REMEDIAL ALTERNATIVES FOR AGRICULTURAL CONTAMINATION

S.W. Anderson and K.M. Yerraguntla
Black & Veatch Corporation, 101 North Wacker Drive, Suite 1100, Chicago, IL 60606;
Phone: (312) 346-3775; Fax: (312) 346-4781.

ABSTRACT

Agricultural soils contaminated with chemicals such as pesticides and fertilizers are affecting chemical quality of groundwater in many Midwestern states. A study conducted by the Wisconsin Department of Agriculture randomly investigated 27 agriculture application businesses and found that 93% had pesticide-contaminated soils. At least half of the 27 sites had pesticides in the groundwater. Persistent pesticides pose a threat to the well-being of the environment and to human health. Much consideration and research needs to go into the decision-making process for an effective remediation of a particular site. This paper provides information which has been accumulated about remedial technologies for source materials and soils and water media (surface water and groundwater) at industrial/commercial sites that may have applicability to agricultural problems, and explains a remedial alternatives evaluation process. Prior to the application of a particular remediation technology to a site, the key first step is to develop remedial alternatives that represent a range of feasible actions at the site. The alternatives normally range from No Action, where no additional action is taken to reduce the volume, mobility, or toxicity of chemical constituents present at the site, to full treatment. The alternatives are then screened in a subsequent planning step. The screening criteria include implementability of the alternative, effectiveness of the alternative, and total cost. *In situ* bioremediation, monitored natural attenuation, phytoremediation, land farming, and bioventing are promising remediation technologies for agricultural contamination. Soils should contain low moisture content and high permeability for the application of bioventing and *in situ* bioremediation technologies. Phytoremediation requires a large surface area of land and is limited to sites with lower chemical constituent concentrations in shallow soils. Land farming also requires a large land area for treatment and is relatively simple to design. Application of any of the above remediation technologies to agricultural contamination creates minimal disturbance to site operations, can be used to address inaccessible areas, may not require costly off-gas treatment, and easily combined with other technologies such as installation of vertical barriers, groundwater extraction, air sparging etc. Also, application of *in situ* bioremediation and monitored natural attenuation to the contaminates water media remediates chemical constituents that are absorbed onto or trapped within geological materials, produces no waste products that need to be disposed, and requires continued monitoring and maintenance. Vertical barriers are generally used to retard or restrict the flow of contaminated groundwater or to restrict the flow of clean groundwater into an impacted area. When a vertical barrier is placed upgradient of the agricultural contamination, it acts like an umbrella, keeping the groundwater from flowing through the area. When the barrier is placed downgradient of the agricultural contamination, it acts like a dam, retarding or restricting the groundwater flow. When the barrier is placed around the entire circumference of the impacted zone, it acts to isolate the chemical constituents from both upgradient and downgradient influences. Therefore, selection and application of a remediation technology or combination of remediation technologies to agricultural contamination will depend on the availability of the site-specific information.

Key words: agricultural contamination, phytoremediating, *in situ* bioremediation, barriers

INTRODUCTION

Agriculture may be facing remediation challenges that are similar to those addressed by Superfund in the last two decades. USEPA officials mention ethanol plants and confinement operations, and non-point source runoff as environmental challenges creating water quality problems. A Wisconsin Department of Agriculture study of 27 agriculture businesses found that 93% had pesticide-contaminated soils. At least half of the 27 sites had pesticides in the groundwater. Much consideration and research needs to go into the decision-making process for an effective remediation of a particular site. The objective of this paper is to share information that has been accumulated in a *Remedial Alternatives Manual* (Black & Veatch, 1999); discuss some of the most common remedial technologies for source materials, soils, and water that may have applicability to agricultural problems; and briefly describe the remedial alternatives evaluation process.

