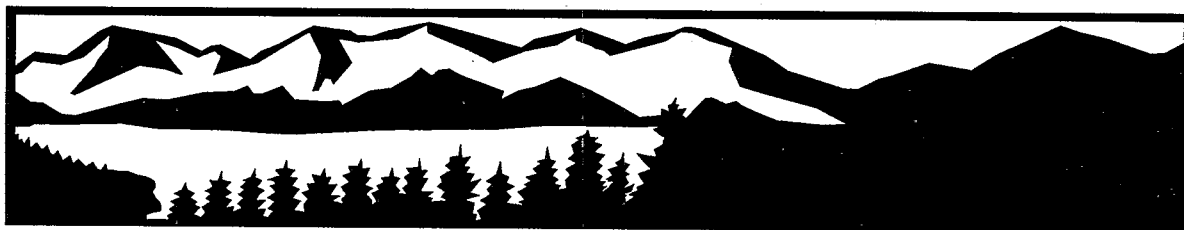


Common Cleanup Methods



At Superfund Sites



INTRODUCTION

This booklet contains one page fact sheets on some of the common clean-up methods used at hazardous waste sites across the nation. It is meant to help you understand more about the various treatment methods.

It answers such questions as: What is the type of clean-up method?, How does it work?, Where is it used most?, and What are the reasons for using it?

The treatments discussed in this booklet are:

- Activated Carbon Treatment
- Air Stripping
- Bioremediation
- Capping
- Excavation
- Groundwater Monitoring
- Immobilization
- In Situ Vitrification
- Incineration
- Leachate Collection
- Pump and Treat
- Soil Washing
- Thermal Desorption

If you have more questions about the clean-up methods mentioned in this booklet or would like more information on the U.S. Environmental Protection Agency's Superfund hazardous waste cleanup program, please call the *Superfund Hotline* at 1-800-424-9346 or 1-800-535-0202.



EPA Facts About *Activated Carbon Treatment*

June 1992

What is activated carbon treatment?

The process of activated carbon treatment makes use of a particular physical attribute of the chemical carbon. Carbon has the ability to adsorb, or grab onto passing organic molecules and hold them in pores within the carbon granule. Organic molecules are those that contain carbon and are usually associated with natural processes. When a waste stream containing organic contaminants is pumped through a filter of carbon granules, a large portion of the contaminant becomes trapped in the pores. Essentially the same process is used in the filter of most household aquariums.

After a certain length of time, all the surface area inside the pores is used up and the filter is said to be saturated or spent. At this point, the carbon in the filter must be replaced or regenerated. This regeneration is usually accomplished by heating the carbon and passing an air stream through it. The heat loosens the organic molecules, and they are swept away by the air stream. The freed organic molecules are subsequently collected and treated or destroyed.

Most hazardous waste treatment applications use adsorption units that contain granular activated carbon (GAC). Figure 1 presents the essential parts of the GAC treatment method.

What is adsorption?

Adsorption is the adherence (ability to stick to) of one substance to the surface of another by physical or chemical processes. The treatment of waste streams using the adsorption process is essentially a method of transferring and concentrating the contaminants from the waste stream to another material. The most commonly used material is activated carbon in granule form.

Activated carbon granules are highly porous (full of holes). Adsorption takes place on the walls of these pores because of an imbalance of forces on the atoms of the walls. The adsorption of organic molecules serves to balance these forces.

Adsorption treatment usually involves pumping the waste stream through a container (normally columns) of activated carbon granules. Relatively large spaces between granules (voids) ensure that the waste stream is allowed to move through the column and contacts many granules. The treated waste stream leaves the column with reduced concentrations of contaminants. It can be directed into a series of these columns; each column removing more and more of the contaminant. Some duplication is built into the system to allow for some columns to be taken out of service while the activated carbon is replaced or regenerated. This allows the operation to proceed with minimal delays. The activated carbon in each column will eventually become saturated and can be disposed of in approved landfills, or regenerated as mentioned above.

What is the value of GAC?

Activated carbon is an effective and reliable means of removing organic contaminants. It is suitable for treating a wide range of organics over a broad concentration range. The use of several carbon adsorption columns at a site can provide considerable flexibility. Several columns can be arranged in series (one after the other) to increase the service life between regeneration of any particular column. They can also be arranged in parallel so that a maximum volume can be treated at any one time. The piping between columns would allow for one or more column to be taken out of service to be regenerated while the other columns continue to work.

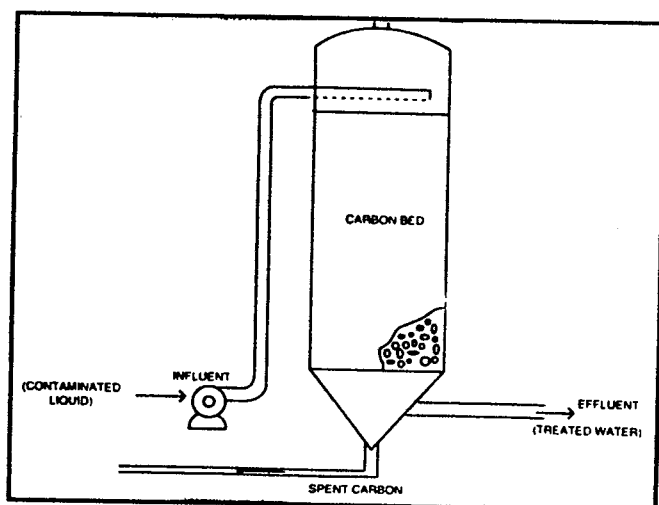


Figure 1 Schematic Diagram of Fixed-Bed GAC System

The most obvious maintenance consideration associated with activated carbon is the regeneration of the saturated carbon for re-use. Regeneration must be performed for each column as it becomes saturated so that the carbon can be restored as close as possible to its original condition. If regeneration is not used, the carbon can be disposed of in an approved landfill. Most other operations and maintenance procedures are minimal for this technology if appropriate automatic controls have been installed.

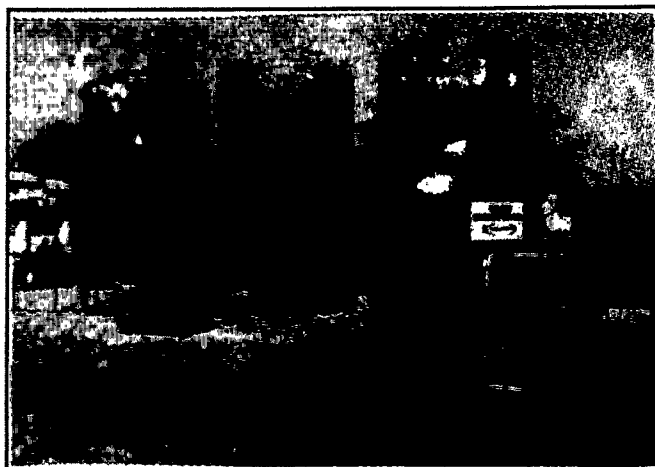


Figure 2 Arrangement of Carbon Adsorption Columns

What are the applications of granular activated carbon (GAC)?

Activated carbon is a well developed technology which is widely used in the treatment of hazardous waste streams. It is especially well suited for the removal of organic contaminants from liquid wastes.

Some metals and inorganic chemicals may also be removed from a waste stream with some success, including antimony, arsenic, bismuth, chromium, tin, silver, mercury, cobalt, zirconium, chlorine, bromine, and iodine.

Carbon adsorption is generally accepted for use in the control of volatile organic compounds (VOCs), hydrogen sulfide, and some radioactive elements such as iodine, krypton, and xenon. VOCs are organic compounds that evaporate rapidly when heated or disturbed in any way. The odor that surrounds us when we pump gasoline into the tank is a good example. Carbon adsorption can also be used to control sulfur oxides, nitrogen oxides, and carbon monoxide.

Carbon adsorption is widely used in industry for air pollution and odor control. Often these systems are operated in association with a recovery and re-use program for the contaminants.

Adsorption by activated carbon has a long history of use as a treatment for municipal, industrial and hazardous wastes. The relative effectiveness of carbon adsorption is related to the chemical composition and molecular structure of the contaminant.

What is the technology of GAC?

Carbon is an excellent adsorbent material because of its large porous surface area. This area is made up of many different surfaces which are highly attractive to many different kinds of contaminants. Regular carbon is made into activated carbon through a process that produces an extensive network of internal pores.

The process of adsorption takes place in three steps. First, the contaminant moves to the external surface of the activated carbon granules. It then moves deeper into the pore structure. Finally, a physical or chemical bond forms between the contaminant and the internal carbon surface.

What process residuals result from GAC?

The main residual produced from an activated carbon system is the spent carbon which contains the hazardous contaminants. When the carbon is regenerated, the contaminants are released from the carbon and must be recovered or destroyed. If the carbon cannot be economically regenerated, it must be treated and disposed of in an approved landfill.

For more information about Activated Carbon Treatment you may contact EPA at the following address:

*U.S. Environmental Protection Agency
ATTN: Superfund Hotline
401 M Street, S.W.
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1-800-424-9346 or 1-800-535-0202*



EPA Facts About *Air Stripping*

June 1992

What is air stripping?

Air stripping is a process used to remove volatile or certain semi-volatile organic compounds from contaminated groundwater or surface water. Organic compounds are those that contain carbon and are usually associated with life processes. Volatile organic compounds, or VOCs as they are called, are chemicals which tend to vaporize rapidly when heated or disturbed in any way. An example would be the gasoline fumes that you smell as you fill the tank on your car. In air stripping, these vapors are transferred from the water in which they were dissolved into a passing air stream. This air stream can be further treated to allow for the final collection and re-use or destruction of the VOCs.

How does air stripping work?

Air stripping is used to remediate (clean up) groundwater or surface water that has been contaminated by VOCs. This method of remediation is often accomplished in a packed tower that is attached to an air blower. This "packed tower" is simply a large metal cylinder that is packed with material. The water stream is pumped into the top and the air stream is pumped into the bottom. The material in the tower is designed to force the water stream to trickle down through various channels and air spaces. Meanwhile, the air stream is being forced into the bottom and flows upward, exiting at the top. This is called "counter-current" flow. As the two streams flow past each other, the VOCs tend to vaporize out of the disturbed water stream and are collected in the air stream.

