A Citizen's Guide to Monitored Natural Attenuation

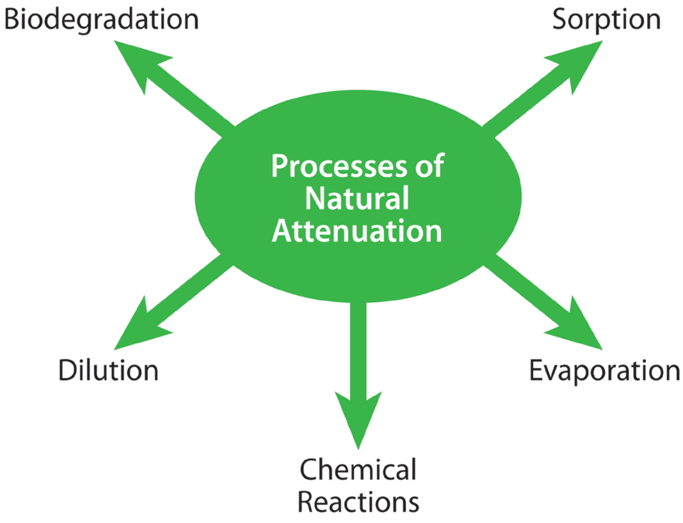
What Is Monitored Natural Attenuation?

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?

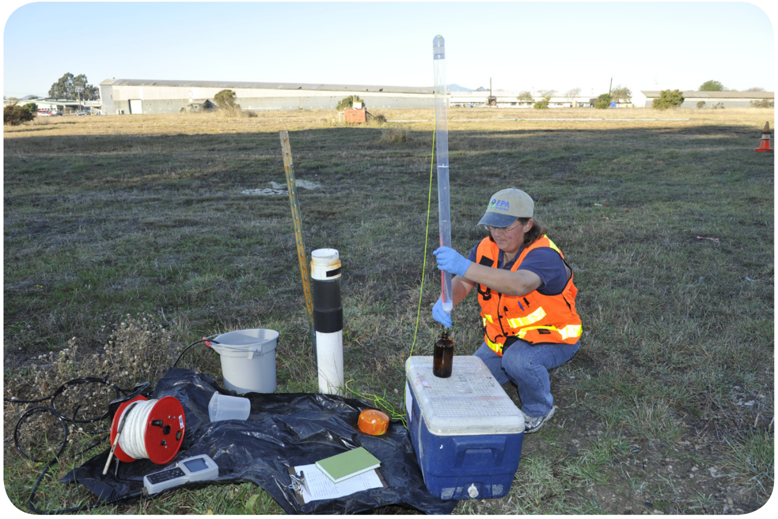
MNA does not pose a threat to the community or to site workers. MNA does not involve excavating soil or pumping groundwater to the surface for above ground treatment, so the potential to contact contaminants is limited. Long-term, regular monitoring is conducted to make sure contamination does not leave 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 about this and other technologies in the Citizen's Guide Series, visit:

www.cluin.org/remediation
www.cluin.org/products/citguide
www.cluin.org/products/MNA

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A Citizen's Guide to Bioremediation

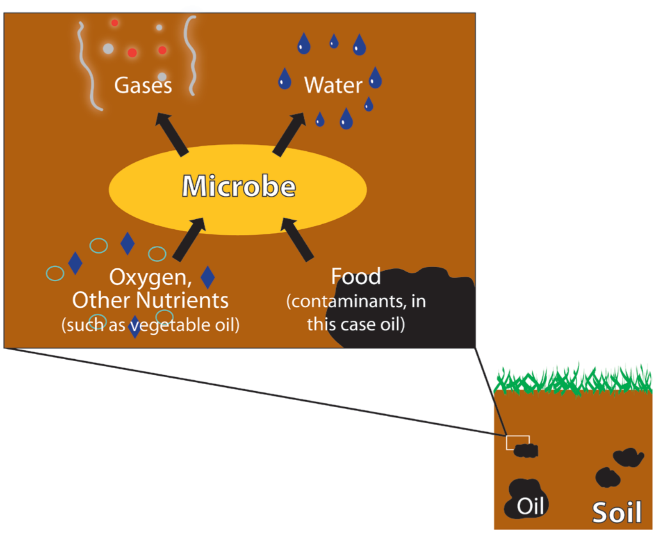
What Is Bioremediation?

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

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

www.cluin.org/remediation
www.cluin.org/products/citguide
www.cluin.org/bioreactor
www.cluin.org/bioremediation

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A Citizen's Guide to Activated Carbon Treatment

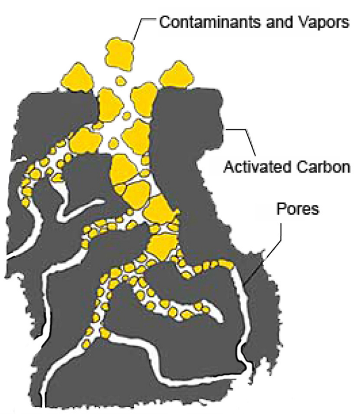
What Is Activated Carbon Treatment?

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 about this and other technologies in the Citizen's Guide Series, visit:

www.cluin.org/remediation
www.cluin.org/products/citguide

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