REMEDIAL ALTERNATIVES

Most common remedial technologies for source materials, soils, and water, fall under the following four categories:

- Containment
- Removal
- Treatment
- Disposal

Containment

If chemicals of interest are present at the site at concentrations exceeding the state or federal regulatory standards for exposure pathways such as ingestion, inhalation, and soil component of groundwater migration, then containment such as engineered barriers can be used to eliminate the potential for ingestion, inhalation, and migration to groundwater; thereby, eliminating these exposure pathways. Vertical engineered barriers are generally used to retard or restrict the flow of impacted groundwater, or to restrict the flow of clean groundwater into an impacted area. Barriers eliminate the potential for impacted groundwater to migrate to drinking water wells. The following are two of the popular vertical engineered barriers for contaminated agricultural sites:

1. Slurry Wall
2. Sheetpile Wall

Slurry Wall

A slurry wall is constructed below grade using the slurry construction method. A bentonite-water mixture forms slurry which is maintained in an excavation. The slurry forms a filter cake on the side walls of the excavation. The hydraulic pressure of the slurry on the filter cake membrane and the sidewall soils holds the excavation open. The excavation continues directly through the slurry fluid. After the excavation is dug to the depth needed to achieve the desired results, a backfill material is placed into the open trench. The backfill is designed to displace the slurry and to achieve the desired improvements in permeability reduction. Slurry walls can also be installed by drilling overlapping columns and by jet grouting.

The following conditions should be met to install a slurry wall:

1. Site should be relatively flat, since the slurry that holds the excavation open is a fluid. The open excavation zone must have an elevation difference of less than about three feet.
2. Aquitard must be within 100 feet of the surface over the entire affected area.
3. Slurry wall material must be compatible with chemicals present at the site.
4. Site must be secure.
5. Site must have adequate working area.

Slurry wall is very effective and reliable in containing wastes; however, long-term monitoring is needed. Slurry wall may degrade over time and may have potential long-term damage from freeze-thaw cycles, temperature fluctuations, flood damage, seismic damage, root and rodent penetration, and photodegradation.

Sheetpile Wall

A sheetpile wall is constructed below grade by driving interlocking sheets through the overlying soils to the aquitard. Figure 1 presents a typical installation of a sheetpile wall. Sheets are generally fabricated from heavy gauge steel sheet stock. Shape and gauge of the sheet determine the strength of the constructed wall. The sheets interlock at the ends to provide continuity of the wall.

The conditions required to install a slurry wall also apply to the sheetpile wall installation. Like the slurry wall, sheetpile wall is also very effective and reliable in containing wastes with no known limitations.

Figure 1. Sheetpile wall installation.

Removal by Excavation or Extraction

Removal of materials at the site includes excavation of contaminated soils and extraction of contaminated groundwater.

Excavation

Excavation is the process of removing soils from the surface and subsurface of the contaminated sites. After excavation, the removed materials are subject to additional treatment or disposal, which will be discussed under the Treatment and Disposal categories.

Excavation can be used where or when *in situ* or in-place treatment technologies are ineffective or inappropriate for the volume or concentration of chemicals present at Figure 1 Sheetpile Wall Installation the contaminated site. Figures 2 and 3 present excavation of contaminated soil/source material and lime sludge, respectively.

The following factors affect implementation of excavation:

1. Generally, materials to be excavated must be above the water table. Controlled groundwater extraction may be used to lower the water table temporarily, if needed, to allow for deeper excavation.
2. Materials to be excavated must have adequate handling properties. *In situ* stabilization blending may be appropriate to improve handling properties.
3. Excavation practices must be conducted in a manner to protect workers from potential exposure to site chemicals.
4. Excavations must be constructed, sheeted, or shored to protect workers from potential cave-ins or side wall failures.

Figure 2a. Excavation of contaminated soil.

5. Site odors and air emissions must be controlled and monitored. Site dust-control measures must be implemented as appropriate.
6. Site drainage must be controlled to limit runon into the excavation area and to limit runoff of impacted liquids from the excavation area to surrounding areas. Dikes, ditches, and retention basins should be implemented as appropriate.
7. Erosion-control plans and measures must be implemented for large, open excavation areas.

Extraction

Extraction wells are used to remove groundwater for one of two purposes:

1. To modify the natural groundwater gradients to affect hydraulic containment of chemicals present at the site.
2. To treat the extracted groundwater to reduce the toxicity or concentration of chemicals present at the site.