Figure 1 presents a diagram of the air stripping process. The contaminated surface water or groundwater is pumped from its source and is collected in large pre-treatment storage tanks. The water is then pumped into the top of the tower and leaves from the bottom. It is collected and sent on to be treated further if this is necessary. The air stream is also collected and treated to remove or destroy the VOCs.

The air stripper is an example of a liquid-gas contactor. The most efficient type of liquid-gas contactor is the packed tower. Inside the packed tower, the packing material provides more surface area for the water stream to form a thin film on. This allows much more of the air stream to come into contact with the water stream. Selecting packing material that maximizes this wetted surface area will improve the efficiency of the air stripper. Smaller packing material sizes generally increase the area available for stripping and improves the transfer process. Once the packing material has been selected, it can be packed in two different ways. First, it could simply be dumped into the top of the tower to fill it up. This is called random packing. In the second method, the packing material is arranged on trays attached at certain levels inside the tower. These trays are made of metal gauze, sheet metal, or plastic. This is called structured packing. Random packing is generally less expensive, but the structured packing allows for easier maintenance.

There are several variations of the packed tower. In one, the "cross-flow tower", the water stream flows down through the packing in the same way as the counter-current tower. The air stream, however, is pulled across the water by a fan, instead of being forced upward through the tower. The "coke tray aerator" is a simple, low maintenance process that doesn't use a blower for the air stream. The water stream is simply allowed to trickle through several layers of trays. This produces a large surface area in contact with the surrounding air. Another method, "diffused aeration stripping", uses basins instead of a tower. The water stream flows either from the top to bottom of the basin or from one side to the other while air is dispersed from the bottom of the basin and allowed to "bubble-up" through the water. These fine bubbles tend to disturb the liquid and carry some of the VOCs away when they leave the liquid at the top. Finally, "rotary air stripping" uses the centrifugal force caused by a rotating cylinder instead of gravity to pull the liquid through the packing material. The use of centrifugal force seems to be more efficient because the liquid is spread in thinner layers over the packing material. The revolving motion also tends to disturb the liquid a great deal. Both of these factors increase the efficiency of this type of air stripper. The biggest advantage, however, is the smaller size of the device. A small rotary device can strip the same amount of water as a much larger packed tower.

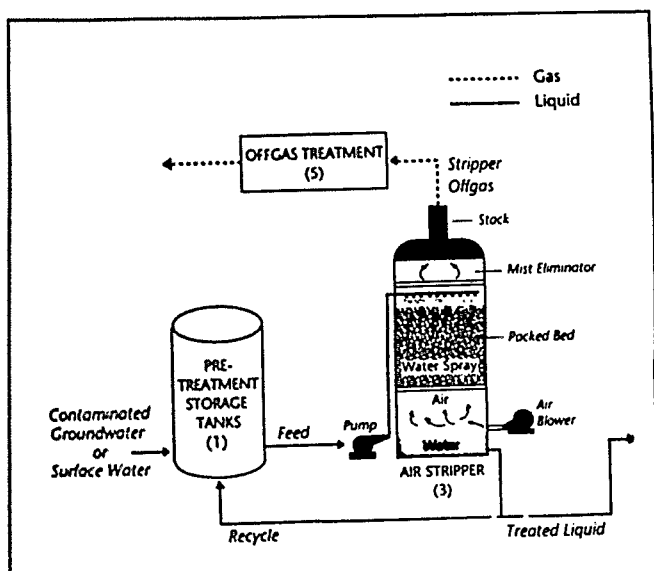


Figure 1 Schematic Diagram of Air Stripping System

What are the applications of air stripping?

Air stripping is used to remove volatile organic contaminants from liquids. These organic compounds include 1,1,1-trichloroethane, trichloroethylene, dichloroethylene, chlorobenzene, and vinyl chloride. Stripping is only partially effective in some cases. In these cases, stripping must be followed by another process to remove the remaining contaminant. The equipment used in air stripping is relatively simple, allowing for quick start-up and shut-down. The modular design of packed towers allows for easy maintenance. These factors make air stripping well suited for hazardous waste site operations.

An important factor to consider when looking at air stripping as a remediation option is the air pollution impact. The gases generated during an air stripping may require the collection and treatment of the waste air stream. Often, computer modeling of the air stripper is required before operations can begin. These models are used to predict the stripper impact on the surrounding atmosphere.

How well does air stripping work?

Air stripping has been successfully used to treat water that has been contaminated with volatile organic compounds (VOCs) and semi-volatile compounds. Air stripping has been shown to be capable of removing up to 98 percent of VOCs and up to 80 percent of certain semi-volatile compounds. The method is not suitable for the removal of some low-volatility compounds, metals, or inorganic contaminants. Air stripping has commonly been used with pump-and-treat methods for treating

contaminated groundwater. In this method, the groundwater is removed from the ground by pumps, treated in the packed tower and often returned to the same area.

Where have air strippers been used?

An air stripping system was installed at the Sydney Mine site in Valrico, Florida. The packed tower was 42 feet tall, four feet in diameter, and contained a 24-foot section of packing material. The packing material was 3.5-inch diameter (baseball-sized) polyethylene balls. The average water flow rate was 150 gallons per minute.

Air stripping was also used at a municipal well site in the city of Tacoma, Washington. Five towers were installed in this operation. Each tower was 12 feet in diameter and was packed with one-inch saddle shaped packing material to a depth of 20 feet. The average water flow was 700 gallons per minute for each tower. The towers consistently removed 94 to 98 percent of the contaminants.

Are residues generated by air stripping?

The primary residues created with air stripping systems are the waste gas coming from the top of the tower and the treated water coming from the bottom. The gas is released to the atmosphere only after it is treated to remove or destroy the contaminants. The treated water may require further treatment if it contains other contaminants that were not removed during the air stripping. If the water requires further, it is treated on-site or stored for transportation to another treatment facility. Once an acceptable level of contaminants has been removed from the water, it can either be sent to a sewage treatment facility, released to a surface water body, or returned to its source if it was removed from the ground.

For more information about Air Stripping, you may contact EPA at the following address:

*U.S. Environmental Protection Agency
ATTN: Superfund Hotline
401 M Street, S.W.
Washington, D.C. 20460
1-800-424-9346 or 1-800-535-0202*



EPA Facts About *Bioremediation*

June 1992

What is bioremediation?

Bioremediation - a process that uses *microorganisms* to transform harmful substances into nontoxic compounds - is one of the most promising new technologies for treating chemical spills and hazardous wastes.

This process uses naturally occurring microorganisms, such as bacteria, fungi, or yeast, to degrade harmful chemicals into less toxic or nontoxic compounds. Toxic substances are poisonous or hazardous, and can have harmful qualities. Microorganisms, like all living organisms, need nutrients (such as nitrogen, phosphate, and trace metals), carbon and energy to survive. Microorganisms break down a wide variety of organic (carbon-containing) compounds found in nature to obtain energy for their growth. Many species of soil bacteria, for example, use petroleum hydrocarbons as a food and energy source, transforming them into harmless substances consisting mainly of carbon dioxide, water, and fatty acids. Bioremediation harnesses this natural process by promoting the growth of microorganisms that can degrade contaminants and convert them into nontoxic by-products.

When microorganisms are exposed to contaminants, they tend to develop an increased ability to degrade those substances. For example, when soil bacteria are exposed to organic contaminants, new strains of bacteria often naturally appear that break down these substances to obtain energy.

biodegradable materials, such as wood chips, are combined with a small percentage of biodegradable wastes. This creates conditions for accelerated degrading of the wastes. A bioreactor, or closed vessel, is used to mix contaminated soil or sludge with water, nutrients, and oxygen to create a slurry (a thin mixture of water and soil). The water and soil are separated following treatment and the cleaned soil is distributed on the site. Contaminated solids can be placed in a lined bed with nutrients, moisture and oxygen added to promote decomposition. *Leachate* and air emissions produced during degradation of the waste are collected and treated.

What chemicals and sites are best suited to bioremediation?

Bioremediation has been used for nearly two decades to degrade petroleum products and hydrocarbons. It is a potentially effective treatment technique for many of the 10,000 to 15,000 oil spills that occur each year. In addition, approximately 15% of the nation's underground tanks that store petroleum, heating oil, and other materials are leaking. Many more underground tanks may begin to leak in the next 5 to 10 years. Bioremediation may be suitable for cleaning up soil and ground water at many of these sites as well.

Wood preserving sites represent another promising application of bioremediation. The estimated 700 wood preserving plants located in the U.S. use more than 495,000 tons of *creosote* per year. Creosote leaking from holding tanks and wood treatment areas can seep into the soil and groundwater. Microorganisms that degrade creosote are currently the focus of extensive research efforts by EPA.

How does bioremediation work?

One bioremediation technique known as *In situ* Bioremediation is used to treat wastes "in-place" without removing the contaminated soil or water. This technique can be used to treat contamination in the top 6 to 12 inches of soil by *tilling* the soil to provide aeration and by adding nutrients and water to stimulate bacterial growth. Treatment of contamination at depths up to 40 feet usually requires the installation of *injection wells* to deliver nutrients and oxygen to support *microbial activity*.

Another bioremediation technique treats soil or water in either a *compost pile* or a *bioreactor*. In composting, highly

Why do some biodegradable organic chemicals persist in the environment?

A number of environmental conditions may slow down or stop the biodegradation process. Some reasons for this are: (1) the concentration of the chemical may be so high that it is toxic to the microorganisms; (2) soil (or other contaminated media) conditions may be too acidic or alkaline; (3) the microorganisms may lack sufficient nutrients (such as nitrogen, phosphorous, potassium, sulfur, or trace elements), which they need to use the chemical as a food source; (4) moisture conditions may be unfavorable; or (5) the microorganisms may

lack the oxygen, nitrate, or sulfate they need to use the chemical as an energy source.

