells" to the ground surface, either directly into a treatment system or into a holding tank until treatment can begin. The treatment system may consist of a single cleanup method, such as activated carbon or air stripping, to clean the water. (See *A Citizen's Guide to Activated Carbon* [EPA 542-F-12-001] and *A Citizen's Guide to Air Stripping* [EPA 542-F-12-002].) However, treatment often requires several cleanup methods if the groundwater contains different types of contaminants or high concentrations of a single contaminant. The approach to treatment may be modified as contaminant concentrations decrease.



Example of a Pump and Treat System with Two Extraction Wells.

Once treated water meets regulatory standards, it may be discharged for disposal or further use. For example, treated water may be pumped back underground or into a nearby stream, or a sprinkler system may distribute the water over the ground surface to irrigate soil and plants. Treated water also may be discharged to the area's public sewer system for further treatment at the local wastewater treatment plant. Other wastes produced as a result of treatment, such as sludge or used filters, are disposed of properly.

Is Pump And Treat Safe?

Pump and treat is a safe way to both clean up contaminated groundwater and keep it from moving to other areas where it may affect drinking water supplies, wildlife habitats, or recreational rivers and lakes. Although pumping brings contamination to the ground surface, it does not expose people to that contamination. A pump and treat system is monitored to ensure the extraction wells and treatment units operate as designed. Also, the groundwater is sampled to ensure the plume is decreasing in concentration and is not spreading.

How Long Will It Take?

Pump and treat may last from a few years to several decades. The actual cleanup time will depend on several factors, which vary from site to site. For example, it may take longer where:

- Contaminant concentrations are high, or the contamination source has not been completely removed.
- The contaminant plume is large.
- Groundwater flow is slow, or the flow path is complex.

How Might It Affect Me?

People living or working near the site may see increased truck traffic while the system is being built as drill rigs and construction supplies arrive at the site. They also may hear the machinery used to drill wells or construct the treatment system. Treatment systems usually are designed to minimize noise while operating. Because pump and treat cleanups can take a long time, systems can be designed so that other site activities may continue during cleanup. For example, the treatment system may be constructed in a location as far as possible from an office building or parking lot. It also may be enclosed by a fence or a shed so that it is less obvious.

Why Use Pump And Treat?

Pump and treat is used to remove a wide range of contaminants that are dissolved in groundwater. Pump and treat typically is used once the source of groundwater contamination, such as leaking drums and contaminated soil, has been treated or removed from the site. It also is used to contain plumes so that they do not move offsite or toward lakes, streams, and water supplies. Pump and treat is the most common cleanup method for groundwater. It has been selected or is being used at over 800 Superfund sites across the country.

Groundwater Pumping Wells

Groundwater Treatment Building

Indoor Treatment Facility

Outdoor Treatment Facility

Example

The Baird and McGuire Superfund site in Massachusetts was contaminated when chemicals stored in tanks leaked into the soil and groundwater. The contaminated groundwater plume flowed offsite, contaminating and closing the town's main water supply. Since 1993, a pump and treat system has been containing the plume and cleaning up groundwater.

Pump and treat began after much of the contaminated soil at the site was excavated for treatment. Eight pumping wells were installed at the site (seven still operate) typically pumping a total of about 127 gallons of groundwater per minute. The treatment plant includes a metals removal system, air strippers, and activated carbon units to remove a wide range of contaminants. It also has filters and a sludge disposal system. Treated water is pumped back underground at the site. Groundwater sampling has shown that treatment continues to protect human health and the environment by containing the plume and removing contaminants. The system is expected to operate well into the future.

For More Information

For more information on this and other technologies in the Citizen's Guide Series, contact:

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A Citizen's Guide to Soil Vapor Extraction and Air Sparging

What Are Soil Vapor Extraction And Air Sparging?

Both soil vapor extraction, or "SVE," and air sparging extract (remove) contaminant vapors from below ground for treatment above ground. Vapors are the gases that form when chemicals evaporate. SVE extracts vapors from the soil *above* the water table by applying a vacuum to pull the vapors out. Air sparging, on the other hand, pumps air underground to help extract vapors from groundwater and wet soil found *beneath* the water table. The addition of air makes the chemicals evaporate faster, which makes them easier to extract with another technology, such as SVE.

Both methods are used for chemicals that evaporate easily—like those found in solvents and gasoline. These chemicals are known as "volatile organic compounds," or "VOCs."

How Do They Work?