Extraction wells can also be used to remove the heaviest concentrations of LNAPL (floaters) and DNAPL (sinkers). Extraction wells are typically placed vertically into the aquifer, and groundwater is drawn to the well from an area around it. Figure 4 presents extraction well-drilling. The size of the area affected is related to the hydraulic conductivity (permeability) of the aquifer, the thickness of the aquifer, the pumping rate, and the pumping duration. Extraction wells are normally placed to provide full coverage of at least the leading edge of the contaminant plume.

Requirements for the use of wells for the extraction of groundwater for subsequent treatment or disposal are as follows:

1. Site must have aquifer conductivity that allows for the chemicals to be effectively removed.
2. Chemicals present at the site must be sufficiently mobile to allow for extraction.

Figure 2b. Excavation of contaminated soil.

3. Site must have adequate surface area to allow for setting up the well installation equipment.
4. Site must be secure to protect well head equipment.
5. Aquifer must be confined at the bottom or otherwise suitable locale to control migration of chemicals.

Extraction is not suitable to chemicals with high residual saturation, high sorption capabilities, and homogenous aquifers with hydraulic conductivity less than 10^{-5} cm/s.

Collector Trench

A collector trench is used to intercept and collect groundwater. Collector trenches are typically placed vertically into the aquifer at a point where groundwater will naturally flow to it. A system of pipes or other collection devices are provided inside the trench to allow for collection and removal of the liquids, and subsequent treatment and disposal. Requirements for use of collector trenches for the extraction of groundwater are as follows:

1. Site must have aquifer conductivity that allows for the chemicals to be effectively removed.
2. Site must have an adequate natural groundwater gradient so that groundwater flows to and into the trench with a minimum of pumping.
3. Chemicals present at the site must be sufficiently mobile to allow for extraction.

A collector trench is very effective for the collection and removal of relatively shallow groundwater.

TREATMENT

Contaminated materials (solids and liquids) at agriculture sites are required to be treated either *in situ* or *ex situ*. To implement *ex situ* treatment options, the materials must be removed as described above under the removal category. The following are some of the popular treatment options for contaminated materials at the agricultural sites:

Figure 2c. Excavation of contaminated soil.

1. *In Situ* Stabilization/Solidification
2. *In Situ* Bioremediation
3. Bioventing
4. Air Sparging
5. ORC/HRC Injection
6. Treatment Walls
7. Chemical/Biological
8. Phytoremediation
9. Monitored Natural Attenuation

The above treatment options are further discussed below.

In Situ *Stabilization/Solidification*

Stabilization/solidification is a process that treats contaminated soils to reduce the toxicity or mobility of chemicals present at the site. The process consists of injecting and mixing stabilizing reagents with surface soils through the use of augers or tillers. Stabilizing reagents typically used are Portland cement, lime, and proprietary chemicals such as silicas and polymers. The type of reagent used, as well as the ratio of reagent to soil, varies depending on the type of chemicals present at the site, and characteristics of soil and water content. Reagents can be introduced into the impacted area in either a powder or liquid form. The reagents are simultaneously injected and mixed into the soil. The soil is typically mixed by augers of two to three meters in diameter. The soil is mixed in overlapping circles to ensure complete mixing.

Requirements for use of this process option are as follows:

1. No boulders 8 inches and larger to interfere with the operation of the augers.

Figure 3. Excavation of lime sludge lagoon.

2. Nonhomogeneous soil or large quantities of debris could require different reagents.
3. Selected analytical tests are required on the soil samples.

The process is very effective for inorganics and less effective against pesticides and semivolatile compounds. The process requires treatability tests.