In many instances, these environmental conditions can be altered to enhance the biodegradation process. By altering the types of microorganisms present, nutrients, and climatic conditions (i.e., pH, moisture, temperature and oxygen levels) microbial degradation can be enhanced.

What are some reasons we use bioremediation?

Bioremediation can be an attractive option for many reasons: (1) It is an ecologically sound, "natural" process. New strains of bacteria which most efficiently break down organic wastes often appear naturally. As a result, the population of these strains explodes, propelling the "breaking down of hazardous wastes" or bioremediation process forward. When soil bacteria are exposed to organic contaminants, they tend to develop an increased ability to degrade those substances. These bacteria can increase in numbers when a food source (the wastes) is present. When the contaminant is degraded, the microbial population naturally declines; (2) Instead of merely transferring the contaminants from one place to another, for example, to a hazardous waste landfill, bioremediation destroys the target chemicals -- residues from the biological treatment are usually harmless products; (3) It is usually less expensive than other technologies; and (4) Bioremediation can often be accomplished where the problem is located. This eliminates the need to transport large quantities of contaminated waste off site and the potential threats to health and the environment that can arise during such transport.

For more information about Bioremediation, please contact EPA at the following address:

U.S. Environmental Protection Agency
ATTN: Superfund Hotline
401 M Street, S.W.
Washington, D.C. 20460
1-800-424-9346 or 1-800-535-0202

GLOSSARY

Bioreactor: Any closed vessel in which hazardous wastes are combined with bacteria, nutrients, moisture and oxygen in proportions which will produce optimal, biological activity for the purpose of degrading the wastes into harmless, non-toxic substances.

Compost Pile: An open area in which hazardous wastes are blended with a mixture of organic matter, nutrients, moisture and oxygen for the purpose of degrading (breaking down) the wastes and rendering them harmless.

Creosote: A complex mixture of over 200 individual chemicals, including some substances known to cause cancer, used in the preservation of wood.

Injection Wells: A hole sunk into the ground for the purpose of pumping materials to an area below the surface of the ground. Nutrients, oxygen or water can be delivered to an underground area in which bioremediation is being performed.

Leachate: A contaminated liquid that results from water collecting contaminants as it trickles through wastes, agricultural pesticides, or fertilizers. Leaching can cause hazardous substances to enter the soil, surface water, or groundwater.

Microbial Activity: The biological action of microscopic organisms in which substances are consumed by these living organisms to produce energy and food. In bioremediation, hazardous materials are physically or chemical transformed into non-toxic substances.

Microorganisms: Microscopic animal or plant organism; particularly any of the bacteria, protozoans, viruses, etc.

Tilling: Cultivating or plowing the soil so as to break it into smaller particles and to mix organic matter, minerals and other soil additives into surface soil. In bioremediation, tilling is performed to increase the amount of soil exposed to the air (oxygen) and to promote the merging of microorganisms, nutrients and moisture.



EPA Facts About *Capping*

June 1992

What is capping?

Capping is a process used to cover buried waste materials to prevent migration (movement) of the contaminants. This migration can be caused by rainwater or surface water moving over or through the site, or by the wind blowing over the site. Caps are generally made of a combination of such materials as synthetic fibers, heavy clays, and sometimes concrete. The caps are designed to meet several goals. First, they must minimize the movement of water through the wastes, by efficiently draining the site after rain showers. Second, they should be easily maintained. Third, caps should be resistant to damage caused by settling. Finally, they should be capable of funnelling away as much water as the underlying filter or soils are capable of handling. This will prevent standing water. A variety of cap designs and cap materials are available.

What are the applications of capping?

Capping is required when contaminated materials are to be left in place at a site. It is used when the underground contamination is so extensive that it prohibits excavation and removal. It may also be used if the removal of wastes from the site would pose a greater threat to human health and the environment than simply leaving them in place.

Capping is often used in combination with groundwater extraction (removal) or containment technologies to reduce and, if possible, prevent contaminant migration. Groundwater monitoring wells are often used in the area where a cap has been installed to detect any unexpected migration of the wastes. A gas collection system should always be a part of a cap when wastes may generate gases. Capping is also associated with surface water controls such as ditches, dikes, and berms. These structures are used to receive rainwater drainage from the cap.

What are the long-term maintenance requirements?

All caps require periodic inspection for settlement, standing water, erosion, or disturbance by deep-rooted plants. In addition, the groundwater monitoring wells

usually associated with caps need to be sampled periodically (to monitor for migration) and maintained. However, the long-term maintenance requirements are usually more economical than many other alternatives.

Caps generally have a minimum design life of 20 years when a synthetic liner is the only barrier to outside liquids. This period can be extended to over 100 years when the synthetic liner is supported by a non-porous base, such as clay and the contaminants are above the water table. Proper maintenance will extend the life of the cap even longer. Rigid barriers such as concrete are subject to cracking and chemical deterioration. However, these cracks can be exposed, cleaned, and repaired with relative ease. Concrete covers may have a design life of about 50 years, except when they are used to cap caustic or physically unstable landfill areas.

A final cap should be inspected on a regular basis for signs of erosion and settlement. Maintenance of the final cap should be limited to periodic mowing of the vegetation to prevent any deep-rooted plants from growing, and to deny cover to burrowing animals. Any signs of settling should be addressed immediately by removing the soil cover to inspect and repair the affected areas.

What are the types of cap design?

The primary purpose of a cap is to minimize contact between rain or surface water and the buried waste. Two types of caps that serve this purpose are:

- **Multi-layered Caps** - This type of cap generally has three layers; vegetation, drainage, and water-resistant. The vegetation layer prevents erosion of the soils of the cap. The drainage layer channels rainwater away from the cap and keeps water from collecting on the water-resistant layer which covers the waste.
- **Single-layer Caps** - This type of cap can be constructed of any material that resists the penetration of water. The most effective single-layer caps are made of concrete or asphalt. Single-layer caps are not usually acceptable unless there are valid reasons for not using a multi-layered cap.

What installation factors must be considered?

The first layer of a multi-layered cap is the foundation layer. It should be composed of soil materials that are structurally capable of supporting the weight of the finished cap. The foundation material should be spread over the wastes in six-inch increments and compacted. Structural stability tests should be run on each increment to assure uniformity.

The water-resistant layer should be placed in six-inch increments and compacted with a bulldozer or other heavy equipment. The thickness of the water-resistant layer should be at least two feet, but should be increased if settling is expected in the underlying wastes. A synthetic liner should be placed and sealed according to the manufacturers specifications. The liner should be at least 20 mils thick. (One mil is equal to one-thousandth of an inch.) A thicker liner should be used if more than a few inches of settling is expected.

The drainage layer should also be placed in six-inch increments and should be at least one foot thick. If the drainage layer is placed directly over the liner, it must be free of sharp objects that could puncture the liner. Filter fabric should be placed above the drainage layer to prevent the soil from the vegetation layer from clogging the drainage pores. The pore size of this layer should be large enough to allow for proper drainage, but small enough to prevent the soil from moving into the drainage layer.

The vegetation layer should be at least two feet thick to accommodate root penetration. It should be spread evenly and not overly compacted. The vegetation should be non-woody plants, preferable grasses, which will require low maintenance.

How "good" is capping?

Capping is a reliable technology for sealing off contamination from the aboveground environment and significantly reducing underground migration of wastes away from the site. Caps can be constructed over virtually any site, and can be completed relatively quickly if the ground is not frozen or saturated with water. The soils and other material for capping are readily available in most areas of the country. Standard road construction equipment is used in this method of remediation.

The performance of a properly installed, multi-layered cap is generally excellent for at least the first twenty years of service. Proper monitoring and maintenance will extend the useful life of the cap even longer. Capping is an attractive alternative when excavation and/or treatment is not cost-effective or protective of human health and the environment.

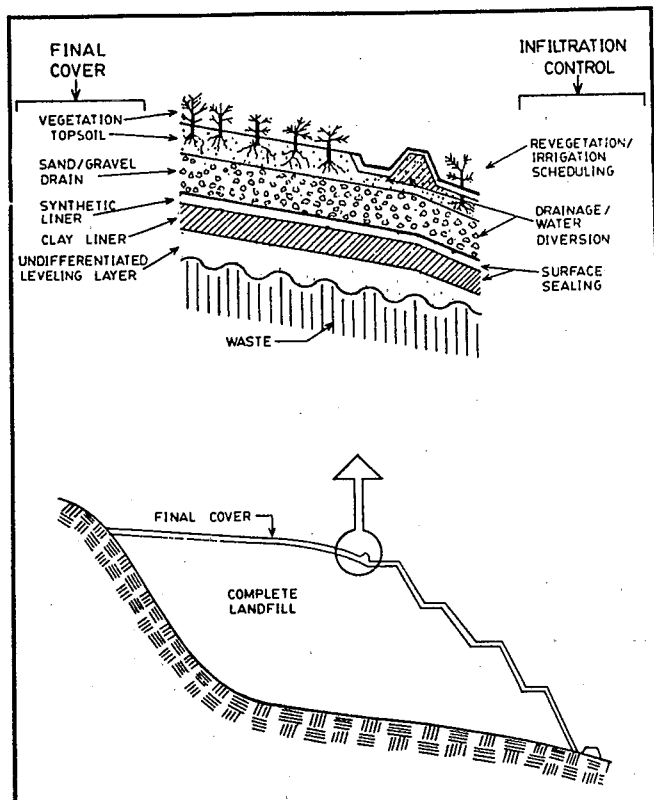


Figure 1 Infiltration Control Technologies

For more information about Capping, you may contact EPA at the following address:

*U.S. Environmental Protection Agency
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401 M Street, S.W.
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EPA Facts About *Excavation*

June 1992

What is excavation?

Excavation is the removal of contaminated material from a hazardous waste site using heavy construction equipment. This equipment is the same type of equipment that might be seen at road building projects such as backhoes, bulldozers, and front loaders. On certain sites, specially designed equipment may be used to prevent the spread of contaminated waste.

How does excavation work?