Extraction:

SVE involves drilling one or more *extraction* wells into the contaminated soil to a depth above the water table, which must be deeper than 3 feet below the ground surface. Attached to the wells is equipment (such as a blower or vacuum pump) that creates a vacuum. The vacuum pulls air and vapors through the soil and up the well to the ground surface for treatment.

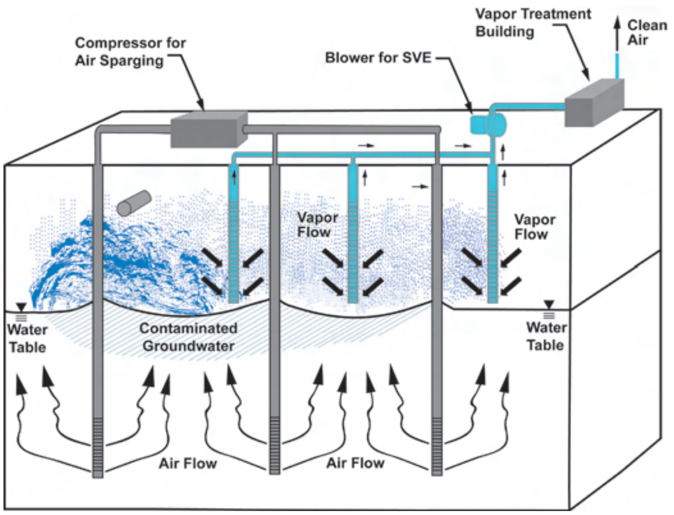

Illustration of a combined air sparging and SVE system.

Sometimes the ground must be paved or covered with a tarp to make sure that the vacuum does not pull air from above into the system. Pulling in clean air would reduce the efficiency of the cleanup. The cover also prevents any vapors from escaping from the ground to the air above.

Air sparging involves drilling one or more *injection* wells into the groundwater-soaked soil below the water table. An air compressor at the surface pumps air underground through the wells. As air bubbles through the groundwater, it carries contaminant vapors upward into the soil above the water table. The mixture of air and vapors is then pulled out of the ground for treatment using SVE.

Treatment:

Extracted air and contaminant vapors, sometimes referred to as "off-gases," are treated to remove any harmful levels of contaminants. The off-gases are first piped from the extraction wells to an air-water separator to remove moisture, which interferes with treatment. The vapors are then separated from the air, usually by pumping them through containers of activated carbon. The chemicals are captured by the carbon while clean air exits to the atmosphere. (See *A Citizen's Guide to Activated Carbon Treatment* [EPA 542-12-001.]).

Filter materials other than activated carbon may be used. In a process called "biofiltration," tiny microbes (bacteria) are added to break down the vapors into gases, such as carbon dioxide and water vapor. Another option is to destroy vapors by heating them to high temperatures.

How Long Will They Take?

Cleaning up a site using SVE or air sparging may take several years. The actual cleanup time depends on several factors. For example, cleanup may take longer where:

- Contaminant concentrations are high.
- The contaminated area is large or deep.
- The soil is dense or moist, which slows the movement of vapors.

These factors vary from site to site.

Are SVE And Air Sparging Safe?

When properly designed and operated, SVE and air sparging pose little risk to site workers or the community. Treatment of the vapors involves no harmful chemicals that must be transported to the site. Chemical vapors are contained from extraction to treatment so they cannot be accidentally inhaled by anyone nearby. Only clean air that meets air quality standards is released. The air released to the atmosphere following treatment may be sampled to make sure all harmful vapors have been removed or destroyed.

How Might It Affect Me?

Area neighborhoods may experience some increased truck traffic as the equipment for SVE or air sparging is delivered and later removed. Installation of the systems involves the use of drilling rigs and sometimes other heavy machinery to install wells, blowers, and treatment equipment. Sheds or larger buildings may be built to house the treatment systems, keeping any noise to a minimum. Workers will visit these systems regularly to ensure they are working.

Why Use Soil Vapor Extraction And Air Sparging?

SVE and air sparging are efficient ways to remove VOCs above and below the water table. Both methods can help clean up contamination under buildings, and cause little disruption to nearby activities when in full operation. SVE and air sparging are often used together. SVE and air sparging are being used or have been selected for use at approximately 285 and 80 Superfund sites, respectively.

Pipes transport vapors from the underground SVE extraction well to treatment.

Above-ground treatment system includes two tanks of activated carbon.