In Situ *Bioremediation*

Bioremediation is a general term used for the destruction of organic constituents in impacted soil and groundwater by biological mechanisms. It works on the basis of bacteria in the soil or water which breaks down the long, hydrocarbon molecular chains. Either bacteria are introduced into the subsurface environment, or the indigenous bacteria are provided with nutrients and oxygen to increase their population, or both. This process option involves the addition or injection of microorganisms (e.g., fungi, bacteria, and other microbes) or nutrients (e.g., oxygen, nitrates) to the subsurface environment to accelerate the natural biodegradation process. During the process the microorganisms eat and digest the organic substances for nutrients and energy. White-rot fungi may be useful for degrading chemical constituents such as chlordane, lindane, and DDT.

Requirements for use of this process option are as follows:

1. Soil permeability must be relatively high with low moisture content to allow the nutrients to reach indigenous microorganisms.
2. Chemicals present at the site must be biodegradable.
3. Treatability study for selection of materials must be conducted.
4. Introduce only hot water or gas to accelerate the remediation process, as higher temperatures support degradation.

Figure 4. Drilling for the installation of an extraction well.

This process cannot degrade inorganic constituents such as metals; however, it can be used to immobilize these constituents. Therefore, this process is only applicable to remediate soils and groundwater impacted with VOCs, SVOCs, and pesticides, and should be subjected to evaluation including bench and field treatability testing.

Bioventing

Bioventing stimulates the naturally occurring soil microorganisms to degrade chemicals present in the soil by providing oxygen. The rate of natural degradation is generally limited by the lack of oxygen and other electron acceptors, rather than by the lack of nutrients. In conventional bioventing systems, oxygen is delivered by an electric blower through subsurface wells to the vadose zone. The process uses low airflow rates to provide only enough oxygen to sustain microbial activity. Passive bioventing systems use natural air exchange to deliver oxygen to the subsurface via bioventing wells. A one-way valve is installed on a vent well, which allows air to enter the well when the pressure inside the well is lower than atmospheric pressure. When atmospheric pressure drops below the subsurface pressure, the valve closes, trapping the air in the well and increasing oxygen to soils surrounding the well.

Requirements for use of this process option are as follows:

1. Subsurface soil should contain low moisture content and high permeability.
2. Chemical constituents must be biodegradable and environmental conditions must promote biodegradation.
3. Monitoring of vapor at the soil surface is required.
4. Installation of injection wells is required.
5. Analytical testing is needed to show moisture content and permeability results.

Figure 5. Soil Vapor Extraction (SVE) System.

Air Sparging

Air sparging is an *in situ* process and involves injecting air directly into groundwater through air-injection wells. The process remediates groundwater by volatilizing organic chemicals and enhancing biodegradation. Air is bubbled through the groundwater *in situ* and it removes chemical constituents from the water through volatilization. The air containing the VOCs is generally collected using soil vapor extraction (SVE) for further treatment or management. Figure 5 presents an SVE system installed at an industrial/ commercial site. Air is usually introduced into the groundwater through a network of injection wells. The injected air bubbles out from the well and up to the surface. The higher the air pressure and volume of delivery, the larger the radius of influence will be for each well. As the chemical constituents move up into the soil, an SVE system is usually used to remove vapors. The addition of oxygen to impacted groundwater and soils also enhances biodegradation of chemical constituents in and above the water table, as it acts as a nutrient for bacteria.

Requirements for use of this process option are as follows:

1. Chemical constituents must be sufficiently volatile to be removable from groundwater.
2. Site must have appropriate permeabilities in the sparged zone and in the overlying vadose zone. Process will be effective if *in situ* permeabilities range from 1×10^{-2} to 1×10^{-6} cm/sec.
3. Vacuum extraction of contaminated vapors, gases, and moisture is necessary.
4. Pilot testing must be done to estimate the radius of influence that can be produced at the site.

Oxygen Release Compound (ORC) Injection

ORC is a patented formulation of magnesium peroxide that slowly releases oxygen as an electron acceptor upon hydration for about six months to one year. ORC can enhance remediation of any aerobically degradable chemical constituents, such as BTEX, MTBE, and vinyl chloride, by providing a long-lasting oxygen supply. These chemical constituents degrade aerobically much faster than anaerobically. ORC can be injected into the subsurface using direct-push equipment or inserted into monitoring wells in pre-packaged exchangeable “filter socks” to enhance aerobically degradable compounds such as BTEX, MTBE, and vinyl chloride.