The first step in excavation involves the sampling of the contaminated area. Typically a grid is laid out on the ground so that sampling locations can be identified. Drilling equipment is used to take samples of the soil and groundwater at each location identified by the grid. Samples are taken at several different depths in the same location so that a vertical, as well as horizontal, map of the contamination can be pieced together. Special sensing equipment can be used to identify the nature of contamination on sites that are suspected of holding wastes in metal drums. Historical records such as photographs, eye witness accounts from past employees, and the contamination's effects on vegetation can also be used to pinpoint the area to be excavated.

Once the area of contamination is fully mapped, the actual removal of material can begin. Excavation is accomplished by digging up the contaminated materials and loading them onto trucks for hauling. If on-site remediation of "cleanup" treatment is used, the excavated waste may be taken to a staging area for treatment such as soil washing. The soil is then returned to its original location for use as backfill. If off-site treatment is required, the trucks will be properly covered and marked. The trucks will then haul the soil to the treatment location. After the soil is cleaned, it may be returned to the site to be used as backfill.

In cases where hazardous wastes have been buried in the ground, it may be necessary to remove a layer of soil prior to excavating the waste. This layer, called overburden, is removed and set aside in a clean area to await replacement to its original location.

Soil testing is accomplished in the walls and bottom of the excavated area to ensure that all contaminated soil has been removed. Large volumes of soil next to the waste area may have been contaminated by leaching. Leaching occurs when rain, surface or groundwater flowing through the soil carries some of the contaminants away from the original source and into neighboring areas. Excavation proceeds until the cleanup goals are met. The concentration of waste materials in surrounding areas should no longer represent a threat to human health, wildlife and natural habitats, or groundwater supplies.

In some cases, the leaching process may have carried the contaminants vertically downward into an aquifer. An aquifer is an underground rock and soil formation that is capable of holding large amounts of water. To carry out excavation in areas where the contaminants has entered the aquifer, it may be necessary to install a vertical barrier around the excavation site (see Figure 1). The water in the site area is then pumped out so that the soil can be more easily removed. The water that is removed from the site will probably need to be treated before it can be returned to the soil or discharged to a sewage treatment plant. The vertical barrier will be removed once the site is backfilled, to allow the aquifer to return to its original state.

Excavation of hazardous wastes or contaminated materials must be carefully planned. This planning will include operations to minimize the spread of contamination to clean areas of the site. Once excavation equipment is in a contaminated area, it must remain there until the work is completed. The equipment must be thoroughly cleaned and decontaminated prior to leaving the site.

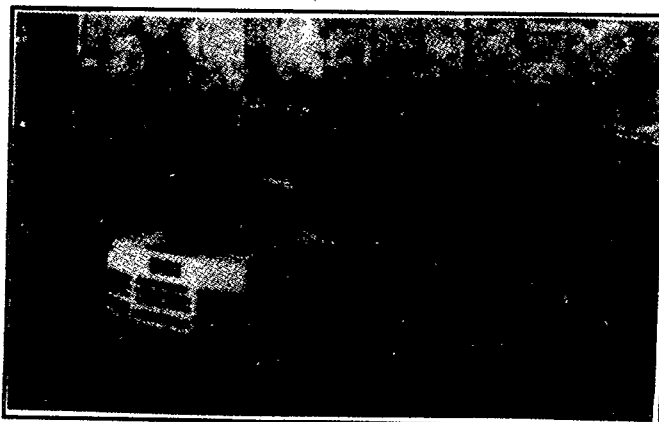


Figure 1: Excavation Below The Water Table Showing Vertical Barrier

How is monitoring well sampling performed?

The sampling of monitoring wells is usually done by trained field personnel from the testing laboratory or by groundwater consultants. In general, a sample is taken only after the pH, electrical conductivity, and temperature of the water being pumped from the well have stabilized. (pH is a numerical measure of the relative acidity of the water; zero to seven indicate decreasing acidity, seven to fourteen indicate increasing alkalinity, while seven is considered neutral.)

How is contaminant movement predicted?

In many instances of groundwater contamination, the ability to predict how the contaminant plume will behave in the future can only be based on the results of expensive drilling and sampling programs. Many scientists interested in the movements of contaminants in groundwater believe that it will soon be possible to use mathematical modeling techniques to estimate the spread of a particular contaminant and its concentration at any point in the plume.

How are the locations of monitoring wells determined?

Once the general limits of the plume have been identified, several monitoring wells are installed in or near the plume. The purpose of these monitoring wells is to:

- Determine the properties of the rock formation in which the contamination is found and the surrounding aquifers.
- Determine the level of groundwater of all aquifers in the area.
- Provide samples of groundwater for the detection of contaminants.
- Monitor the movement of the contaminant plume.

Usually one monitoring well is located near the center of the plume in the path of the groundwater as it moves away from the site. Another is installed farther away, but in the path of the plume. Background conditions are recorded from a third monitoring well that is located in an uncontaminated area (see Figure 3).

The most difficult decision is usually not where to place the monitoring well, but at what depth the samples should be taken. Selection of the most appropriate depths depend on the characteristics of both the contaminant and the aquifer or soil surrounding the site. The design of the well and sampling plan are extremely important if meaningful and accurate information concerning the extent of contamination is to be obtained. Proper placement of the monitoring wells is also important and must be based on accurate information concerning the pattern of groundwater flow and the type of contamination.

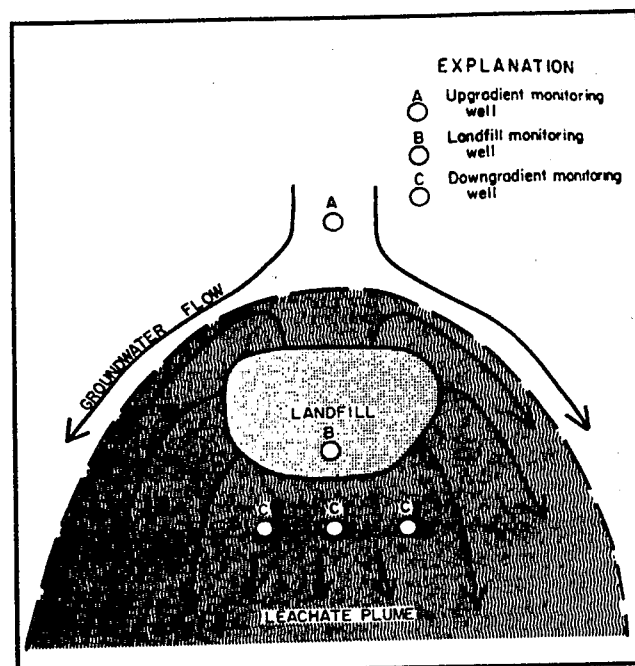


Figure 3: Typical Arrangement of Monitoring Wells

For more information about Groundwater Monitoring, please contact EPA at the following address:

U.S. Environmental Protection Agency
ATTN: Superfund Hotline
401 M Street, S.W.
Washington, D.C. 20460
1-800-424-9346 or 1-800-535-0202



EPA Facts About Immobilization

June 1992

What is immobilization?

Immobilization is a treatment process used to prevent migration (movement) of toxic and hazardous chemicals from soil slurries and waste sludges from spreading to the surrounding environment. This process binds the hazardous chemicals into immobile (insoluble) forms, binding them in an insoluble mass which minimizes the surface area of the waste chemicals exposed to migration through leaching. Leaching is caused when water, either surface water or groundwater, moves through wastes (much as water percolates through coffee grounds) picking up contaminants.

How does immobilization work?

Immobilization involves solidification and stabilization processes in which chemicals, reagents, and cement-like binding materials are mixed with contaminated soil to

render the waste immobile and inactive. Solidification results in a monolithic block of treated waste with high structural rigidity. Stabilization results in either reducing the *toxic* effects of the treated waste or limiting its solubility. The application of immobilization to contaminated soil results in a high-strength, non-leaching block that can be placed into the ground without double liners or covering caps. Often the immobilized product has structural strength sufficient to help protect itself from further fracturing, thereby preventing increased leaching. Environmental damage is significantly reduced as the hazardous chemicals are encapsulated in a solid block.

Solidification and stabilization processes have two key components: the chemical reactants and the mixing equipment. The chemicals typically include portland cement, lime, fly ash, clay, silicates, and a *proprietary chemical*. The proprietary chemical is supposed to react with the metals and organics to form insoluble compounds and to prevent the organic constituents from interfering with the pozzolanic (cement) reactions.

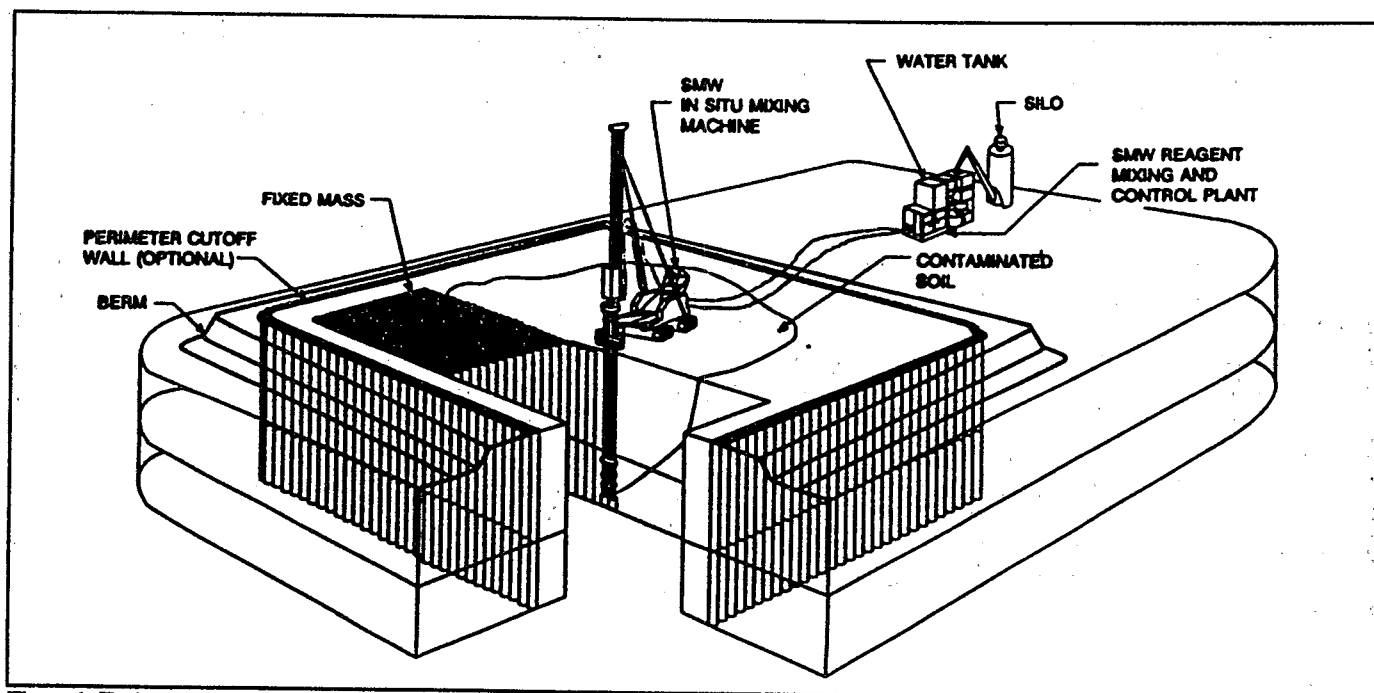


Figure 1: Typical In Situ Immobilization Process

How are agents mixed with contaminated soils?

