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Once this fluid gels in the rock or soil voids, it greatly reduces the permeability and increases the mechanical strength of the grouted mass. Grouting is rarely used when ground water has to be controlled in soil or loose overburden. The most common use of curtain grouting is to seal voids in porous or fractured rock where other methods of ground water control are impractical. The injection process itself involves drilling holes to the desired depth and injecting the grout with the use of special equipment. Ideally, the grout injected in adjacent holes should fuse between them. If this process is done properly, a continuous, barrier (curtain) will be formed.

2.3 Horizontal Barriers

2.3.1 Liners

A liner can serve as a technology which deters the movement of the chemicals in the soil into the ground water. Liners are installed after excavating the impacted soil. A three-foot layer of recompact clay, with a hydraulic conductivity of no more than 1×10^{-7} cm/sec is placed at the bottom of the excavation. The clay may then be covered by a flexible membrane liner (FML) which prevents migration of constituents into the clay liner.

A leachate collection system consisting of a pipe network is installed both above and below the FML. The collection systems serve both as warning devices indicating a possible hole in the membrane and as a collection system which reduces the hydrostatic pressure on the FML caused by infiltrated surface water.

2.3.2 Bottom Sealing by Grouting

Bottom sealing by grouting is a direct technique for installing a barrier to downward leachate migration. Grout is injected in the soil to form a bottom underneath the contaminants. The grout is injected horizontally from jets at the bottom of a pipe, which is inserted with a pneumatic

hammer. A grid of injected grout forms a contiguous bottom seal. Grout materials are typically silicate or Portland cement.

2.4 Surface Controls

2.4.1 Diversion/Collection

Diversion/collection systems are drainage ditches or trenches used to intercept overland flow or shallow ground water flow and control surface discharge. Ground water impacts may also be minimized by such measures. Ditches usually run around the perimeter of a site and may complement ground water or surface water control techniques by collecting water from subsurface drains or off caps. They may be lined with a clay or a synthetic membrane to prevent infiltration or with stone to prevent erosion.

2.4.2 Grading

Grading is the general term for the process of reshaping the surface of the ground to control surface water runoff and infiltration, as well as to minimize erosion and prepare the site for revegetation or sealing of the surface. The three basic steps in the process are hauling, spreading, and compacting. The latter two steps are routinely practiced at sanitary landfills. The equipment and methods used in grading are essentially the same for all surfaces, but applications of grading technology will vary on a site-specific basis. Grading is often performed in conjunction with surface sealing practices and revegetation as part of an integrated plan for the closure of a landfill.

2.5 Dust Controls

2.5.1 Revegetation

Revegetation decreases wind and water erosion, contributes to the development of a naturally fertile and stable surface, and reduces infiltration by

enhancing evapotranspiration (ie, increased loss of soil moisture). Reestablishing a vegetative cover may stabilize the surface of hazardous waste disposal sites, especially when preceded by surface sealing and grading. Short-term vegetative stabilization (ie, on a semiannual or seasonal basis) can be used during ongoing remedial actions.

2.5.2 Capping

Soil without additional media to cover it has the potential to lose moisture and result in uncontrolled dust. Capping a site with a material such as asphalt, concrete, or gravel would reduce the rate of evaporation and reduce the possibility of dust containing chemical residues from endangering human health and the environment.

2.5.3 Dust Suppressants

Control of fugitive dust, which may be impacted by chemical constituents from the site, could be achieved by the application of dust suppressants. This technology consists of the surface application of a liquid such as water or oil in affected areas that are not covered with vegetation. The technology is widely used to control dust at construction projects and on gravel roads. The effectiveness of each liquid application generally is of relatively short duration. Dust suppressants must be periodically reapplied for long-term control.

3.0 REMOVAL OPTIONS

Four technology types have been considered which may be capable of removing the constituents from the impacted site media. The technology types include the following: ground water collection/extraction, soil excavation, bulk sludge removal, and structures demolition.

3.1 Ground Water Collection/Extraction

3.1.1 Recovery Wells

Ground water extraction involves the pumping of ground water from strategically located recovery wells. The placement of recovery wells will be dictated by the objectives of the extraction system. Such objectives can include the following:

1. Extraction of chemical-bearing ground water for purposes of remediation;
2. Control and/or remediation of chemical source areas;
3. Hydraulic containment of chemical-bearing ground water plumes.

Ground water extraction can also be combined with other technologies to accomplish ground water remediation.

The effectiveness of this technology depends upon hydrogeologic conditions at the site. To be effective, the capture areas or areas of influence (depending on the specific purpose of the pumping) created by the recovery wells must intercept the chemical-bearing ground water in all affected aquifer zones. The technology has a proven performance history and uses a series of interceptor wells and pumps whose limitations and operating characteristics can be readily defined.

3.1.2 Interceptor Trenches

A ground water extraction trench containing a collector pipe and gravel backfill material acts like a continuous line of closely spaced extraction wells. The extraction trench or trenches can be used to contain the ground water carrying chemical residues. The ground water can be pumped from the trench for treatment and disposal or reinjection.

Criteria to be used in the design of an extraction trench may include the slope of the ground surface, depth of the trench, depth to the water table, the desired depth of drawdown, and the horizontal area to be affected. Interceptor trenches are often lined with a geotextile fabric to filter the fine, suspended soils from the ground water. The downgradient face of an interceptor trench may be lined with a synthetic membrane to reduce further migration.

3.2 Soil Excavation

3.2.1 Partial Soil Excavation

Partial soil excavation would involve the excavation of only those soils containing high concentrations of chemicals that are readily accessible to excavation. Soil would be excavated around the building and other structures on-site. Partial excavation would make the soils accessible for subsequent treatment or removal from the site. The limits of partial soil excavation may be selected to provide a specific reduction in the potential risks associated with dermal contact or ingestion of residuals, or may be related to anticipated ground water impacts associated with particular residual concentrations in unexcavated soil.

Partial soil excavation is generally accomplished by one or more of the following techniques: open-pit, caisson, and sheet pile excavations. Open-pit excavations include soil removal with backhoe or bulldozer. Limitations are imposed by the soil type, depth of water table, and relative locations of structures. Caisson excavations are accomplished by

vertically excavating the soil with a caisson rig. Sheet piling may also be driven next to the impacted zone. These piles provide stability to the soil. The impacted soils may be excavated on one side of the piling without decreasing the stability of the soils or foundations on the other side of the piling.

3.2.2 Complete Soil Excavation

Full soil excavation involves the excavation and removal of all soils containing chemical residues, together with sufficient quantities of adjacent soils to allow access and safe removal of the soils requiring remediation. Soils that are excavated would be stockpiled and made accessible either for treatment or for removal from the site. Full excavation of all soils containing chemical residues would require the destruction of some or all of the existing buildings and structures.

3.3 Bulk Sludge Removal

The sludges on-site contained in some of the process equipment and sumps may need to be removed for treatment and/or disposal. This will likely be accomplished by laborers using shovels or scrapers, transferring the residue into drums or pails.