Requirements for use of this process option are as follows:

1. Installation of injection wells.
2. Use of direct-push equipment to deliver ORC to the subsurface environment.

Hydrogen Release Compound (HRC) Injection

HRC is a polylactate (lactic acid) ester used to remediate anaerobically degradable chlorinated hydrocarbons such as perchloroethylene (PCE) and trichloroethylene (TCE). HRC is injected into the subsurface environment using direct-push technologies. When injected into the subsurface environment, lactic acid, which is an effective electron donor, is released continuously into groundwater. Microbes metabolize the lactic acid, release hydrogen, and use it for bioremediation. HRC’s patented time-release feature provides a steady hydrogen source for a minimum of six months to one year. Because this material can be injected directly into the subsurface environment, it can be used to deliver nutrients passively and enhance active biodegradation of chemical constituents.

Requirements for use of this process option are as follows:

1. Installation of injection wells.
2. Use of direct-push technology to deliver HRC to the subsurface environment.

Treatment Walls

This process, also called passive barriers or trenches, involves backfilling the in-ground trench with reactive media to provide passive treatment of impacted groundwater passing through the trench. The treatment wall is excavated at a strategic location to intercept the chemical plume and backfilled with microorganism-enhanced filter media, zeolite, activated carbon, peat, bentonite, limestone, or zero-valence iron, based on specific chemical constituents. The treatment processes, which occur within the treatment wall, are typically chemical or biological degradation, sorption, or precipitation. This process is applicable to a wide range of organic and inorganic chemical constituents.

Requirements for use of this process option are as follows:

1. Replacement or rejuvenation of the reactive media, if the treatment wall loses its reactive capacity or if the media is dissolved in the water.
2. Periodic removal of precipitates from the reactive media.

Chemical/Biological

This process involves two phases—biological treatment followed by a chemical treatment.

The biological treatment consists of adjusting soil pH, injecting liquid nutrients, and supplying oxygen by air sparging into the impacted area. The treatment fluids will be injected through the injection wells, while simultaneously withdrawing fluid from the recovery wells. Following the pH adjustment to approximately 8 and the addition of nutrients, air sparging will be started. During this treatment phase, soil samples will be collected on a daily and weekly basis to assess bacterial growth and activity.

The chemical treatment consists of injecting hydrogen peroxide and chelated iron into the injection wells. During this treatment phase, the soil pH and hydrogen peroxide concentration in the effluent water will be closely monitored. Tests will be performed on soil to confirm the removal of leachable chemical constituents adequately. Following the chemical treatment, if needed, another biological treatment will be carried out as a polishing step to eliminate any remaining or re-charged leachable chemical constituents from the soil.

Requirements for use of this process option are as follows:

1. Treatability tests to determine the removal efficiency.
2. Site characteristics.
3. Injectivity test to determine water-injection capacity in the target area.
4. Tracer test to determine the rate of groundwater movement.
5. Slug test to determine the initial conductivity of the impacted area.
6. Installation of treatment wells and surface facilities.

The process is effective for readily degradable organic compounds.

Phytoremediation

This is a bioremediation process that uses various types of plants to remove, transfer, stabilize, and/or destroy chemical constituents present in soil and groundwater.

The following are different types of phytoremediation mechanisms:

1. Rhizosphere biodegradation

   In this process, the plant releases natural substances through its roots that supply nutrients to microorganisms in the soil. The microorganisms enhance biological degradation.

2. Phytostabilization

   In this process, chemical compounds produced by the plant immobilize chemical constituents, rather than degrade them.

3. Phyto-accumulation

   In this process, plant roots sorb the chemical constituents, along with other nutrients and water. The chemical constituent mass is not destroyed but ends up in the plant shoots and leaves. This method is used primarily for wastes containing metals.

1. Rhizofiltration

   This process is similar to phyto-accumulation, but the plants used for cleanup are raised in greenhouses with their roots in water. As the roots become saturated with chemical constituents, they are harvested and disposed of.