Example

Both SVE and air sparging are being used to clean up several acres of contaminated soil and groundwater at the Vienna PCE Superfund site in West Virginia. Two dry cleaning facilities contaminated the area with PCE (also known as perchloroethene or "perc"), a solvent used to clean clothing, forcing the shutdown of the town's drinking water wells.

In 2005, construction of the cleanup systems was completed and included 74 air sparging wells, 34 extraction wells, and four treatment buildings. The off-gases are piped to an air-water separator, followed by containers of activated carbon for treatment. By 2010, 1,618 pounds of PCE had been removed and PCE concentrations had decreased by as much as 99% in some wells. EPA will continue to operate the systems and monitor PCE levels until cleanup objectives have been reached throughout the site.

For More Information

For more information on this and other technologies in the Citizen's Guide Series, contact:

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Or visit:
www.cluin.org/sve
www.cluin.org/airsparging

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A Citizen's Guide to Solidification and Stabilization

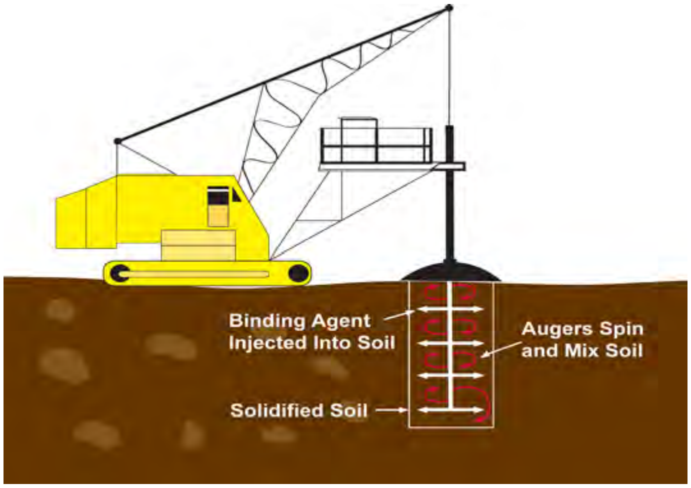
What Are Solidification And Stabilization?

Solidification and stabilization refer to a group of cleanup methods that prevent or slow the release of harmful chemicals from wastes, such as contaminated soil, sediment, and sludge. These methods usually do not destroy the contaminants. Instead, they keep them from "leaching" above safe levels into the surrounding environment. Leaching occurs when water from rain or other sources dissolves contaminants and carries them downward into groundwater or over land into lakes and streams.

Solidification binds the waste in a solid block of material and traps it in place. This block is also less permeable to water than the waste. Stabilization causes a chemical reaction that makes contaminants less likely to be leached into the environment. They are often used together to prevent people and wildlife from being exposed to contaminants, particularly metals and radioactive contaminants. However, certain types of organic contaminants, such as PCBs and pesticides, can also be solidified.

How Does It Work?

Solidification involves mixing a waste with a binding agent, which is a substance that makes loose materials stick together. Common binding agents include cement, asphalt, fly ash, and clay. Water must be added to most mixtures for binding to occur; then the mixture is allowed to dry and harden to form a solid block.



Binding agents can be injected into soil and mixed using augers.

Similar to solidification, stabilization also involves mixing wastes with binding agents. However, the binding agents also cause a chemical reaction with contaminants to make them less likely to be released into the environment. For example, when soil contaminated with metals is mixed with water and lime — a white powder produced from limestone — a reaction changes the metals into a form that will not dissolve in water.

Additives can be mixed into the waste while still in the ground (often referred to as "in situ"). This usually involves drilling holes using cranes with large mixers or augers, which both inject the additives underground and mix them with the waste. The number of holes needed depends on the size of the augers and the contaminated area. Dozens of holes may need to be drilled. When the waste is shallow enough, the contaminated soil or waste is excavated and additives are mixed with it above ground (often referred to as "ex situ"). The waste is either mixed using backhoes and front end loaders or placed in machines called "pug mills." Pug mills can grind and mix materials at the same time.

Solidified or stabilized waste mixed above ground is either used to fill in the excavation or transported to a landfill for disposal. Waste mixed in situ is usually covered with a "cap" to prevent water from contacting treated waste (See *A Citizen's Guide to Capping* [EPA 542-12-004].)

How Long Will It Take?

Solidification and stabilization may take weeks or months to complete. The actual time it takes will depend on several factors. For example, they may take longer where:

- The contaminated area is large or deep.
- The soil is dense or rocky, making it harder to mix with the binding agent.
- Mixing occurs above ground, which requires excavation.
- Extreme cold or rainfall delays treatment.