3.4 Structures Demolition

The on-site structures that are found to be permeated or covered with chemical residues, and those structures that must be removed for soil excavation, may be demolished. These structures include the incinerator, the concrete pads, the Still Building, the scrubber building, and possibly the old church. Demolition would likely be performed using standard construction equipment. Steam cleaning or high-pressure washing may be required in order to remove chemical residues from impervious materials prior to disposal. Such decontamination options are discussed in Section 6.0.

4.0 TREATMENT OPTIONS

Seven technology types have been considered which may be capable of treating the constituents present in the impacted site media. The technology types include the following: physical treatment, chemical treatment, thermal treatment, biological treatment, in-situ treatment, solidification/stabilization, and solids processing/treatment.

4.1 Physical Treatment

4.1.1 Ground Water

4.1.1.1 Sedimentation

Sedimentation is a physical process whereby the particles suspended in the water are allowed to settle by means of gravitational forces. Sedimentation generally involves the use of a large tank in which the water moves slow enough to allow the particles to settle. The sediment is then removed from the tank bottom and disposed of and/or treated as a sludge. Sedimentation removes solids only and cannot remove dissolved organic or inorganics from the water.

4.1.1.2 Flocculation

Flocculation is a term describing the binding together of small particles in water into large particles as a result of the addition of a chemical coagulant. After the particles flocculate, they are allowed to settle out of the water in large tanks in which the water moves slow enough to allow the particles to settle. The sediment is then removed and disposed of and/or treated as a sludge. Flocculation, like sedimentation, cannot remove dissolved organics or inorganics from the water.

4.1.1.3 Filtration/Ultrafiltration

Filtration is generally used as a means of removing additional suspended solids after flocculation and sedimentation. Sand is a common filtration medium through which water is allowed to gravitationally flow and is capable of removing a satisfactory amount of solids. Sand filtration is often used as a pretreatment so that suspended solids do not plug or otherwise adversely affect other treatment systems.

Ultrafiltration involves forcing the water by pressure through a membrane, thus removing the suspended solids. This method has the ability to more effectively remove the particles, but is usually more costly than the filtration method. Filtration removes solids only, and cannot remove dissolved organics or inorganics from the water.

4.1.1.4 Reverse Osmosis

Osmosis is the movement of water through a membrane from a region of high constituent concentration to one of low concentration. Reverse osmosis is movement from low concentration to high. This is accomplished by applying pressure to the impacted water and forcing it through the membrane. The constituents then become concentrated on one side of the membrane as a sludge which then may be disposed of and/or treated. Organic and inorganic substances alike can be removed from water streams by this process.

4.1.1.5 Evaporation

Evaporation involves changing the state of a substance from a liquid state to a gaseous state. It can be used to separate inorganic compounds and other chemical constituents which do not evaporate from a wastewater stream. The water evaporates, leaving behind the chemical residues in the form of a sludge, which may be or disposed of and/or treated.

4.1.1.6 Air Stripping/Steam Stripping

Air stripping involves the volatilization of chemicals from water using either ambient temperature or elevated temperature air. It is widely applied to the remediation of aquifers impacted by solvents. Air stripping is most efficiently accomplished in a packed tower with countercurrent flow of air and water. The impacted water is pumped to the top of the tower and distributed uniformly across the packing. Air is blown into the base of the tower and flows upward, contacting the water. The dissolved organics in the ground water are transferred from the water to the air. The impacted air stream may then be treated or emitted. Volatile organic compounds (VOCs) with Henry's law constants greater than 10 atm are readily air strippable at ambient temperatures. Methyl ethyl ketone (MEK), which is found in the ground water of the UCC Site, is not readily strippable because of its low relative volatility as indicated by its Henry's law constant of 5.0 atm (24°C).

Like air stripping, steam stripping can be used to remove VOCs from water or aqueous waste streams. Instead of injecting air to the packed tower, steam may be used. As the steam moves vertically through the tower, the organics in the water are transferred to the steam. The steam exiting the top of the tower is then condensed and disposed of and/or treated. Steam stripping is more broadly applicable, in that it can treat more soluble, less volatile compounds, and achieve low effluent concentrations when the influent concentrations are very high. Due to higher capital and operating costs, steam stripping is not considered for ground water remediation where air stripping systems provide adequate reduction of organic components in the effluent.

4.1.1.7 Distillation

Many compounds found on the CERCLA Hazardous Substance List are hydrocarbons with boiling points between 80°C and 420°C. Heating these compounds to 300°C to 400°C would recover a large fraction of the components by

vaporization and distillation. Distillation is a unit process which is employed to segregate or purify liquid organic product streams. The process is usually nondestructive and can produce products of any desired consistency. Distillation is the boiling of a liquid and the condensation of the vapor when separation is desired.

Components which are separated by distillation are present in both the liquid phase as well as the vapor phase, but in different concentrations. If there are only two components in the liquid, one concentrates in the condensed vapor (condensate) and the other in the residual liquid. If there are more than two components, the less volatile components concentrate in the residual liquid and the more volatile in the vapor or vapor condensate.

4.1.1.8 Carbon Adsorption

Activated carbon adsorption is used in ground water treatment systems to remove organic compounds. The process is relatively nonspecific, and thus, is a good broad-spectrum treatment operation for influent streams with chemical compositions that are not fully understood and are variable. This process is capable of effectively removing VOCs from waste streams with the exception of water soluble compounds such as MEK and other ketones. Systems typically utilize granular activated carbon (GAC) in a flowthrough column vessel. The system is efficient and relatively simple to operate. Also, because the adsorption process is reversible, the adsorbed chemical constituents can be removed after the adsorption capacity of the carbon has been exhausted. Since the carbon can be regenerated, it can be reused. Thermal regeneration is typically employed where VOCs are being treated, since organic constituents are destroyed in the process. If regeneration is determined not to be cost effective, the exhausted carbon can be disposed of in an off-site landfill.

Liquid phase carbon adsorption is used to treat the ground water directly. Vapor phase carbon adsorption is used to treat air streams from in-situ or surface soil aeration operations or from air stripping units.

4.1.1.9 Ion Exchange

Ion exchange is a process that removes unwanted ions from impacted ground water by transferring the residue to a solid resin material "in exchange" for an equivalent number of innocuous ions stored in the ion exchanger material. Ion exchange is a relatively expensive process which can selectively remove a specific metal or metals from the waste stream. The ion exchanger has a limited capacity for storage of ions and eventually becomes saturated. It is then washed with a strong regenerating solution containing the innocuous ions, and these then replace the accumulated undesirable ions, returning the exchange material to a usable condition.

4.1.1.10 Dissolved Air Flotation

Solid or liquid particles which are lighter than the surrounding liquid can be separated from that liquid by air flotation. In this process, a stream of fine air bubbles is introduced into the bottom of the flotation tank. The air bubbles adhere to the particles or droplets and carry them to the surface of the liquid.

Electroflotation processes utilize hydrogen and oxygen gases to provide the flotation. These gases are generated at the surface of electrodes inserted into the solution. The waste particles, which are often charged, migrate to the electrode and coalesce on the emerging bubbles.

Flotation processes are generally followed by drainage processes whereby the liquid is drained from underneath the flotation solids. Air flotation and electroflotation are commonly used to separate oil and latex emulsions; the residues are dried and taken to land disposal facilities.