2. Phyto-volatilization

   In this process, plants take up water containing organic chemical constituents and release the constituents into the air through their leaves.

3. Phytodegradation

   In this process, plants actually metabolize and destroy chemical constituents within plant tissues.

4. Hydraulic control

   In this process, trees indirectly remediate by controlling groundwater movement. Trees act as natural pumps when their roots reach down towards the water table and establish a dense root mass that takes up large quantities of water. Poplar trees, for example, extract 30 gallons of water per day, and cottonwoods can absorb up to 350 gallons per day.

The treatment zone is determined by the plant root depth. In most cases, it is limited to shallow soils, streams, and groundwater.

Requirements for use of this process option are as follows:

1. Low concentrations of chemical constituents.
2. No polychlorinated bipheyls (PCBs).
3. Large surface area.
4. Analytical tests.
5. Preliminary studies helpful for enhanced degradation of pesticides, such as atrazine and a few others.

Monitored Natural Attenuation (MNA)

This process is ideal for containment and reduction of the mass and concentration of organic chemical constituents in the environment. MNA is remediation of contaminated media without active treatment. MNA generally describes monitoring a range of physical and biological processes which reduce the concentration, toxicity, or mobility of chemical constituents. These processes take place whether or not other active cleanup measures are in place. MNA can be classified as destructive and non-destructive processes. Destructive processes include biodegradation and hydrolysis. Non-destructive processes include sorption, dispersion, dilution, and volatilization.

Long-term monitoring is necessary to demonstrate that chemical constituent concentrations continue to decrease at a rate sufficient to ensure that they will not become a health threat or violate regulatory criteria.

Requirements for use of this process option are as follows:

1. Site characterization.
2. Biodegradable, chemical constituents soil and environmental conditions promote degradation.
3. Assessments of potential risks.
1. Institutional controls.
2. Intensive monitoring program.

Landfarming/Biopiles

Landfarming is a bioremediation process in which impacted soil will be treated in a series of multiple lifts placed in a clay-lined biopad. The process involves setting up the following facilities on site:

1. Impacted soil staging area.
2. Impacted soil biological treatment area or biopad.
3. Groundwater and runoff water storage pond.
4. Water treatment facility.

The biopad facility of desired area will be constructed using a series of lifts of clay, compacted after each lift to provide required permeability. The biopad will be designed for multiple lift use to hold large volumes of soil per lift. During the construction of the biopad, impacted soil will be excavated and placed on the biopad. Bench-scale studies indicate that use of a specific aerobic bacteria amendment, along with soil nitrification, accelerates biodegradation.

The periphery of the biopad will be bermed to contain and prevent runoff of surface water. Impacted water can be treated on site and discharged to a storm drain or transported off site to a liquid recycling facility for treatment and disposal.

Thermal Desorption

This process involves excavating and heating soil containing VOCs until the chemical constituent concentrations in it are below regulatory standards and meet land disposal treatment standards. The resultant material may then be suitable for land disposal. The process is completed in several steps. First, the excavated soil is screened to accept material of appropriate size. The soil is then carried by a conveyor belt where it is weighed, recording the tonnage, and transported into a thermal desorber. The thermal desorption units are small thermal processors which heat soil to low temperatures, typical range between 700 and 1300°F, desorbing organic chemical constituents from the soil matrix. Production rates can vary from 15 to 120 tons per hour, depending on size of the impacted soil load and type of thermal processor. After thermal treatment of soil, high-pressure jets spray water on the soil to cool and rehydrate it before being stockpiled. Upon completion of laboratory testing to confirm removal of all chemical constituents to below land disposal standards, the soil can be disposed off site at a landfill or backfilled on site.

Requirements for use of this process option are as follows:

1. No moisture content greater than 14 to 15% by weight.
2. No debris greater than 2 inches in size.
3. No hazardous material.