Are Solidification And Stabilization Safe?

The additives used in solidification and stabilization often are materials used in construction and other activities. When properly handled, these materials do not pose a threat to workers or the community. Water or foam can be sprayed on the ground to make sure that dust and contaminants are not released to the air during mixing. If necessary, the waste can be mixed inside tanks, or the mixing area can be covered to minimize dust and vapors. The final solidified or stabilized product is tested to ensure that contaminants do not leach. The strength and durability of the solidified materials are also tested.

Large augers inject and mix binding agent with contaminated soil.

How Might It Affect Me?

Nearby residents or businesses may notice increased truck traffic as equipment and additives are brought to the site or as treated waste is transported to a landfill. They also may hear earth-moving equipment as waste is excavated or mixed. When cleanup is complete, the land often can be redeveloped.

Why Use Solidification Or Stabilization?

Solidification and stabilization provide a relatively quick and lower-cost way to prevent exposure to contaminants, particularly metals and radioactive contaminants. Solidification and stabilization have been selected or are being used in cleanups at over 250 Superfund sites across the country.

Contaminated soil mixed with cement in a pug mill is spread on the ground as pavement.

Example

Solidification and stabilization were used to clean up contaminated sludge and soil at the South 8th Street Landfill Superfund site in Arkansas. From the 1960s to 1970s, municipal and industrial wastes were disposed at the site, including a 2.5-acre pit of waste-oil sludge. In the 1980s, that area was found to be contaminated with oily wastes, PCBs, pesticides, and lead.

In 1999, cranes with augers were used to inject and mix limestone, fly ash, and Portland cement with 40,000 cubic yards of sludge and soil in the pit. These additives helped solidify the mixture as well as stabilize the lead and other metals. The hardened material was left in place and covered with a soil cap. Evaluations in 2004 and 2009 indicated that the cleanup approach is still protecting human health and the environment. The site has been deleted from the National Priorities List, the list of the nations most serious hazardous waste sites.

For More Information

For more information on this and other technologies in the Citizen's Guide Series, contact:

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United States Environmental Protection Agency

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A Citizen's Guide to Thermal Desorption

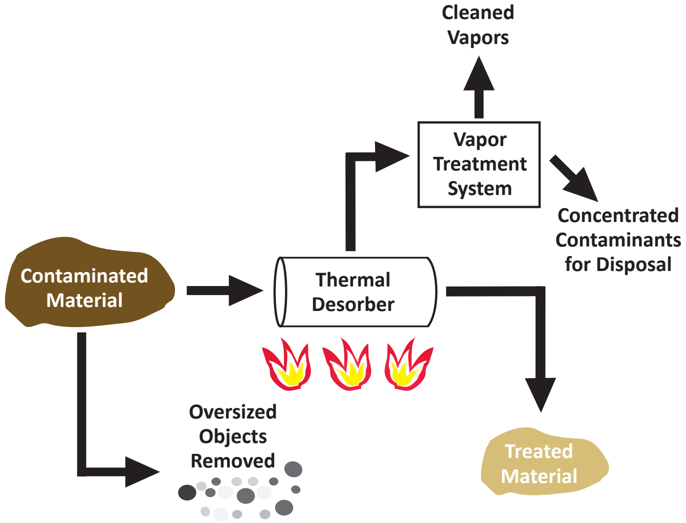
What Is Thermal Desorption?

Thermal desorption removes organic contaminants from soil, sludge or sediment by heating them in a machine called a "thermal desorber" to evaporate the contaminants. Evaporation changes the contaminants into vapors (gases) and separates them from the solid material. Many organic contaminants can be removed by thermal desorption. These include volatile organic compounds or "VOCs" and some semi-volatile organic compounds or "SVOCs." VOCs such as solvents and gasoline evaporate easily when heated. SVOCs require higher temperatures to evaporate and include diesel fuel, creosote (a wood preservative), coal tar, and several pesticides. Thermal desorption generally is not used to treat metals but can partially remove metals like mercury and arsenic, which evaporate at the temperatures sometimes reached in thermal desorption.

A thermal desorber is not the same as an incinerator, which heats contaminated materials to temperatures high enough to destroy the contaminants. (See *A Citizen's Guide to Incineration* [EPA 542-12-010].)

How Does It Work?