4.1.1.11 Liquid-Liquid Extraction

Liquid-liquid solvent extraction is the separation of the constituents of a liquid solution by contact with a second immiscible solvent in which the constituents are more soluble. The constituents in the original solution

are preferentially distributed into the second solvent and a certain degree of separation and concentration results. This may be enhanced by use of multiple contacts.

This process is not applicable to ionized species dissolved in water.

Solvent extraction is applicable to the removal of certain organic chemicals from water.

4.1.1.12 Electrodialysis

Electrodialysis is a combination of membrane technology and ion exchange technology. Electrodialysis uses ion exchangers in membrane form. The driving force across the membrane is provided by electric current. The ions are thus removed from the water and pass through the membrane, attracted by the opposite electric charge on the other side of the membrane.

The advantages of the system are that the residence time controls the amount of dissolved solids removed, and that the system can be run continuously with no regeneration required. The disadvantage of the system is that the water must carry an electric current. The cleaner the water, the more resistance to the current, which increases the cost of operation.

4.1.2 Soil

4.1.2.1 Liquefied Gas Solvent Extraction

This technology uses liquefied propane and/or butane solvent to extract organics from impacted sludges and soils.

The impacted solids or slurries are fed into an extractor. Solvent (gas condensed by compression) is also fed to the extractor, making nonreactive contact with the waste. Typically, the solvent separates more than 99 percent of the organics from the feed waste. Following phase separation of

the solvent and organics, the treated soil is removed from the extractor while the mixture of solvent and organics passes to the separator through a valve, where pressure is partially reduced. In the separator, the solvent is vaporized and recycled as fresh solvent. The organics are drawn off from the separator and either disposed of or reused.

This technology can be applied to waste containing carbon tetrachloride, chloroform, benzene, naphthalene, gasoline, vinyl acetate, furfural, butyric acid, higher organic acids, dichloroethane, oils and grease, xylene, toluene, methyl acetate, acetone, higher alcohols, butanol, propanol, phenol, heptane, polychlorinated biphenyls, and other complex organics.

4.1.2.2 Ambient Temperature Aeration

In ambient temperature aeration processes, soils impacted by VOCs are excavated and placed in designated aeration areas in layers approximately six inches thick. The soils are disked and exposed to air to facilitate the aeration process. The aeration process may be conducted inside an enclosure to minimize migration of fugitive dust and organic vapors. Organics present in the soils volatilize, are contained within the enclosure, and if necessary, are treated with vapor phase carbon adsorption prior to venting to the atmosphere. After processing, the soils may be returned to the excavation and compacted.

Where the aeration areas are outside, monitoring of ambient air may be required to document that ambient air quality is not adversely impacted. Monitoring of ground water or vadose zone soils beneath the aeration areas may be required in order to detect further soil impacts if the impacted soils are not placed on liners. Treatment levels achievable are variable and may depend on the constituents of interest and operating conditions.

4.1.2.3 Water/Solvent Leaching

Solvent leaching or solvent extraction is the separation of chemical compounds from solids by contact with a liquid in which the compounds readily dissolve. Solvent leaching is applicable, in principle, to the physical separation of selected waste constituents from sludge, soils, or solid mixtures. In practice, an appropriate solvent must be found. Extraction solvents are not currently available for all chemical constituents, and extraction efficiencies vary for different types of soils, concentrations, and other site-specific parameters.

4.1.3 Sludge

4.1.3.1 Freeze Crystallization

A freeze-crystallization process separates water from solutions (including hazardous wastes) by cooling the solution until ice crystals begin to form. Ice, with few exceptions, crystallizes as a pure material. The ice is separated from the remaining liquid and impurities, washed, and melted to produce a purified stream. The dissolved components of the stream are concentrated into a reduced volume.

The freeze-crystallization process is inherently insensitive to the composition of the waste stream it is processing. The process adapts automatically to changes in influent composition. It can handle a wide variety of waste stream components without pretreatment.

4.2 Chemical Treatment

4.2.1 Ground Water

4.2.1.1 Neutralization

Neutralization is a technique of accepted technical and economic feasibility by which certain hazardous wastes can be prepared for treatment.

The process involves the addition of an acid or an alkali to adjust the pH of the product to a level which allows the actual treatment technology to be more effective. The neutralization technique can be used to adjust the pH of ground water, sludges, or soils.

4.2.1.2 Chemical Precipitation

Chemical precipitation requires mixing chemicals with the solution of water and dissolved inorganic compounds to force the metals out of the solution. The inorganic constituents fall to the bottom of the solution as precipitates and are physically removed in a settling tank. This technology is well established and effective at removing inorganic constituents which are present in the water at high concentrations.

4.2.1.3 Chemical Oxidation

Chemical oxidation techniques have the ability to render many organic chemicals less toxic and can destroy some organic chemicals. Ozone and hydrogen peroxide are chemicals found to be quite effective as oxidizing agents. Even more effective than either oxidant alone is its use in conjunction with ultraviolet light. This technology is commonly referred to as UV/oxidation. Hypochlorite is another oxidizing agent, but has the tendency to change many organic molecules to substances more toxic than had existed at the site prior to treatment.

4.2.1.4 Alkaline Chlorination

Alkaline chlorination involves using an oxidizing agent such as hypochlorite to oxidize the inorganic constituents in the water. Before the oxidizing agent is added, however, the solution is made alkaline. By increasing the alkalinity of the impacted water, the solubility of residuals is reduced, thus, causing a higher rate of precipitation and a greater efficiency in removal of inorganic constituents.

Hypochlorite is an effective oxidizing agent, but has the tendency to render many organic molecules more toxic after oxidation than they were previous to treatment.

4.2.1.5 Catalytic Dehydrohalogenation

This process is capable of detoxifying halogenated organic molecules. The process does this by removing the halogen atom from the molecule, rendering it less toxic. Although this process has been accomplished in the laboratory, it has not been documented as applicable to field situations.

4.2.1.6 Electrochemical Operation

This technology uses the principle of electrolysis to remove inorganic constituents from water streams. The constituents are taken out of solution by electrical forces and plated onto the electrical probes which conduct the current. Because this process uses large amounts of electricity, it is, in general, financially infeasible.

4.2.1.7 Chelation

This technology involves the use of chelating agents. Chelating agents are materials similar to weak acids which exhibit a high degree of selectivity for metals such as copper, mercury, nickel, and lead. The result of mixing some metals and chelating agents is a metal-chelate complex which is less capable of migrating and resistant to decomposition and degradation.

4.2.2 Soil

4.2.2.1 Lime Neutralization

Soil can easily be neutralized by the addition of lime (CaCO_3). Similar to ground water (Section 4.2.1.1), soil is neutralized in order to prepare the medium for constituent removal.

4.2.3 Sludge

4.2.3.1 Oxidation/Reduction

A description of chemical oxidation/reduction is provided in Section 4.2.1.3. Sludges, as well as water, can be treated by this method, although its application is more common to water.