Incineration

This process involves excavating, stabilizing, and transporting impacted soil to an incinerator for thermal destruction of chemical constituents such as pesticides and other organic compounds present in the soil. In the process, the soil is burned in the incinerator in two stages. Initial incineration takes place in a rotary kiln at a minimum temperature of 1600°F. Gaseous products, volatilized by the primary combustion chamber, enter the secondary combustion chamber where they are re-incinerated at temperatures up to 2400°F. Gases leaving the secondary combustion chamber will be cooled to about 200°F and are cleansed by air pollution control systems. Ash, slag, and other solid residues discharged from the incineration chambers drop into ash removal systems for cooling. All residues, including ash and those residues discharged from dry air pollution control systems, are laboratory tested to verify that they meet land disposal standards prior to the land disposal.

Requirements for use of this process option are as follows:

1. Soil must pass paint filter test and be non-tacky (no free liquids).
2. No debris can be greater than 2 inches in size.

Requirements for use of this process option are as follows:

1. Soil must be homogeneous.
2. Chemical constituents and bacteria levels in the soil must be monitored.
3. Moisture content in the soil must be maintained.

DISPOSAL

Landfill

Impacted soils excavated from the site can be disposed at landfills provided the soil must be analyzed for RCRA characteristics to determine if it is hazardous or nonhazardous. Soil exhibiting a characteristic of hazardous waste or containing hazardous chemical constituents from listed hazardous wastes at the point of generation are subjected to land disposal restrictions (LDRs). EPA established land disposal treatment standards for characteristic hazardous soil based on the reductions in chemical constituent concentrations that can be achieved using “Best Demonstrated Available Technology (BDAT) .” In the case of hazardous soil, the land disposal treatment standards require treating the chemical constituent that caused the soil to be hazardous, as well as all underlying hazardous constituents that are present in the soil, to the land disposal treatment standards. If laboratory testing of the site soil determines the soil is nonhazardous, the soil can be disposed in the landfill.

Landfill disposal requirements are as follows:

1. Soil must be nonhazardous at the point of generation.
2. Soil must pass paint filter test (no free liquids allowed).
3. Analytical testing of soil for landfill required parameters is necessary.

Pretreatment to POTW Discharge

This process involves pretreatment of the effluent prior to discharging to the publicly-owned treatment works (POTW).

Pretreatment—Pesticide treatment studies show the following:

1. Organophosphate pesticides—Malathion and Parathion can be degraded using aerobic bioreactors.
2. Organochloride pesticides—Chlordane, DDT, and Toxaphene appear to require cycling of aerobic anaerobic processes. Aerobic process mineralizes the compound.

A permit is required to discharge water to the POTW facility for further treatment.

Surface Water Discharge

This process involves discharging treated water from on site to surface water bodies. Surface water discharges normally require that an NPDES discharge permit be obtained. Treated water must meet discharge requirements for the aquatic water standards.

Recycling Facility

This process involves transporting liquids encountered during excavation, dewatering, groundwater extraction, and decontamination activities at the site to an off-site liquid recycling facility, or industrial waste treatment facilities, for treatment and disposal. At the recycling facility, the untreated liquid is either recycled or treated and disposed, depending upon the characteristics of the chemical constituents. This method of treatment and disposal is ideal for small quantities of untreated liquids.

CONCLUSIONS

Agricultural soils contaminated with chemicals such as pesticides and fertilizers are affecting chemical quality of groundwater. Persistent pesticides pose a threat to the well-being of the environment and to human health. Therefore, much consideration and research needs to go into the decision-making process for an effective remediation of a particular agricultural site, based on the contamination. Innovative technologies are being documented by EPA programs such as the SITE (Superfund Innovative Technology

Evaluation) and Federal Remediation Technologies Roundtable. Information regarding some of the popular remedial technologies appropriate for agricultural contamination is provided in this paper.

The following are to be considered prior to selecting a particular remedial technology:

1. Review site conditions and known data for each media (soil and groundwater).
2. Determine size and volumes of key media quantities to be managed.
3. Identify technologies that are potentially applicable to the strength and other characteristics of chemical constituents found in each site media.
4. Screen out technologies that are not suitable for the strengths, volumes, or other characteristics of chemical constituents.
5. Review case study documentation and perform treatability studies.

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