Thermal desorption involves excavating soil or other contaminated material for treatment in a thermal desorber. The desorber may be assembled at the site for onsite treatment, or the material may be loaded into trucks and transported to an offsite thermal desorption facility. To prepare the soil for treatment, large rocks or debris first must be removed or crushed. The smaller particle size allows heat to more easily and evenly separate contaminants from the solid material. If the material is very wet, the water may need to be removed to improve treatment. This water removed may require treatment using other methods.



Thermal desorber heats contaminated material to evaporate contaminants.

The prepared soil is placed in the thermal desorber to be heated. Low-temperature thermal desorption is used to heat the solid material to 200-600ºF to treat VOCs. If SVOCs are present, then high-temperature thermal desorption is used to heat the soil to 600-1000ºF.

Gas collection equipment captures the contaminated vapors. Vapors often require further treatment, such as removing dust particles. The remaining organic vapors are usually destroyed using a thermal oxidizer, which heats the vapors to temperatures high enough to convert them to carbon dioxide and water vapor. At some sites with high concentrations of organic vapors, the vapors may be cooled and condensed to change them back to a liquid form. The liquid chemicals may be recycled for reuse, or treated by incineration. If the concentrations of contaminants are low enough, and dust is not a problem, the vapors may be released without treatment to the atmosphere.

Often, treated soil can be used to fill in the excavation at the site. If the treated soil contains contaminants that do not evaporate, such as most metals, they may be disposed of and capped onsite, or transported offsite to an appropriate landfill.

How Long Will It Take?

Thermal desorption may take from a few weeks to a few years. The actual cleanup time will depend on several factors. For example, thermal desorption may take longer where:

- The contaminated area is large or deep.
- Contaminant concentrations are high.
- The soil contains a lot of dust, clay, or organic material, which causes contaminants to stick to the soil and not evaporate easily.

- A lot of debris must be crushed or removed.
- The capacity of the desorber is small. (Most thermal desorbers can clean over 25 tons of contaminated material per hour.)

These factors vary from site to site.

Is Thermal Desorption Safe?

Thermal desorption has been safely used at many Superfund sites. EPA makes sure that materials are handled properly at each stage of the process. Workers take measures, such as covering loose soil, to control dust and vapors during excavation and treatment. If necessary, they collect and treat the gases that are produced in the desorber.

How Might It Affect Me?

Excavating soil and other contaminated materials for thermal desorption involves the use of heavy machinery, such as backhoes and bulldozers, which may be noisy. Excavation of soil and sediment may release dust and vapors into the air but this is controlled with covers, foam, or water. Nearby residents and businesses also may see increased truck traffic when excavation equipment and thermal desorption systems are delivered to the site. If an offsite desorber is used, truckloads of soil must be transported from the site to the desorber.

Why Use Thermal Desorption?

Thermal desorption is typically used to clean up soil that is contaminated with VOCs and SVOCs at depths shallow enough to reach through excavation. Thermal desorption may be faster and provide better cleanup than other methods, particularly at sites that have high concentrations of contaminants. A faster cleanup may be important if a contaminated site poses a threat to the community or needs to be cleaned up quickly so that it can be reused.

Onsite thermal desorber.

Thermal desorption is being used or has been selected for use at over 70 Superfund sites across the country.

Example

High-temperature thermal desorption was used to clean up contaminated soil at the Industrial Latex Superfund site in New Jersey. From 1951 to 1983, Industrial Latex manufactured rubber and adhesives, contaminating soil with SVOCs, PCBs, and arsenic.

From April 1999 to June 2000, about 53,600 cubic yards of contaminated material were excavated to depths of up to 14 feet. Materials greater than 2 inches in diameter were removed before placing the soil in the desorber and heating it to 900°F. About 225 tons of contaminated soil were treated each day. A small amount of treated soil had to be placed back in the desorber a second time to meet cleanup goals for PCBs, SVOCs, and arsenic. The cleaned soil was used to backfill the areas that had been excavated.

Vapors from the desorber passed through scrubbers and filters that removed dust particles and a filter that removed contaminant vapors. Air quality was monitored daily to make sure the air released from the desorber met permitted levels.