Effective mixing is required whether the waste and chemicals are mixed in situ or above ground in tanks, drums, pits, or mills. Without thorough mixing, the chemicals cannot immobilize the hazardous constituents. Immobilization for soils can be achieved by the injection method for wastes below ground or in a specially designed mill above ground for excavated contaminated soil. In the injection method, immobilization agents (cement, fly ash or patented additives) are injected into the waste materials in a liquid or slurry form. Figure 1 shows a typical "in situ" or in place immobilization process. Injection can be achieved by pumping the immobilization reagent inside a porous tube to the required depth. In above ground application, the excavated contaminated material is screened to remove pieces larger than one inch and stored in a feed hopper. A conveyor belt moves it from the feed hopper to the weight feeder, where it is measured. The homogenizer mixes the wastes with water to achieve the desired moisture content. The wetted material then moves to a pug mill, where it is thoroughly mixed with reagents. After the material is blended, it is discharged and allowed to harden. The final product is a solidified mass of soil.

What are typical solidification and stabilization methods and common uses?

Cement-based fixation process treats sludges and soils containing metals, radioactive wastes, and solid organic wastes (plastics, resins, tars) by the addition of large amounts of siliceous materials combined with cement to form a dewatered, stabilized solidified product. Soluble silicates are added to accelerate hardening and containment. Larger amounts of dissolved sulfate salts or metallic anions, such as arsenate and borates, will hamper solidification. Organic matter, lignite, silt, or clay in the wastes will increase setting time.

Pozzolanic-based fixation process treats sludges and soils containing heavy metals, waste oils, solvents, and low-level radioactive wastes, onsite by the addition of large amounts of pozzolanic materials (fly-ash, lime) combined with cement to form a dewatered stabilized, solidified product. Materials such as borates, sulphates, and carbohydrates, interfere with the process.

Vitrification is a process that uses a very high temperature to convert hazardous wastes into a glass-like substance. The process is carried out by inserting large electrode into contaminated soils containing significant levels of silicates. Graphite on the surface connects the electrodes to the soil. A high current of electricity passes through the electrodes and graphite. The heat causes a melt that gradually works downward through the soil. Some organic contaminants are *volatilized* and escape from the soil surface as gases, and must be collected by a vacuum system. Inorganic and some organics are trapped in the melt, which as it cools, becomes a form of obsidian (gemstone like) or very strong glass. When the melt is cooled, it forms a stable noncrystalline solid.

GLOSSARY

Proprietary Chemical: Reagents used in the immobilization process which have been developed under a protected patent. These chemicals improve the effectiveness of the process.

Sludges: A semi-solid waste product generated from air or water treatment processes such as precipitation or sedimentation.

Toxic: A poisonous or hazardous substance.

Volatilized: Chemicals may be vaporized or evaporated into air as gases, generally caused by heating or movement.

For more information about Immobilization, please contact EPA at the following address:

U.S. Environmental Protection Agency
ATTN: Superfund Hotline
401 M Street, S.W.
Washington, D.C. 20460
1-800-424-9346 or 1-800-535-0202



EPA Facts About *In Situ Vitrification*

June 1992

What is in situ vitrification?

In situ vitrification (ISV) is the process of melting waste and soils or *sludges* "in place" to bind the waste into a glassy, solid mass resistant to leaching. This mass is more durable than either granite or marble. This thermal process destroys organic (carbon-containing) pollutants and immobilizes and traps inorganic pollutants. ISV technology is based on extremely high temperatures, in the range of 2,900°F to 3,600°F, to electrically melt soil or sludge. It destroys organic pollutants by *pyrolysis*, chemically decomposing the substances through heat. Although the process was initially developed to stabilize previously disposed radioactive wastes, it may also be used to destroy or immobilize many organic and inorganic chemical wastes, such as heavy metals, PCBs, process sludges, and plating wastes.

Vitrification technology converts contaminated soils, sediments, and sludges into glass-like substances, rendering them non-toxic. Inorganic and toxic wastes are chemically bonded through heat into glass and are changed chemically to a non-toxic form.

How does in situ vitrification work?

In the ISV process, large electrodes are inserted into the soil to the desired treatment depth. Because soil typically has a low electrical conductivity, flaked graphite and small glass fragments may be placed on the soil surface between the electrodes to provide a started path for electric current. The electric current passes through the electrodes and begins to melt soil at the surface. As the current flows, the soil is heated to 2900-3600°F, which is well above a typical soil's melting temperature. This melting process continues to grow downward, at a rate of 1 to 2 inches per hour using the above temperature ranges. Placement of electrodes in the soil may vary to encompass a total melt volume of 1,000 tons and a maximum width of 30 feet. A diagram of a typical ISV treatment process stages is shown in Figure 1.

The pyrolyzed by-products migrate to the surface of the melt zone, where they ignite in the presence of oxygen. A hood placed over the melt zone to collect both the organic and inorganic gases, drawing the escaping gases into a treatment system before release to the atmosphere. Convective currents (heat-driven) within the melt zone uniformly mix the materials in the soil. When the electric current ceases, the molten volume cools and solidifies.

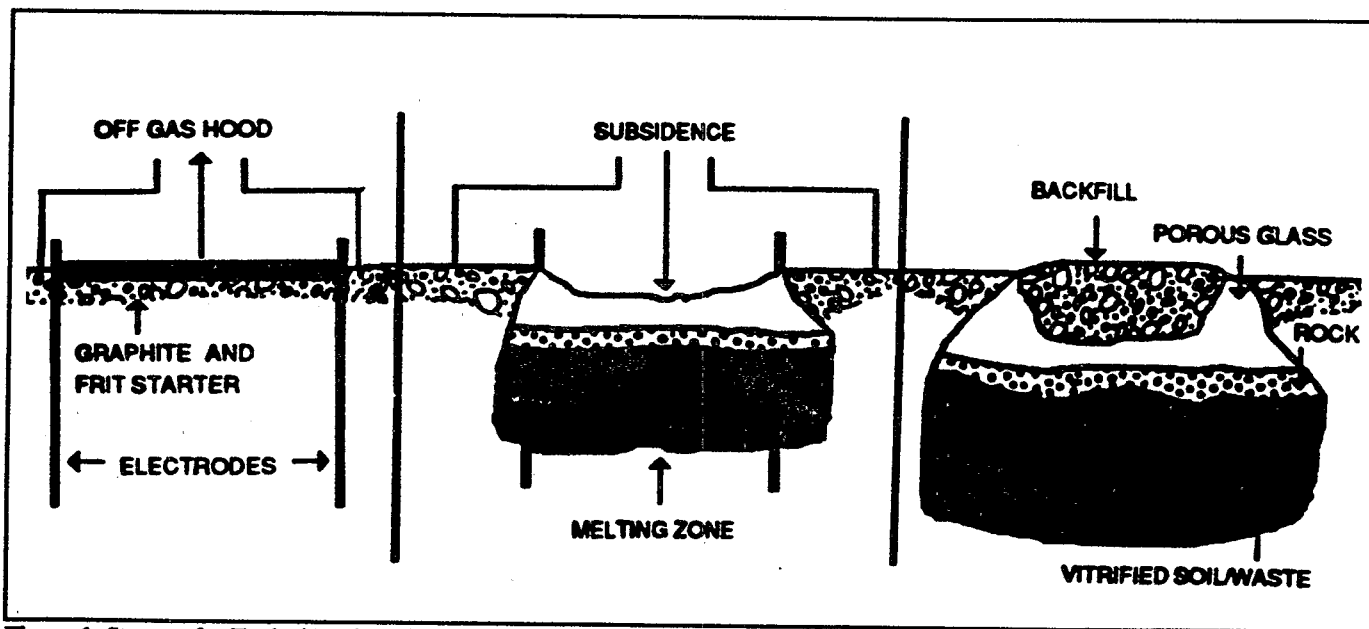


Figure 1: Stages of a Typical In situ Vitrification Process

What conditions are required?

Two conditions must be met to successfully vitrify soils, sediments, and sludges: (1) the development of glass compositions tailored to the waste being treated; and (2) the development of a glass melting technology that can convert the waste and additives into a stable glass without producing toxic emissions. Specific site characteristics must be considered in determining the appropriateness of ISV. In the event that feasibility tests indicate problems in the soil electrical conductivity or vitrification, sand, soda ash, or glass frit (fragments) can be mixed with the soil to improve the process. Generally, ISV can treat contaminated soils which are not more than 5 to 10 percent organic materials by weight and not more than 5 to 15 percent inorganic materials by weight.

Soil moisture is an important factor in the operation of the ISV process. More electrical power and time are required to evaporate the water as soil moisture increases. A combination of high soil permeability (excessive air space in soils) and the presence of groundwater can significantly increase the cost of ISV. The process will work with fully saturated soils; however, the water in the soil must be driven off through evaporation before the soil will begin to melt. If the soil moisture is being recharged by an aquifer, there is an additional economic impact. Engineered barriers, which block groundwater from entering the treatment area, may be required to vitrify soils below the water table.