4.3 Thermal Treatment

4.3.1 Ground Water

4.3.1.1 Wet Air Oxidation

Wet air oxidation (WAO) is a high temperature, high-pressure process using oxygen as the oxidizing agent. The contaminated stream is mixed with air at temperatures from 350°C to 750°C and at pressures as high as 2,000 pounds per square inch. The WAO process is capable of treating a wide variety of organic compounds. It is suited for treating nonhalogenated compounds such as phenols, nonhalogenated pesticides, and cyanides.

4.3.2 Soil

4.3.2.1 Incineration

Incineration is a treatment method which uses high temperature oxidation under controlled conditions to degrade a substance into products that generally include carbon dioxide, water vapor, sulphur dioxide, NO_x, HCl, and ash. Thermal destruction methods can be used to destroy organic contaminants in liquid, gaseous, and solid waste streams. The most common incineration technologies applicable to hazardous wastes include liquid injection, rotary kiln, fluidized bed, multiple hearth, and fume incineration.

4.3.2.2 Pyrolysis

Pyrolysis is defined as the chemical decomposition or change brought about by heating in the absence of oxygen. Application of pyrolysis to hazardous waste treatment leads to a two-step process for disposal. In the first step, wastes are heated, separating the volatile from nonvolatile components. In the second step, volatile components are burned under the proper conditions to assure incineration of all hazardous components.

There are several variations of the process that include energy recovery and recovery of valuable components from the volatiles and/or solid residual. Pyrolysis is especially applicable to hazardous waste treatment because it provides precise control of the combustion process.

The first step of the pyrolysis treatment of hazardous waste is endothermic and generally completed at 425°C to 760°C. The heating chamber is called the pyrolyzer. The endothermic property makes the process much easier to control. Hazardous organic compounds can be volatilized at this low temperature, leaving a clean residue. In the second step, the volatiles are oxidized in a fume incinerator at conditions which result in a destruction efficiency of more than 99.9999 percent. Alternatively, the volatile fumes may be recondensed for off-site disposal or for recycling.

4.3.2.3 Low Temperature Thermal Aeration

The Low Temperature Thermal Aeration (LTTASM) process treats soils impacted by volatile and semivolatile organics by processing the soils through a low temperature (300°F to 400°F) thermal treatment unit. Air entering the treatment unit (in a counter-flow pattern) is heated to 300°F to 400°F, and comes in contact with the soil. This results in volatilization of chemicals. The effluent air stream is then directed to a baghouse to remove particulate matter, and then to a scrubber to remove any acid vapors. The final treatment of the effluent air consists of vapor-phase carbon adsorption. The treatment process occurs in a closed system, thereby minimizing

fugitive dust and containing the VOCs that are removed from the soil until the exhaust has been treated through the carbon adsorption system.

Soils may be economically treated by the LTTASM process to reduce semi-volatile organics to less than 1 ppm per constituent and to reduce volatile organics to nondetectable levels. Treatment capacity for this patented technology ranges from 100 to 250 cubic yards per 10-hour work day, depending on the soil type.

Generally, this technology is economical on sites where at least 2,000 cubic yards of soil must be remediated.

4.4 Biological Treatment

4.4.1 Ground Water

4.4.1.1 Trickling Filters

Trickling filters are fixed growth biological systems in which the impacted water is contacted with microbial growths attached to the surfaces of the supporting area. The impacted stream sprinkled over the fixed media provides the organic matter necessary to produce biological slimes that coat the surface. These bacterial growths adhere to the bed packing and biochemically oxidize the organic matter to CO₂ and produce new biological cells.

Trickling filters or biological filters are normally designed according to the applied hydraulic and organic loadings and are classified as high rate or low rate. Trickling filters and biological filters have been extensively used in the treatment of water contaminated with aromatic hydrocarbons, phenols, and pesticides. The process has been often employed as a roughing treatment process due to the ability to handle variations in influent waste composition. This process has also been reputed to be less inhibited by metals concentrations.

4.4.1.2 Rotating Biological Contactors

This system is a form of fixed-film biological treatment. A slime layer of microorganisms grows attached to polystyrene or polyvinyl chloride disks 6 to 12 feet in diameter. The disks are mounted vertically on a horizontal axis of rotation in treatment tanks. Rotation of the disks exposes the slime surfaces alternately to oxygen in the atmosphere and the chemical constituents in the water. Both oxygen and chemicals are metabolized. The chemicals are assimilated as microbial mass or degraded to form carbon dioxide, water and other metabolic byproducts by aerobic microorganisms. The rotation mixes and aerates the contents of the tank and causes excess lime layers to be sloughed off as growth continues. Sloughed slime is subsequently separated from the water in a settling system. A complete rotating biological contactor system may consist of two or more trains of disks with each train consisting of several stages.

4.4.1.3 Activated Sludge

This treatment technology involves introducing chemical-laden water into a reactor where an aerobic bacterial culture is maintained in suspension (mixed liquor). The bacteria degrade organic chemicals to form carbon dioxide, water, and metabolic byproducts and assimilate another fraction to form more cells. Oxygen is supplied to the reactor by mechanical or diffused aeration with air or an oxygen-enriched gas stream. Contact between impacted water, sludge, and oxygen is maintained in a properly operating reactor. A portion of the mixed liquor is continuously passed to a settling tank (clarifier) where sludge (primarily bacterial cells) is separated from effluent. A portion of the settled sludge is returned to the reactor to maintain the proper balance of microorganisms, while the remainder is removed from the system. Typical equipment includes aeration tanks and basins, clarifiers, compressors, aerators (diffused or mechanical), and recycle pumps and plumbing.

4.4.1.4 Sequencing Batch Reactors

The sequencing batch reactor (SBR) involves five process steps in one or more tanks. A batch reactor uses time to accomplish what a continuous reactor accomplished with space. The individual time sequences used in the SBR are as follows:

1. Fill - Raw waste is introduced to a reaction vessel that contains the bioorganisms used in the process. At the start of the fill cycle, the reactor contents are at a minimum level commonly known as the "bottom water level." Waste is added until the top water level is reached; all further operations cycle between the bottom water level and the top water level. The fill cycle usually begins with mixing, but no aeration.
2. React - Sufficient time is allowed for biodegradation reactions to occur under active mixing and aeration conditions.
3. Settle - Mixing and aeration are stopped, and suspended solids are allowed to settle under quiescent conditions.
4. Draw - Clarified water is removed from the reactor, which restores the fluid level in the tank to the bottom water level.
5. Idle - Bioorganisms are retained in the batch reactor, but no raw waste is treated. Depending on the nature of the waste being treated and the volume of sludge generated during the reaction phase, some withdrawal of biological sludge can occur during the idle portion of the cycle.

Several advantages that are important for hazardous waste applications are claimed for the SBR. In some cases, impacted water is not extracted in sufficient volume to justify a continuous treatment plant. Using an SBR system, the waste can be accumulated in a holding tank for periodic treatment.

4.4.1.5 Submerged Fixed Film Bioreactor

This submerged fixed-film bioreactor system relies on aerobic microbial processes to metabolize contaminants present in a liquid waste stream. The unique design of this system allows it to biologically treat liquids containing low concentrations (less than 20 ppm) of readily biodegradable materials and discharge concentrations in the low parts per billion (ppb) range. The bioreactor can also operate at hydraulic retention times as low as one hour.