For More Information

For more information on this and other technologies in the Citizen's Guide Series, contact:

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Or visit:
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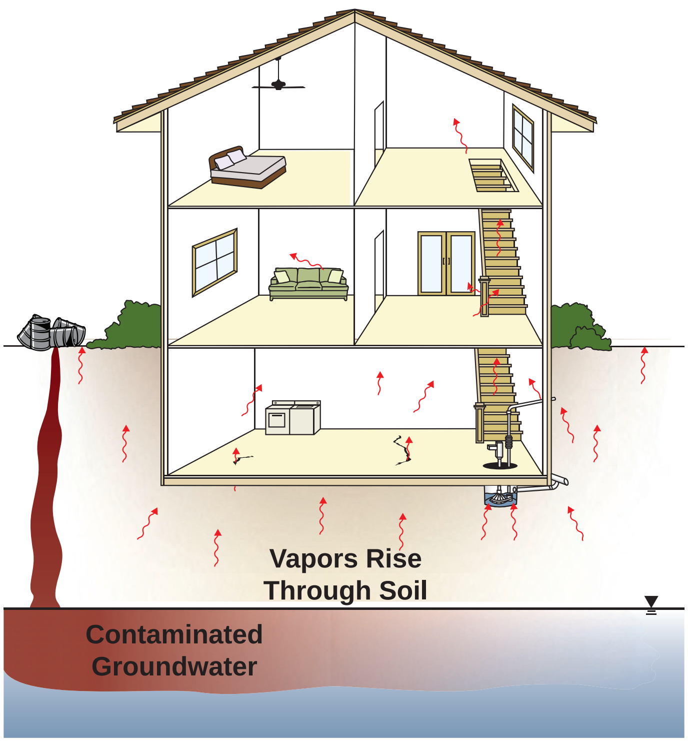
A Citizen's Guide to Vapor Intrusion Mitigation

What Is Vapor Intrusion Mitigation?

Vapor intrusion is the movement of chemical vapors from contaminated soil and groundwater into nearby buildings. Vapors primarily enter through openings in the building foundation or basement walls — such as cracks in the concrete slab, gaps around utility lines, and sumps. It also is possible for vapors to pass through concrete, which is naturally porous. Once inside the home or workplace, vapors may be inhaled posing immediate or long-term health risks for the occupants. In rare cases, the buildup of vapors, such as those from gasoline, may cause explosive conditions. Risks will depend on the types of chemical vapors and their concentrations, how much time people spend in the building, and the building's ventilation. Vapor concentrations will be higher indoors when windows and doors remain closed.

Mitigation methods, which lessen the effects of vapor intrusion, may be needed until contaminated soil or groundwater is cleaned up. Mitigation methods are available for both existing buildings and those planned for construction near the contaminated area.



Vapor intrusion into a home.

How Does It Work?

Vapor intrusion mitigation methods are classified as either "passive" or "active." Passive methods prevent the entry of chemical vapors into the building, while active methods change the pressure difference between the sub-slab and the inside of the building to keep vapors out. Passive mitigation methods tend to be cheaper, while active methods tend to be more effective. Examples of each include:

Passive Vapor Intrusion Mitigation Methods:

- **Sealing openings** involves filling in cracks in the floor slab and gaps around pipes and utility lines found in basement walls. Concrete can be poured over unfinished dirt floors.
- Installing **vapor barriers** involves placing sheets of "geomembrane" or strong plastic beneath a building to prevent vapor entry. Vapor barriers are best installed during building construction, but can be installed in existing buildings that have crawl spaces.
- **Passive venting** involves installing a venting layer beneath a building. Wind or the build-up of vapors causes vapors to move through the venting layer toward the sides of the building where it is vented outdoors. A venting layer can be installed prior to building construction as well as within existing buildings. It is usually used with a vapor barrier.

Active Vapor Intrustion Mitigation Methods:

- **Sub-slab depressurization** involves connecting a blower (an electric fan) to a small suction pit dug into the slab in order to vent vapors outdoors. (Most common method.)
- **Building over-pressurization** involves adjusting the building's heating, ventilation, and air-conditioning system to increase the pressure indoors relative to the sub-slab area. This method is typically used for office buildings and other large structures.

How Long Will It Take?

Mitigation will be needed to prevent vapor migration into buildings as long as vapor intrusion poses a health risk to occupants. This may be several years, or even decades, until cleanup of soil and groundwater is complete.

Is It Safe?

Vapor intrusion mitigation systems are quite safe to use and will improve the quality of the indoor air by removing chemical vapors due to vapor intrusion as well as radon (another health risk) and moisture, which may lead to mold growth. However, mitigation systems will not reduce vapors from indoor sources of chemicals, such as paints, plastic items, and hobby supplies.