The environmental impact of the escaping gases must also be addressed when considering ISV. A hood must be placed over the processing area to collect volatiles (wastes compounds which can vaporize rapidly as gases and present an exposure risk through inhalation) driven off during start-up, combustion gases, and steam and convey them into a gas treatment system.

What benefits can ISV provide?

ISV eliminates the need for excavation, processing, and reburial of the hazardous compounds, and minimizes worker exposure to the contaminants. The process produces a stable, glassified mass that has excellent long-term durability and an extremely low leach rate, requiring little or no site monitoring.

Following the ISV process, there is a significant volume reduction in the amount of contaminated material. The percentage of removal of contaminated organic material is approximately 99.999%; inorganic material is permanently immobilized.

A melting unit which uses electricity rather than fossil fuels as the heat source helps to limit the emissions associated with these fuels. Since molten glass is a good conductor, the electrodes melting the waste can do so under a thick blanket of the molten glass. This blanket essentially forms a scrubber for volatile emissions. In contrast, fossil fuels melters have large, exposed molten glass surface areas from which hazardous constituents can vaporize into the ambient air. Typical experience with commercial electric melters has shown that the loss of inorganic volatile constituents, which are high in fossil fuel melters is significantly reduced. Because of its low emission rate and small volume of exhaust gases, electric melting is a promising technology for incorporating high-level nuclear waste into a stable glass.

GLOSSARY

In situ Vitrification: The process of melting waste and soils or sludges "in-place" to bind the waste in a glassy, solid resistant to leaching.

Pyrolysis: Chemical decomposition of a substance by heat.

Sludges: A semi-solid waste product generated from air or water treatment processes.

For more information about In situ Vitrification, please contact EPA at the following address:

*U.S. Environmental Protection Agency
ATTN: Superfund Hotline
401 M Street, S.W.
Washington, D.C. 20460
1-800-424-9346 or 1-800-535-0202*



EPA Facts About *Incineration*

June 1992

What is incineration?

Incineration is one of the technologies available to treat hazardous wastes. It can destroy organic compounds in wastes such as dioxins and polychlorinated biphenyls (PCBs). Incinerators can handle many forms of waste, including contaminated soils, *sludges*, solids and liquids. Some incinerators provide for the recovery of energy.

Incineration, however, destroys only organic substances, it is not effective in the treatment of *inorganic substances* such as hydrochloric acid, salts, and metals.

How does incineration work?

Incineration is accomplished by using high temperatures (between 1600°F and 2500°F) to degrade contaminants. Toxic chemicals can be reduced to the basic elements (hydrogen, carbon, chlorine, nitrogen, etc.). These combine with oxygen to form non-toxic substances such as water (hydrogen and oxygen), carbon dioxide (carbon and oxygen), and nitrogen oxides (nitrogen and oxygen). Inert ash, organic-free *particulate matter*, hydrogen chloride, and small concentrations of organic materials may also be present in the combustion gas. Properly done, high-temperature incineration is an effective, odorless, and smokeless process.

What happens to the residues produced by incineration?

The U.S. Environmental Protection Agency (EPA) incinerator regulations assume that all ash and particulates removed from the stack and the bottom of the burner unit are hazardous. Accordingly, they must be disposed of at a RCRA-permitted facility; (The Resource Conservation and Recovery Act, or RCRA, as it is called, is the law that regulates the handling of hazardous wastes). In addition, *scrubber water* must meet the Clean Water Act standards before it can be discharged to surface waters.

Can highly toxic wastes be destroyed by incineration?

A common misconception is that the more toxic the chemical, the more difficult it is to burn. Although some chemical compounds are more difficult to destroy by incineration than others, ease of *thermal decomposition* is not related to *toxicity*. EPA research has demonstrated that destruction of organic wastes occurs independent of toxicity. This is encouraging news, because it means that chemicals ranging from complex pesticides to PCBs, benzene and dioxin all break down under heat; provided that specific conditions are met.

Are the wastes completely destroyed by incineration?

No incinerator can destroy 100 percent of the hazardous wastes fed into it. Small amounts are released into the atmosphere through the incinerator stack or are mixed with the ash. EPA requires that each incinerator meet stringent performance standards. A standard of 99.99 percent has been set for destruction and removal of all hazardous wastes processed in incinerators. For PCBs and dioxin-listed wastes, the standard is 99.9999 percent or that only one pound of an organic compound may be released to the air for every 1,000,000 pounds fed into the incinerator. When operated properly, hazardous waste incinerators can meet or exceed these requirements which have been developed to protect human health and the environment.

What are the advantages of incineration?

Incineration offers a permanent solution to much of our hazardous waste problem by destroying wastes that would otherwise require space in a landfill. Incineration has proven effective in the destruction of all organic compounds, usually accomplishing well over 99% reduction of organics.

How does EPA know that standards are being met?

EPA requires "trial burns" to demonstrate the effectiveness of each incinerator. The incinerator is fed measured volumes of various hazardous wastes which are representative samples of the wastes expected to be incinerated during normal operations. The trial burn is designed to test the performance of the incinerator unit under the most demanding operating conditions the unit may experience. For each test batch, EPA selects up to six compounds known to be the most concentrated and most difficult to incinerate. If the operators of the incinerator cannot demonstrate a *destruction and removal efficiency* of 99.99 percent, the waste feed used during the trial burn cannot be accepted for processing by the unit.

The results of the trial burn are used to establish conditions under which each permitted facility must operate. The permit defines such operating thresholds as: the maximum carbon monoxide level in *stack gases*, maximum *feed rates*, minimum combustion temperature, maximum combustion gas velocity, etc. Essentially, these conditions are designed to deliver a "complete burn" of the hazardous waste by ensuring optimal operating circumstances. Safeguards are required which cut off the waste feed when these circumstances do not meet the stated permit conditions.

Which agency regulates incinerators?

All hazardous waste incinerators are regulated by EPA or state agencies acting under authority of EPA. Incineration is one of the final steps in the *cradle to grave* regulatory management system created by Congress under RCRA legislation.

All owners and operators of incinerators are required to submit information on the design, operation, and future closure of the incinerator. They must also submit information on their financial capacity to cover the closing of the unit and liability for bodily injury or property damage to third parties. The permittee must specify what analyses will be done for all hazardous wastes prior to incineration to ensure that the wastes are suited to the technology. Security measures, such as installation of a fence around the incinerator and adequate surveillance, are also required. Owners and operators must develop and follow a written inspection schedule to assess the overall safety of the incinerator facility, and they must employ trained personnel. They are also required to prepare an action plan for emergencies and ensure that emergency prevention measures

are taken. Finally, accurate recordkeeping and reporting on the operation of the incinerator are required.

Glossary

Cradle to Grave: EPA requires hazardous substances to be tracked from the time of production to final disposal or destruction.

Destruction and Removal Efficiency: A measure of the amount of an organic compound removed or destroyed in an incinerator relative to the amount which enters the incinerator.

Feed Rate: A measure of the flow of hazardous substances into the incinerator.

Inorganic Substances: Materials which do not contain carbon and are generally derived from minerals.

Particulate Matter: Material composed of tiny particles. Smoke is composed of gases and airborne particulate matter (soot).

Scrubber Water: Water used to remove residual inert (non-reactive) materials and organics present in the gases exiting the combustion chamber.

Sludges: Thick forms of hazardous wastes, usually a combination of oils and organic matter such as soil or sediment.

Stack Gases: Gases from the combustion process which exit the stack after treatment by air pollution control devices. These gases are composed primarily of harmless carbon dioxide and water, plus small quantities of ash, carbon monoxide and organics.

Thermal Decomposition: The destruction or breakdown of substances through heating, in this case extreme heating, i.e., burning or incineration.

Toxicity: A measure of the poisonous or harmful nature of a substance.

For more information about Incineration, please contact EPA at the following address:

U.S. Environmental Protection Agency
ATTN: Superfund Hotline
401 M Street, S.W.
Washington, D.C. 20460
1-800-424-9346 or 1-800-535-0202



EPA Facts About *Leachate Collection*

June 1992

What is leachate?

Leachate is a liquid that has passed through buried waste and, as a result, contains dissolved or finely suspended solid matter and microbial waste products. This solid matter and waste products may consist of organic and inorganic substances, groundwater or infiltrating surface water moving through solid wastes can produce leachate. Leachate may leave the fill at the ground surface as a spring or percolate through the soil and rock that underlie and surround the waste.

Why is leachate collection important?

This fact sheet only applies to leachate collection under the U.S. Environmental Protection Agency (EPA) Superfund program. It does not apply to Resource Conservation and Recovery Act, Subtitle C and Subtitle D facilities where the design and monitoring requirements are much more stringent than reflected here.

Leachate is perhaps the most significant problem in the pollution of groundwater. Leachate develops at sanitary landfills by groundwater or surface water filtering through the solid waste. Leachate is a highly complex mixture of soluble, insoluble, organic, and bacteriological contaminants in a water-based solution. Bacteriological contaminants are usually filtered from the leachate after traveling through several feet of most soils. Suspended solids, however, travel greater distances, creating groundwater pollution.

As water passes through the cover material and down through buried wastes in our landfills, it picks up solids and dissolves some portion into solution. Leachates generated by the disposal of hazardous wastes may include high concentrations of such heavy metals as mercury, cadmium, and lead; toxic substances such as barium and arsenic; organic compounds, including chlorinated solvents, aromatic hydrocarbons, and organic esters; and various corrosive, ignitable or

infectious materials. Landfill leachates degrade groundwater quality by introducing hazardous constituents as well as biological contamination.