The biological treatment system consists of an aboveground fixed-film reactor, supplemental nutrient storage tank and pump, sump tank with pump, cartridge filter, and final activated carbon filter. The bioreactor is operated on a one-pass, continuous-flow basis. The process begins when water from a ground water well or equalization tank is pumped directly into the bioreactor. The influent stream is evenly dispersed over the reactor packing through the use of a header-distribution system.

High surface area plastic media is used to fill the reactor, and the water level within the reactor is set to cover all of the packing material. Bacterial growth is attached as film to the surface of the plastic media.

As water passes by the biofilm, organics are removed. An air distribution system below the plastic media supplies oxygen to the bacteria in the form of fine bubbles. An effluent water header system collects water from the bottom of the reactor after it has been treated. Water exiting the reactor is passed through a cartridge filter to remove biological solids, and is finally passed through an activated-carbon canister to ensure that all organics have been removed. Depending upon the effluent water discharge criteria, the cartridge and carbon filters may not be needed. The water to be treated must also fall within guidelines for pH (6.5 to 8.5) and temperature (60°F to 95°F), and be free of toxic and/or inhibitory compounds which may include certain metals.

4.4.1.6 Land Treatment

Land treatment or land application is the treatment of contaminated water by using plant cover, biological activity, soil surface, soil profile, and geologic materials to remove certain pollutants. A number of experimental/operational systems have been designed to rennovate contaminated water by land application.

Hazardous wastes in the form of liquids, slurries, or sludges can be mechanically mixed with soil, thus utilizing the absorptive capacity of the soil and perhaps achieving some biological degradation of the wastes by soil microorganisms. This method, sometimes referred to as "chemical landfill," can be accomplished either by spreading the wastes over the soil in thin layers and then periodically mixed into the soil, or by placing the wastes in a trench or shallow pond (up to three feet deep) and then filling soil into the pond, whereby the liquid fraction is absorbed in the soil. Some evaporation may occur, perhaps to a high degree with the thin spreading techniques.

The wastes may be thinly applied to the land surface in the first technique by spreading in shallow furrows, through flood irrigation or by discharging from moving trucks. Use of furrow or flood irrigation would require initial grading of the area to achieve desired slopes; periodic regrading would also be necessary. For long-term use of a disposal area, these techniques rely on the liquids either evaporating or percolating deeper into subsurface soils.

Hazardous properties of some wastes may be degraded due to microbial activity in the soil, thus permitting periodic reuse of the same area for waste treatment. The biological degradation of specific substances at a new area might conceivably be enhanced by seeding with microorganisms. The inherent ion exchange capacity of the soil may also provide some beneficial treatment. The upper soil zone receiving the wastes eventually will become loaded to its ultimate capacity, and disposal operations will have to be terminated. Unless the waste materials will eventually decompose or

weather to nondeleterious products, the entire area used for waste disposal will require covering with soil material.

4.4.1.7 Enzymatic Degradation

The technology of enzymatic degradation requires the use of bio-catalyst carriers. These carriers are rigid, porous, silica-based materials that are designed to provide a protected environment where microorganisms and enzymes may biodegrade the chemicals present in the waste stream. The microorganisms or enzymes adhere to the carrier surface and are thereby immobilized.

Bio-catalyst carriers are available in a variety of shapes (eg, powders, pellets, spheres, extruded cylindrical tubes, etc), sizes, and pore diameters (ie, from 200 angstroms to greater than 1 micron). Enzymatic degradation has been used to biologically treat water impacted with phenol, paranitrophenol, and chlorinated aliphatic hydrocarbons.

4.4.1.8 AlgaSORB™

The AlgaSORB™ sorption process is designed to remove heavy metal ions from aqueous solutions and is based upon the natural, very strong affinity of the cell walls of algae for heavy metal ions. AlgaSORB™ is comprised of immobilized algal cells in a silica gel polymer. The algae are killed in the process of immobilization.

The process is only capable of removing heavy metal ions from aqueous solutions. Once AlgaSORB™ is saturated with metal ions, the metals are stripped from the algae using acids, bases, or other suitable reagents, thereby producing a small volume of very concentrated metal-containing solutions which must be further treated in order to detoxify them.

4.4.2 Soil

4.4.2.1 Composting

The composting process depends primarily on long detention times and acclimated aerobic microorganisms for systems involving a soil media. Fungi and anaerobic bacteria may also be present in composting systems. During land composting, the soil provides the necessary support for the microorganisms and functions as an adsorbent of refractory organics and metals.

A composting procedure for the windrow pile process might involve the following steps. First, soil and microorganisms are spread out about two inches thick. The soil may require moisture or pH adjustment. Next, the soil and microorganisms are formed into windrows about four inches high. The piles are flattened again and then piled with more soil and the process is repeated. An earth-moving apparatus is required for piling and turning the windrows during this process.

Moisture content is an important criteria for compost operations with optimum moisture contents of 63 to 79 percent determined for municipal refuse. Temperature is the fundamental parameter for measuring activity during composting operations. Initially, the temperature in the waste is the same as that of the ambient air. Heat is released as the microorganisms utilize the organics in the waste for energy and synthesis reactions. The microbial activity accomplishes rapid decomposition of organics as the temperature increases, with the temperature reaching as high as 70°C. The temperature again returns to ambient when the organic waste has been decomposed.

Metals inhibition of microorganisms during composting operations employing soil media has not been apparent. If the pH is kept neutral to alkaline and the compost beds are sequentially spread and piled to maintain aerobic conditions, the metals may be present as hydroxide, oxide, and/or carbonate precipitates or they may be adsorbed or exchanged onto the soil and/or organic media.

4.5 In-Situ Treatment

4.5.1 Ground Water

4.5.1.1 Aerobic Biodegradation

This remediation approach is based on the use of specific microorganisms as sole treatment agents which biodegrade toxic organic compounds in ground water.

Both broad spectrum removal as well as toxics removal of organics can be accomplished by use of specific microbes. The microbiological system completely degrades the organic contaminants without leaving residual intermediate compounds.

This technology can be used for remediation of ground water contaminated with organic compounds such as hydrocarbons, pesticides, halogenated aliphatic solvents (such as trichloroethylene), and PNA wastes. This technology is also applicable for the removal of certain inorganic compounds such as nitrates.

4.5.2 Soil

4.5.2.1 Enhanced Aerobic Biodegradation

The essence of this biotechnology involves the use of naturally occurring microorganisms to perform biodegradation of targeted organic hazardous waste. Once these microbes are adapted, the process involves the accelerated growth of these microorganisms and their inoculation into contaminated soil or the slurry in which the waste is contained. Nutrients and catalyst are added to the matrix to enhance the microbial activity. The result is the systematic biodegradation of organic contaminants over a time period of about two or four months. Byproducts of this metabolic consumption are carbon dioxide, water, and cell protoplasm. Once the organic contaminants have been biodegraded, the microbes die due to the lack of a

food source. This leaves non-hazardous cell protoplasm behind which in turn acts as a food source for the indigenous microorganisms present in the soil.