Until the threat of vapor intrusion is gone, mitigation systems should be inspected regularly to make sure they are working correctly. For example, floors and walls are checked to see that no new cracks develop, a geomembrane in a crawlspace is checked for rips and holes, and electric fans are checked to ensure they are working correctly. Homeowners should not turn off the electric fans until EPA or state agency notifies them that it is appropriate to do so. Homeowners should report broken fans and vent pipes to the lead agency.

How Might It Affect Me?

An occupant of a home or office constructed with a vapor mitigation system will not likely notice it. However, the installation of systems in existing homes typically takes one or two days, and workers may need to access crawl spaces or indoor living areas. They may need to pull back carpet or move furniture to find and seal cracks or to drill holes in the foundation for sub-slab pipes. They typically place these pipes near the basement walls, in closets, and in low-traffic areas for the convenience of the homeowner. The vent pipes and fan may be visible on the outside of the house. However, in some cases, the pipes may be run through a closet to the attic and vented through the roof. Later, workers may need to visit homes periodically to inspect mitigation systems to ensure the systems are working properly.

Homeowners may notice the hum of the electric fans, if they have a depressurization system. These fans use less electricity than an LED television; electric bills will rise slightly.

Why Use Vapor Intrusion Mitigation?

Vapor intrusion mitigation systems are installed to reduce health risks in buildings where chemical vapors from contaminated soil and groundwater may be inhaled by indoor occupants. They also may be installed as a precaution where vapor intrusion might occur in the future. Installing a system during building construction typically is cheaper, more effective, and less disruptive than waiting until after construction. Depressurization systems offer the added benefit of reducing radon, moisture, and mold inside the building.

Mitigation systems have been installed and operated at hundreds of homes near Superfund sites and other contaminated sites across the country.

Typical fan and vent pipe.

Example

Mitigation is reducing possible risks from vapor intrusion at 43 homes near the Nyanza Superfund site in Massachusetts. Dye manufacturing from the 1910s to 1978 contaminated groundwater with trichloroethene (TCE) and other chemicals. By the 1980s, a plume of groundwater contamination was found to extend beneath a nearby neighborhood. Sampling of indoor air, sub-slab air, and groundwater showed that vapor intrusion was occurring, and TCE concentrations posed a risk to some homeowners. Vapor intrusion also had the potential to occur at several other homes.

As a result, EPA installed depressurization systems in homes located above the most contaminated groundwater where vapor intrusion is most likely to be a problem. Before installing the systems in 2007, EPA sealed cracks in basement walls and floors, and covered sump pits. In homes with dirt basements, they poured a concrete floor or installed a vapor barrier. Following installation, each depressurization system was tested to ensure that it worked properly. The systems are inspected annually to ensure that they continue to work.

For More Information

For more information on this and other technologies in the Citizen's Guide Series, contact:

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A Citizen's Guide to Vertical Engineered Barriers

What Are Vertical Engineered Barriers?

A vertical engineered barrier, or "VEB," is a wall built below ground to control the flow of groundwater. VEBs may be used to divert the direction of contaminated groundwater flow to keep it from reaching drinking water wells, wetlands, or streams. They also may be used to contain and isolate contaminated soil and groundwater to keep them from mixing with clean groundwater. VEBs differ from permeable reactive barriers in that they do not clean up contaminated groundwater. (See *A Citizens Guide to Permeable Reactive Barriers* [EPA 542-F-12-015].) However, cleanup methods often are used together with VEBs to treat the isolated soil or groundwater.

How Do They Work?

VEBs are made of impermeable or slightly permeable materials, which means they prevent or minimize the flow of water and contaminants through the wall. A slurry wall is the most common type of VEB. It is constructed by digging a narrow trench, usually 2 to 4 feet wide with a backhoe or long-reach excavator. The trench is filled with slurry, which consists of soil mixed with water and clay. A type of clay called "bentonite" is used most often because it expands when wet to fill gaps or holes in the VEB. Cement may be added to make the slurry wall stronger.