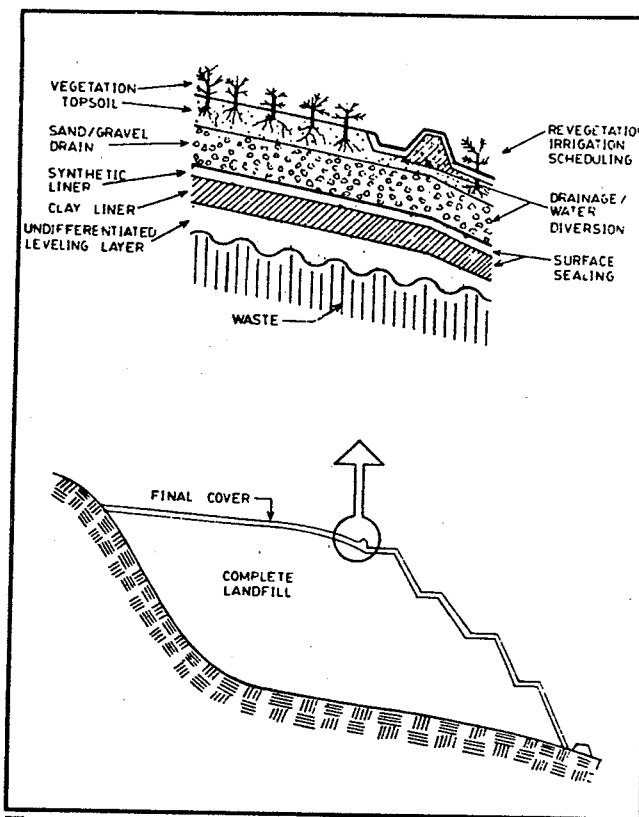


Figure 1: Leachate Control Technologies

What causes leachate?

Leachate is produced when the infiltration of precipitation and other sources of water is applied to the landfill surface which exceed the combined of runoff, *evapotranspiration*, and soil moisture storage. All these are natural cycles which prevent the water from traveling downward through the soil. For example, the net inflow to an area of buried hazardous wastes (called *percolation*) is absorbed by the wastes until the absorption capacity of the buried wastes is reached. As a result, if additional water infiltrates into the waste, it will accumulate as leachate or discharge to the groundwater beneath the wastes.

How soon after the burial of wastes is leachate produced?

The appearance of leachate at a landfill from the initial time the waste was deposited may be delayed by as much as 20 years. Therefore, any short-term study of leachate may not adequately establish the magnitude of the problem. This is dependent on the soil characteristics at the landfill. Leachate may enter the groundwater or overflow onto the surface (like a bath tub overflowing) depending on the permeability of the underlying soil. While soil permeability has no effect on leachate generation, it is controlled by the permeability (the rate of water loss) of the material which covers the waste. Sites with good covers should not generate leachate, even though the site may be underlain by permeable and porous soils.

What is a leachate collection system?

A leachate collection system generally consists of strategically placed perforated drain pipe bedded and backfilled with drain rock. This system resembles a french-drain which is often installed in residential property to promote drainage. The system can be installed completely around the perimeter of the landfill or a network or grid of collection pipes can be installed. The collection system is drained to a sump from which the leachate is withdrawn by pumping.

The configuration of the collection pipe network varies depending on the amount of water which can be allowed to build up in the wastes. For Superfund sites, the minimum collection system should extend completely around the perimeter of the site to provide absolute control of the level to which leachate can rise on this critical boundary. It should be noted that this method should never be used for a RCRA Subtitle C or Subtitle D facility where the height of the rise of accumulating leachate on the liner must not exceed one foot.

What level of maintenance and monitoring is required?

Landfill leachate control systems must include facilities for (1) the monitoring of leachate levels at the base of the landfill, and (2) the withdrawal of leachate to

prevent build-up of a fluid level that would promote unacceptable migration (movement) of leachate from the waste site. The current state-of-the-art in landfill design uses sumps or excavated basins located at low points on the base of the landfill to which a leachate control system or to the surface of the fill provides the means for removing the leachate from the sump in addition to providing a "well" in which the leachate levels can be measured. Leachate sumps are filled with drain rock (large stone) that provides the necessary storage capacity (pore space) while also providing the water movement characteristics necessary to produce flow to the sump pumping location.

GLOSSARY

Evapotranspiration: A process in which green plants move water from the ground and release it to the atmosphere as water vapor.

Superfund Program: The program operated under the legislative authority of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) that funds the EPA solid waste emergency and long-term removal and remedial activities.

Toxic: Acting as a poisonous or hazardous substance; having poisonous or harmful qualities.

For more information about Leachate Collection, please contact EPA at the following address:

U.S. Environmental Protection Agency
ATTN: Superfund Hotline
401 M Street, S.W.
Washington, D.C. 20460
1-800-424-9346 or 1-800-535-0202

The information contained in this fact sheet was compiled from the following publications of the U.S. Environmental Protection Agency: Covers for Uncontrolled Hazardous Waste Sites, September 1985; Guide to Technical Resources for the Design of Land Disposal Facilities, December 1988; and Technical Guidance Document: Final Covers on Hazardous Waste Landfills and Surface Impoundments, July 1989.



EPA Facts About *Pump-and-Treat*

June 1992

What is the pump-and-treat method?

The pump-and-treat method is the most common remedial (cleanup) technology used in purifying contaminated *aquifers*. These aquifers are natural, underground rock formations that are capable of storing large amounts of water. The pump-and-treat process usually includes three steps. First, the contaminated groundwater is recovered from the aquifer through recovery wells. Second, the recovered water is treated. Finally, the treated water is discharged and the contaminants are disposed of.

Groundwater collection systems are designed to capture contaminated groundwater by removing it from the aquifer. These collection systems are also used to prevent the spread of contamination. As the contaminated groundwater is recovered from the aquifer, the contamination is prevented from moving deeper into the aquifer or spreading into surrounding clean aquifers.

Why not simply treat water at the well?

Another form of the pump-and-treat process, called well-head treatment, is sometimes used when drinking water wells are contaminated. In some cases, it has been found to be cost-effective to continue to recover contaminated groundwater, but to remove the contaminants before delivering it to users.

There are several variations of this approach. At some sites, the source of the contamination is known and an auxiliary recovery system has been installed. This auxiliary system is intended to cleanup the contaminated aquifer or may operate simply to prevent further spread of contamination. The contaminated water is drawn away from the drinking water well and redirected. In other cases, the source of contamination is not known and the well-head treatment system may be the only practical alternative.

The system may use a variety of tools to move and redirect groundwater, including *extraction wells*, *injection wells*, *drain intercepts*, and *barrier walls*. Extraction wells are designed to pump groundwater out of the aquifer and to redirect the remaining water. Injection wells use the opposite method; pumping water into an aquifer to change its flow patterns.

Drain intercepts are surface features that are designed to capture and redirect the groundwater flow. Barrier walls may be installed in the cleanup area to create physical barriers to groundwater flow.

Why do we want to pump groundwater?

The treatment of a contaminated aquifer, or "aquifer restoration", is not the only goal of groundwater extraction systems. Another goal is the control of contaminant migration (movement). Groundwater pumping techniques involve the active management of groundwater to contain or remove contaminants. These techniques can also be used to adjust the groundwater level so that no migration will occur.

The area of contaminated groundwater associated with a site is called a plume, and is the groundwater equivalent of smoke from a fire. A water barrier may be constructed by causing the water in an aquifer to move in such a way as to prevent the plume from moving toward a drinking well. Pump-and-treat technology is used to construct these water barriers to prevent off-site migration of contaminants. In most aquifer restoration systems, plume containment is listed as secondary goal. It is usually necessary to establish control of contaminant migration if the aquifer is to be cleaned up. Exceptions to this general rule are sites where the aquifer can restore itself naturally by discharging to surface water bodies or through chemical or biological degradation (breaking down) of the groundwater contaminants to render them harmless to human health and the environment.

Control of groundwater contamination involves one or more of four options: (1) containment of a plume; (2) removal of a plume after the source of contamination has been removed; (3) reduction of groundwater flow to prevent clean groundwater from flowing through a source of contamination, or to prevent contaminated groundwater from moving toward a drinking well; and (4) prevention of a plume by lowering the water table beneath a source of contamination.

Why do we use pump-and-treat?

Groundwater collection and treatment has proven effective over a wide range of site conditions and contaminants. Well collection systems can remove groundwater from the great depths. In addition, the costs associated with this technology are generally moderate.

What makes soil washing a good treatment technology?

Soil washing can significantly reduce the volume of contaminated soil that must be treated by more costly technology. In addition, a wide variety of chemical wastes can be removed from soils using soil washing. Removal efficiencies, that is the percent of wastes removed, depend on the type of waste present as well as the type of soil. Volatile organic compounds, or VOCs, are those compounds that contain carbon and are usually associated with life processes. These compounds, such as gasoline, evaporate quickly when heated or disturbed in any way. This type of compound can usually be removed with 90 to 99 percent efficiency. Semi-volatile organics are harder to remove, but with addition of the proper surfactant, removal efficiencies are normally in the 40 to 90 percent range.

Successful removal of metals and pesticides, both of which are less soluble (harder to dissolve) in water, often require the use of acids or the chelating agents mentioned above. The process can be used for the treatment of soils contaminated with wood-preserving chemicals (e.g., pentachlorophenol and creosote); organic solvents; electroplating residues (e.g., cyanide and heavy metals); organic chemicals production residues; pesticides; and petroleum residues.

Soil washing is most effective in treating sand and gravel soils that have been contaminated with VOCs. It is also effective in treating soils that have been contaminated with inorganic compounds such as metals.

Finally, soil washing provides a closed system that allows operators to control the environment immediately surrounding the treatment facility and minimize the chance of contaminating clean areas at the site. The equipment involved is mobile and, therefore, can be moved to the site. This prevents the possibility of the spread of contamination during transportation to another treatment facility.

Is soil washing a cure-all?

In some cases, soil washing can deliver the performance needed to reduce contaminant concentrations to acceptable levels. In other cases, soil washing may need to be combined with other technologies. It can be cost-effective as a first step in a series of treatments because it reduces the amount of material that subsequent steps must process. It is also useful in

converting the excavated soil into a more uniform consistency that can be more easily treated with other processes.