4.5.2.2 Flushing (With Surfactants)

In-situ soil flushing involves pumping water into and through primarily granular and relatively permeable soils in order to induce or increase a flux of ground water through areas containing high concentrations of chemicals. If flushing water is injected into saturated zones requiring remediation, it can produce artificial mounding of the water table in unconfined aquifer zones and increased pressure gradients in confined aquifer zones. In both cases, gradients and ground water flow rates in the saturated zone are increased. In both confined and unconfined saturated zones, extraction wells are utilized to recover the flushing water that contains the chemicals removed from the soils. In unconfined aquifers, the artificial mounding of the local water table will also allow the injected water to saturate and flush formerly unsaturated portions of aquifer soils that require remediation, but that are not affected by normal ground water flow.

Flushing water can also be introduced directly into unsaturated zones in order to saturate them and create a ground water flux to remove chemicals. Successful application of the technology depends upon the chemicals present, the site conditions, and the flushing rates selected. Flushing can be conducted using either local ground water extracted in the course of site remediation and treated prior to flushing, if necessary, or water from other sources.

The addition of surfactants to the water used in the flushing technology may result in increased removal rates of adsorbed and relatively insoluble chemicals from the subsurface. The ability of surfactants to enhance chemical recovery from soils has been demonstrated in the laboratory, and is currently under development as a remedial technology. However, there are some major concerns with the use of surfactants with respect to the

applicability of this technology to site chemicals and to site conditions, as well as to its anticipated performance.

4.5.2.3 In-Situ Vacuum Extraction/Soil Aeration

In-situ soil aeration is an innovative technology that is applicable to the removal of chemicals from unsaturated subsurface soils, particularly as applied to VOCs. It consists of the application of a vacuum to air extraction wells in order to draw air through the soil pore spaces. As air is transported through the target soils and permeable soil zones interconnecting the target materials with the ground surface, volatile chemicals are vaporized or dissolved in the air stream and are removed from the soil at the air extraction wells. The method is generally more advantageous to remediation of unsaturated soil zones than soil flushing because the rate of transfer of volatile and semivolatile chemicals is greater from soil to air than from soil to water. In-situ vacuum extraction may be implemented in conjunction with a ground water extraction system. The vacuum may be applied to the ground water extraction well, thereby increasing the yield of the well and remediating the unsaturated soil surrounding the extraction well.

4.5.2.4 Radio Frequency Heating

An expensive technology, radio frequency heating, has been applied to the decontamination of uncontrolled hazardous waste landfills. In this technique, the landfills were heated by means of strong radio waves to the point of decomposing, distilling, and vaporizing the hazardous constituents.

This technology, as applied to most hazardous sites, is used to heat the soil to temperatures around 300°C to 400°C. The residues are vaporized and are collected on the surface by a gas- or vapor-recovery system. The vapors are then treated and discharged according to environmental laws.

4.5.2.5 Steam Flushing

A transportable treatment unit is used for in-situ steam and air stripping of volatile organics from contaminated soil during site remediation. Drills are modified to allow the injection of steam and air into the soil through the cutting blades. The ground area being drilled is covered by a containment system to trap and recover the stripped volatiles. In this process, steam is piped to the top of the drills and injected through the cutting blades. The steam heats the ground being remediated increasing the vapor pressure of the volatile contaminants and thereby increasing the rate at which they can be stripped. Both the air and steam serve as carriers to convey these contaminants to the surface. The shroud, a metal box designed to seal the process area above the rotating cutter blades from the outside environment, collects the volatile contaminants and ducts them to the process train. In the process train, the volatile contaminants and the water vapor are removed from the off-gas stream by condensation. The condensed water is separated from the organics by distillation, then filtered through activated carbon beds and subsequently used as make-up water to a wet cooling tower. Steam can also be used to regenerate the activated carbon beds and acts as the source of heat for distillation of the volatile contaminants from the condensed liquid stream.

4.5.2.6 Thermal Stripping

Thermal stripping involves the injection of steam or hot air into unsaturated subsurface soils to increase the rate of chemical volatilization. The volatilized chemicals are then removed from the subsurface using vacuum extraction wells. This technology is considered appropriate for small-scale applications in localized areas. Large-scale applications require substantial (and usually prohibitive) amounts of energy to heat the soil. Although this technology is generally considered experimental, it has been field tested and it may be appropriate for application in combination with in-situ aeration for the remediation of localized occurrences of semivolatile chemicals.

4.5.2.7 Adsorbents

A wide variety of natural and synthetic sorbents can be added to soils to increase their natural sorption capacity. The addition of natural sorbents, such as sewage sludge, agricultural products and byproducts, and activated carbons, to impacted soil should complex, chelate or otherwise remove metals from the soil solution, thus preventing their leaching in ground water. The effectiveness and reliability of these methods, however, is highly site-specific. The reliability of these methods can be affected by such environmental factors as pH, ionic strength, solvents present in the waste, and competition from organics and inorganics in soil.

4.5.2.8 Vittrification

In-situ vittrification (ISV) is based on the concept of joule-heating to electrically melt soil or sludge. Melt temperatures, in the range of 1,600°C to 2,000°C, act to destroy organic pollutants by pyrolysis. Inorganic pollutants are immobilized within the vittrified mass. Both the airborne organic and inorganic combustion byproducts are collected in a negatively pressurized hood which draws the contaminants into an off-gas treatment system that removes particulates and other pollutants of concern.

The vittrification process is carried out by inserting large electrodes into contaminated zones containing sufficient soil to support formation of a melt. Graphite is placed on the surface to complete the circuit between the electrodes. An electric current is passed through the electrodes and graphite, and the heat generated from this current causes a melt that gradually works downward through the soil. This process permits soil or sludge to be vittrified over an area of approximately 27 feet on a side to a depth of 20 feet and requires 7 to 10 days to complete. The system is then moved, and the vittrification process is repeated. This is continued until the entire contaminated soil or sludge volume on the site has been vittrified.

4.5.2.9 Polymerization

This in-situ stabilization technology immobilizes organic and inorganic compounds in wet or dry soils by using reagents (additives) to polymerize with the soils and sludges producing a cement-like mass. Two basic components of this technology are the deep soil mixing system, a system capable of delivering and mixing chemicals with the soil in-situ, and the batch mixing plant that supplies the proprietary treatment chemicals.

The developer states that their proprietary additive generates a complex crystalline connective network of inorganic polymers and that the structural bonding in the polymer is mainly covalent. Furthermore, in the process, there is a two-phase reaction in which the contaminants are complexed first in a fast-acting reaction and then in a slow-acting reaction where the building of macromolecules continues over a long period of time. For each type of waste, the quantity of additives used varies and must be optimized.

This technology can be applied to soils, sediments, and sludge-pond bottoms contaminated with organic compounds and metals.

4.6 Solification/Stabilization

Solidification and stabilization are treatment processes designed to either improve waste-handling and physical characteristics, decrease the surface area across which chemicals can migrate or leach, or limit the solubility of or detoxify the hazardous constituents. Solidification implies that these results are obtained primarily by production of a monolithic block of treated waste with high structural integrity. Stabilization describes processes which limit the solubility of or detoxify the chemical constituents; however, the physical characteristics may or may not be improved or changed.