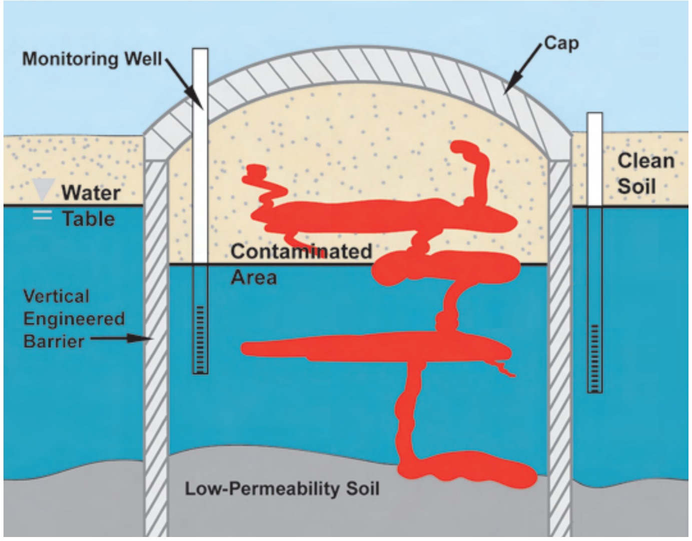

Illustration of a VEB containment system around a contaminated area

A VEB also can be constructed using sheet pilings made of steel, vinyl, or other materials. Sheet pilings are large sheets linked together at their edges to form a wall. Equipment is used to hammer or vibrate the sheets into the ground.

Where possible, the bottom of the VEB is "keyed into" a low-permeability layer of soil or bedrock. This means the bottom of the wall extends several inches into the soil or to the top of the bedrock, which helps to keep groundwater from seeping beneath the wall. A protective cap may be installed atop the VEB to prevent damage from vehicle traffic or other activities. A larger impermeable cap often is placed over the entire contaminated area enclosed by the VEB to prevent rain water and snow melt from entering it. (See *A Citizen's Guide to Capping* [EPA 542-F-12-004].)

Even when surrounded by a VEB and cap, contaminated groundwater may build up in the isolated area or move outward through small openings in the VEB toward clean areas. To prevent this, wells may be drilled within the isolated area to pump out groundwater. Contaminated groundwater that has been pumped to the ground surface usually will require treatment.

The VEB, cap, and pumping wells are maintained and monitored to ensure the contaminated area remains isolated and that contaminated groundwater does not spread to clean areas.

How Long Will It Take?

Building a VEB may take anywhere from several days to several months. Construction of a VEB may take longer where:

- The contaminated area is large or deep.
- Soil is hard or rocky.
- The VEB is wide.

These factors vary from site to site. Some VEBs may stay in place permanently.

Are Vertical Engineered Barriers Safe?

The materials used to construct a VEB generally pose little risk to people or the environment. VEBs are effective at keeping contaminated groundwater from flowing toward clean areas. A VEB will continue to be protective as long as it is properly inspected and maintained. VEBs and the groundwater are monitored to make sure that there is no damage to the wall and contaminants are not moving to other areas.

How Might It Affect Me?

Residents near the site may see increased truck traffic as materials are brought to the site. Construction of the VEB may involve backhoes, pile drivers, or other noisy machines. If sheet pilings are hammered or vibrated into place, nearby residents also may feel the vibrations. If buildings or people are nearby, monitoring can be conducted to make sure noise and vibration levels do not exceed limits. Workers often use equipment that cause as little noise and vibration as possible. Workers will need to access the area for VEB maintenance and repairs or to collect groundwater samples to ensure the VEB is working. At sites where groundwater is being removed and treated, workers may be present for longer periods of time.

Why Use Vertical Engineered Barriers?

VEBs may be selected at sites where cleanup of contaminated groundwater is difficult and expensive, or cannot be completed before contamination spreads to areas where people and wildlife can come in contact with it. VEBs are also helpful in cases where cleanup methods could push contaminants to uncontaminated areas. VEBs typically are less expensive to build and maintain than other types of technologies, especially in large contaminated areas. VEBs have been selected or are being used at dozens Superfund sites across the United States.

Installation of sheet piling

Excavation of a slurry wall trench

Example

Spills of wood-treating chemicals contaminated the soil and groundwater at the Taylor Lumber and Treating Superfund site in Oregon. A 2,040-foot long, 2½-foot wide, VEB was constructed of bentonite and soil to isolate a plume of contaminated groundwater. The VEB encloses a 6-acre area and extends 14 to 16 feet below ground where it is keyed into bedrock. A protective asphalt cap installed over the VEB and contaminated area protect the VEB from heavy equipment traffic and prevent rainwater from soaking into the area it encloses.

As part of the long-term operation and maintenance of the VEB, groundwater is pumped from four wells in the contaminated area to keep contaminants and groundwater from seeping outside the wall. Groundwater outside the VEB is regularly sampled to make sure contaminants remain in the enclosed area and do not pose a threat to human health or the environment.

For More Information

For more information on this and other technologies in the Citizen's Guide Series, contact:

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