Contaminated fine particles of clay and sludges resulting from soil washing may require further processing using accepted treatment technologies in order to permit safe disposal. The used wash water may also require treatment to meet safe discharge standards prior to release into the environment. Any vapor emissions from the waste preparation area and washing unit must be collected and, if necessary, treated to meet regulatory standards.

How do we know soil washing will work?

Thorough testing is required to determine if soil washing will be effective and safe at a given site. The entire process is evaluated, from excavation to final disposal of all the soil and wash water. If the test results are promising, small-scale demonstrations are normally conducted before full-scale operations are begun.

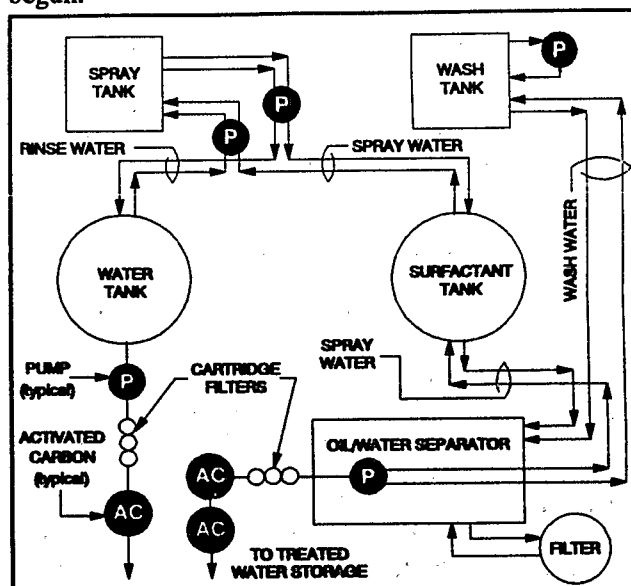


Figure 2: Debris Washing Process

For more information about Soil Washing, please contact EPA at the following address:

U.S. Environmental Protection Agency
ATTN: Superfund Hotline
401 M Street, S.W.
Washington, D.C. 20460
1-800-424-9346 or 1-800-535-0202



EPA Facts About *Thermal Desorption*

June 1992

What is thermal desorption?

Thermal desorption is a low-temperature heat line separation process designed to remove organic contaminants from soils and *sludges*. Contaminated soils are heated at relatively low temperatures (200°F to 900°F) so that only those contaminants with low boiling points will vaporize by turning into a gas. These vaporized contaminants removed from the soils or liquids are collected and treated. Thermal desorption is not an incinerator system, and no hazardous combustion by-products are formed. Thermal desorption technology is useful in treating organic contaminants that become gases at relatively low temperatures. These contaminants include volatile organic compounds (VOCs), polychlorinated biphenyls (PCBs), and some polynuclear aromatic hydrocarbons (PAHs).

How does thermal desorption technology work?

Thermal desorption is a three step process: first, the soil is heated to vaporize the contaminants; next, the vaporized contaminants are treated; and, finally, the treated soil is tested. The contaminated soil is heated at temperatures between 200° F and 900° F to reduce the chance that the organic contaminants will ignite. Four different methods of heating the soil are available. Each method is described below:

(1) **In-place steam extraction** (Figure 1): The contaminated soil is left in place while steam is pumped through the ground. The contaminants vaporize to a gas form, move through the air spaces in the soil, and the gases are collected by a vacuum. Since steam, and not a flame, is used to vaporize the contaminants, there is no risk that the organic contaminants will ignite and form hazardous combustion by-products.

(2) **Direct heating:** This heating method is like heating with a gas oven in your home. A disadvantage of this heating method is that the flame is in direct contact with the contaminants, and therefore, increases the chances that the contaminants will burn and form hazardous combustion by-products.

(3) **Indirect heating:** The contaminated soil is placed in a kiln-type furnace. The outside of the kiln is heated using fuel oil, and the heat is transferred through the kiln's metal surface to the soil. Since the soil is enclosed in the kiln, the fuel's combustion by-products and the vaporized contaminants do not mix.

(4) **Oxygen free heating:** The soil is placed in a container which is sealed to avoid any contact between the soil and oxygen in the air. The outside of the container is heated using a burner system, and the contaminants vaporize. Without air, the risk of forming combustion by-products is virtually eliminated.

What happens once the contaminants are vaporized?

Once vaporized, the contaminants can be treated in the same manner regardless of which heating method is used. The vaporized contaminants may be cooled and condensed into a liquid, which is then placed in drums for treatment or disposal. The vaporized contaminants may also be treated using a carbon filtration system to meet applicable federal, state, and local air emission standards.

Once thermal desorption is completed using one of the four heating methods described above, the soil is tested to verify that all contaminants have been removed. The moisture content is adjusted to eliminate dust particles and produce a solid that is ready to be placed and compacted in its original location. The organic contaminants and water vapor driven from the solids are transported out of the dryer by a nonreactive nitrogen gas. The inert gas flows through a duct to the gas treatment system, where organic vapors, water vapors, and dust particles are removed from the gas. This gas treatment system is made up of a high-energy scrubber in which dust particles and 10 to 30 percent of the organic contaminants are removed. The gases then pass through two heat exchangers, where they are cooled to below 40°F. Most of the remaining water and organic vapors are condensed to liquids in the *heat exchangers*. The cleaned soils and sludges can be returned to the site as backfill.

Why consider thermal desorption?

Thermal desorption has a high success rate in removing volatile organic compounds (VOCs). VOCs are chemicals which tend to vaporize easily into the air, creating an exposure hazard by inhalation. Existing equipment is capable of treating up to 10 tons of contaminated soil per hour. In addition, since thermal desorption operates at low temperatures, the risk of VOCs and other organic contaminants burning and, consequently, forming hazardous gaseous emissions is reduced. Finally, the low temperatures require less fuel than other treatment technologies, and so this method is less costly.

What kinds of waste can be treated by thermal desorption?

This technology was developed primarily for on-site remediation (clean-up) of soils contaminated with organic contaminants. The process can remove and collect volatiles, semi-volatiles, and PCBs, and has been demonstrated on a variety of soils ranging from sand to very heavy clays. Filter cakes from water treatment processes and pond sludges have also been successfully processed. In most cases, volatile organics are reduced to below 1 part per million (ppm) and frequently to below the levels which the laboratory can detect.

Thermal desorption cannot be used to treat heavy metals, with the exception of mercury. Tars and heavy pitches cannot be processed using this technology because they create materials handling problems.

GLOSSARY

Heat Exchangers: A chamber used to add or remove heat; a common example is a car radiator which uses water (coolant) to accept the heat of your car's engine and releases this heat to the atmosphere as the heated water passes through the exposed metal chambers (fins) of the radiator. An air conditioner works on a similar principle.

Scrubber: An air pollution device that uses a spray of water (or reactant) or a dry process (such as filters or centrifugal scrubbers) to trap pollutants in gaseous emissions.

Sludges: A semi-solid waste product generated from air or water treatment processes.

For more information about Thermal Desorption, please contact EPA at the following address:

U.S. Environmental Protection Agency
ATTN: Superfund Hotline
401 M Street, S.W.
Washington, D.C. 20460
1-800-424-9346 or 1-800-535-0202

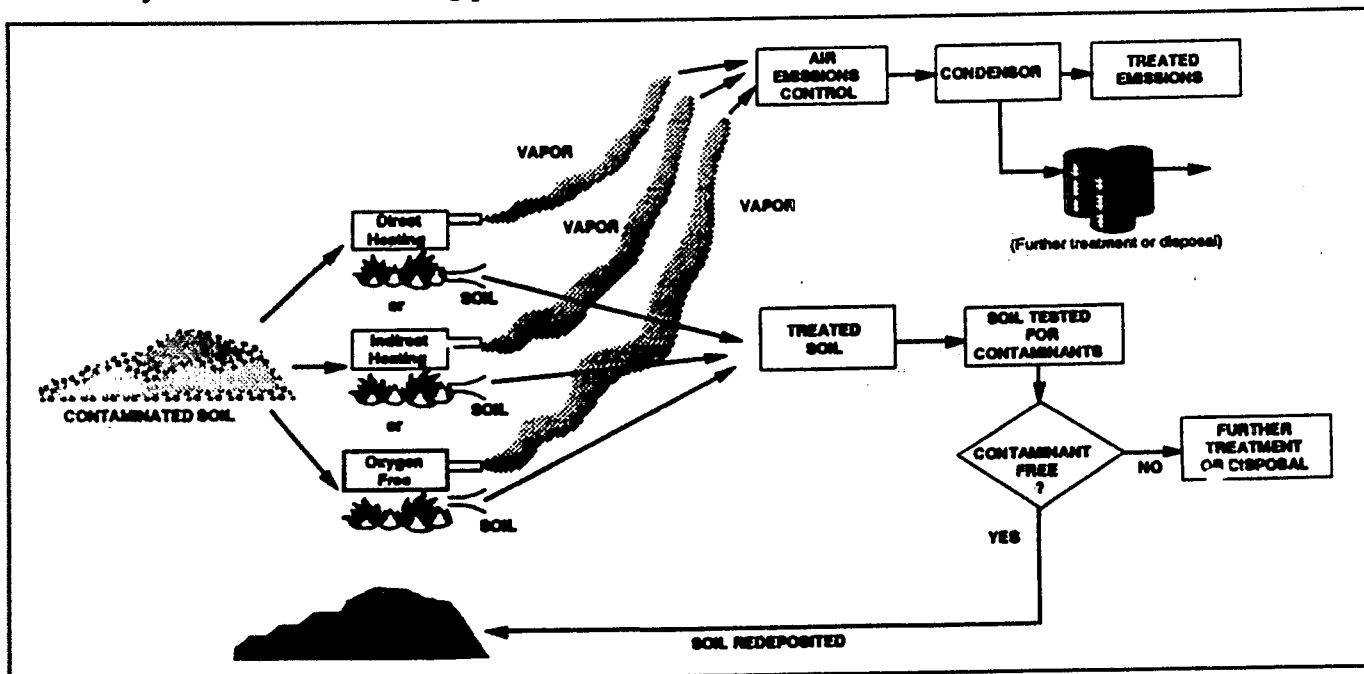


Figure 1: Thermal Desorption Process Following Soil Excavation