Solidification/stabilization of soil can be achieved by adding binders. Binders fall into two general categories: inorganic and organic. Most

inorganic binders used include any combination of silicates, hydraulic cements, or pozzoloans. Organic binders may include epoxy, polyester, asphalt, or urea-formaldehyde.

4.7 Solids Processing/Treatment

Structures or other facilities may contain chemical residues and therefore require decontamination. Demolition of the facilities may also be required to effectively decontaminate the material or to excavate impacted soils located beneath the facilities. Mechanically crushing or grinding the debris can increase the efficiency of the decontamination technology (Section 6.0). Screens and/or magnetic processes can facilitate the crushers and grinders by preventing too large of debris or uncrushable metals from entering the mechanisms.

The objective of the debris decontamination is to remove chemical residues from the surfaces of impervious material so that the material may be disposed of in a sanitary landfill, or removed as scrap. Cleaning effectiveness may be assessed through a visual test, such as the observance of extraneous colors or films on the material to be cleaned. Alternatively, cleaning effectiveness may require that wipe samples be taken on randomly selected areas, with subsequent chemical analysis of the wipe samples to verify that chemical residuals are reduced to acceptable levels.

5.0 DISPOSAL OPTIONS

Four technology types have been considered which may be options for disposal of treated or untreated media. The technology types considered include disposal of the following: ground water, ground water treatment residuals, soil, and sludge.

5.1 Ground Water

5.1.1 Off-Site Disposal

This technology involves pumping extracted ground water into tank trucks. The water could be then hauled to an off-site RCRA facility for treatment and disposal.

5.1.2 Discharge to Publicly Owned Treatment Works

Extracted ground water could be pumped, trucked, or otherwise discharged to the nearest Publicly Owned Treatment Works for treatment and/or disposal.

5.1.3 Discharge to Surface Water After Treatment

Treated ground water could be discharged into Quiggle Brook for disposal. Either trenches or pipes could be used to transport the water from the point of treatment to Quiggle Brook. The treated water would be discharged in accordance with environmental laws which are applicable or relevant and appropriate.

5.1.4 On-Site ReInjection of Treated Ground Water

Disposal of treated ground water by reinjection into an aquifer involves pumping water from the treatment system into wells, trenches, or leach fields that are hydraulically connected to the aquifer. The effectiveness of reinjection is dependent upon the hydrogeology of the area, hydraulic

characteristics of the receiving aquifer, injection and extraction flow rates, chemical concentrations, and inorganic chemical characteristics of the reinjected water. Generally, the recharge capacity of a well is less than its pumping capacity. The hydrogeology of the area and the hydraulic characteristics of the receiving aquifer will determine to a large extent the rate at which water can be reinjected. In general, an extensive, continuous, and relatively permeable aquifer is necessary to allow efficient injection of water. Because the screen length for an injection well is generally much longer than for a pumping well, a relatively thick aquifer is necessary to provide an adequate injection rate.

5.1.5 On-Site Spray Irrigation After Treatment

This operation includes pumping the treated ground water and discharging it via a pipe network and spray nozzles, thus irrigating the vegetation on-site. The sprayed water would infiltrate and/or runoff the ground surface, depending on site conditions.

5.2 Ground Water Treatment Residuals

5.2.1 On-Site Disposal and Off-Site Treatment/Disposal

Residuals from the ground water treatment process could either be treated and/or disposed of on-site in a RCRA landfill or be transported off-site for disposal and/or treatment in accordance with applicable or relevant and appropriate environmental laws.

5.3 Soil

5.3.1 On-Site and Off-Site Disposal of Contaminated Soils in a RCRA Landfill

If the impacted soil is to be excavated, on-site or off-site disposal of the contaminated soil in a RCRA landfill is also an option. On-site disposal of soils which have not been treated requires construction of a

RCRA landfill, possibly in the same location as the excavation, where soils would be placed. Proper monitoring, maintenance, and land use controls are required to ensure safe, long-term performance.

Disposal of excavated soil in an off-site RCRA landfill, unlike on-site disposal, requires transport. This disposal method also requires proper monitoring, maintenance, and land use controls. The excavated areas on-site would require backfilling and/or regrading.

5.3.2 On-Site Disposal of Treated Soils as Backfill

This operation involves disposal of treated soils by returning the soils to the area of excavation. Soils determined to be treated to an acceptable level may be used as backfill for the excavation.

5.3.3 On-Site Storage of Soils

It may be necessary to store some or all of the excavated soils on-site. These soils may or may not be treated prior to storage in impoundments or in vaults. Proper monitoring systems must be included with the impoundments or vaults to detect potential leaks from these structures. Storage may be appropriate where timely excavation is necessary to eliminate further impacts, but treatment units for the soil are unavailable. Storage may also be necessary where no treatment system has been approved by the U.S. EPA for the waste material. In this case, storage is required to minimize the potential for exposure until treatment systems are developed or approved.

5.4 Sludge

5.4.1 On-Site Disposal of Solidified Sludge

If the sludge removed from the on-site process equipment cannot be treated in a cost-effective manner to yield the residuals nonhazardous, the materials may be solidified to minimize potential leaching and then disposed on-site. Various solidification processes are described in Section 4.6. If treatment effectively renders the material nonhazardous, temporary storage may be appropriate while application is made and processed to delist the material.

5.4.2 Off-Site Disposal of Contaminated or Biological Sludge in a RCRA Landfill

The contaminated or biological sludge could be transported and placed into a RCRA landfill as a means of disposal. As with all landfills, proper monitoring, maintenance, and land use control must be implemented to assure minimal risk to human health and the environment.

6.0 DECONTAMINATION OPTIONS

Eight technology types have been considered which may be used to decontaminate the structures, concrete, or equipment which contain toxic residuals. The technology types include the following: dusting/vacuuming/wiping, gritblasting, hydroblasting, painting/coating, scarification, RadKleen®, solvent washing, and steam cleaning.

6.1 Dusting/Vacuuming/Wiping

This method of decontamination is simply the physical removal of hazardous dust and particles from building and equipment surfaces by cleaning techniques including dusting, vacuuming, and wiping. This technique is only capable of treating the surfaces and is ineffective at decontaminating material which has absorbed toxic residuals.

6.2 Gritblasting

Gritblasting is a surface removal technique in which an abrasive material is used for uniform removal of contaminated surface layers from a building or structure. This is an effective technology for surface treatment, but is ineffective at decontaminating more than 0.5 to 1.5 cm below the concrete surface.

6.3 Hydroblasting

A high-pressure water jet is used to remove impacted debris from surfaces. The debris and water are then collected and thermally, physically, or chemically decontaminated. Hydroblasting is relatively inexpensive, but may not effectively remove residues that have penetrated the surface. The method is also incapable of decontaminating dioxin-contaminated surfaces.

6.4 Painting/Coating

Various agents can be used as coatings on contaminated residues to fix or stabilize the contaminant in place and decrease or eliminate exposure hazards. Potentially useful stabilizing agents include molten and solid waxes, carbowaxes (polyoxyethylene glycol), organic dyes, epoxy paint films, and polyester resins. The stabilized contaminants can be left in place or removed later by secondary treatment. In some cases, the stabilizer/fixative coating is applied in-situ to desensitize a contaminant (such as an explosive residue) and prevent reaction or ignition during some other phase of the decontamination process (for example, to prevent explosions during dismantling or demolition).

With this technique, toxic contaminants remain on the site; monitoring of the effectiveness of the barrier coating is required over its lifetime. Removal at a later date may also be required.

6.5 Scarification

This technique is capable of removing up to 2.5 cm of surface layer from concrete or similar materials. The scarifier tool consists of pneumatically operated heads that strike the surface, causing concrete to chip off. The piston heads consist of multi-point tungsten carbide bits.

6.6 RadKleen®

RadKleen® is a commercial process which uses Freon-113 to extract residues from building materials. The solvent is pressure sprayed onto the surface and then reclaimed, volatilized, and reused. The method is ineffective in decontaminating cyanide or heavy metals and must be used in a closed system.

TABLE 1

CERCLA/RCRA/UST SITES CONSIDERING, PLANNING, OR
OPERATING FULL-SCALE BIOREMEDIATION SYSTEMS

Rgn	Site/Location/Lead	Contact/Phone Number	Contaminants/Media	Status	Clean-up Levels	Treatment
I	Baird & McGuire Holbrook, MA Fund lead	Paula Fitzsimmons 617-573-5738 FTS 833-1738	Pesticides (chlordane), dioxin, arsenic/groundwater	Under construction; ROD signed 9/30/88	State of MA drinking water standards	Bioreactor
I	Charles George Landfill* Tinsboro, MA Fund lead	Dave Dickerson 617-573-5735 FTS 833-1735	Arsenic, benzene, toluene, ethyl benzene, xylene, tetrahydrofurans/groundwater, leachate, landfill gas	ROD signed 9/88; initial treatability studies completed 6/90	MCLs and risk-based levels for groundwater and leachate	Bioreactor (activated sludge) for groundwater and leachate treatment
I	Charlestown Navy Yard Boston NHP National Park Service Boston, MA State-lead enforcement	Stephen Carlson 617-242-5680	PAHs from creosote/sediments	Planning pilot project for FY 91	Not yet established	In situ
I	General Electric* Pittsfield, MA TSCA lead	Joan Blake 202-382-6236 FTS 382-6236	PCBs/river sediment, soils	Undergoing pilot treatability studies	2 ppm per peak	Ex situ
I	General Electric Pittsfield, MA TSCA lead	Joan Blake 202-382-6236 FTS 382-6236	PCBs/pond, river sediment	Undergoing pilot treatability studies	2 ppm per peak	In situ
I	Hamilton Standard* Windsor Locks, CT RCRA lead	Gina Snyder 617-573-9874 FTS 833-1874	PCBs, petroleum hydrocarbons/soil	Planning to conduct treatability studies in FY 91	Not yet established	In situ
I	Iron Horse Park Billerica, MA PRP lead	Don McElroy 617-223-5518 FTS 833-1518	Petroleum hydrocarbons/soil	Treatability studies completed 1989; ROD signed 9/15/88; currently in design stage	80-80% removal or less than 1 ppm PAH; 50-80% removal of PHCs; nC ₁₇ /pristane ratio < or =0.2	Excavate to treatment cell-surface treatment
I	Pine Street Canal Burlington, VT Fund lead	Ross Gileland 617-573-5786 FTS 833-1786	Coal tar, PAHs/soils, sediments, groundwater	Conducting bench-scale tests, Fall 1990; supplemental R/VFS in progress	Not yet established	Soil: in situ Groundwater: fixed film reactor
I	Sylvester Nashua, NH State lead enforcement	Chet Janowski 617-573-9823 FTS 833-1623	Phenols, MEK, acetone/groundwater	Treatability study complete; conducting remediation since July 1988	State of NH drinking water standards	Bioreactor (activated sludge with extended air)
II	Alcoa Massena, NY	Lisa Carson 212-264-6857 FTS 264-6857	PCBs/river sediments	Currently in RI stage	Not yet established	Undetermined
II	American Linen* Stillwater, NY Enforcement lead	Frank Paduto NYSDEC 518-457-2482	BTX, PAHs, VOCs, VTX/soil	Began land treatment operations 9/90		Land treatment
II	FAA Technical Center* Atlantic County, NJ PRP lead	Carla Struble 212-264-4595 FTS 264-4595	JP-4 jet fuel/soil, groundwater, floating product	ROD signed 9/29/89; currently in RD stage	NJ soil action levels; NJ MCLs for drinking water	Free product extraction and off-site cement kiln incineration; groundwater extraction and addition of nutrients for subsequent reinjection and in situ biodegradation of VOCs; soil venting; use of off-gas treatment unit for off-gas from soil venting, consisting of either a catalytic incinerator for combustion of VOCs to carbon dioxide and water, or activated carbon adsorption of VOCs

* Indicates a new site in the Table.

* Information regarding this site has been updated for this issue.

Shading depicts a non-CERCLA site.

CERCLA/RCRA/UST SITES CONSIDERING, PLANNING, OR OPERATING FULL-SCALE BIOREMEDIATION SYSTEMS

Rgn	Site/Location/Lead	Contact/Phone Number	Contaminants/Media	Status	Clean-up Levels	Treatment
II	GEMS Landfill* Camden County, NJ State lead	Matt Westgate 212-264-3406 FTS 264-3406	Various organic and inorganic compounds/groundwater, leachate	Phase I FS underway; Phase II construction of remedial action in the design phase	Not yet established	Phase I - cap; Phase II - groundwater pre-treatment and disposal at publicly owned treatment works
II	General Electric* State lead	Jim Harrington NYSDEC 518-457-3957	PCBs	Research/treatability studies	Not yet established	Possibly bioremediation
II	General Motors* Massena, NY Enforcement lead	Lisa Carson 212-264-6857 FTS 264-6857	PCBs, PAHs, volatiles/soil, sludge, sediment, groundwater	Conducting bench-scale studies; ROD signed 12/17/90; beginning negotiations for conducting treatability studies	Proposed 10 ppm PCBs (soil), 1 ppm PCBs (sediment)	Undetermined - possibly biological treatment
II	Knispel Construction Site Horseheads, NY State lead	Frank Peduto NYSDEC 518-457-2462	Gasoline, benzene/soil, groundwater	Remediation completed 10/89	Drinking water standards	In situ (subsurface)
II	Nascolite* Millville, NJ Federal lead	Farnaz Saghafi 212-264-4665 FTS 264-4665	Methylmethacrylate, volatiles and semi-volatiles/soil, groundwater	Soil treatability studies conducted 9/90; ROD scheduled for 1991; treatability studies for groundwater underway; ROD signed 1988	NJ interim soil action levels for methylmethacrylate: 5 ppm (surface soil); 50 ppm (subsurface soil); and 350 ppb (groundwater)	Soil: proposed plan calls for extraction/solidification or soil washing - residuals from soil washing may be treated by bioremediation; Groundwater: Undetermined, possibly bioremediation
II	Osmose* Buffalo, NY State lead	Jim Harrington NYSDEC 518-457-3957	Creosote, fuel oil/soil	Land treatment ongoing	Not yet established	Land treatment
II	Renora, Inc., NJ*	Joyce Harney 212-264-6313 FTS 264-6313	PAHs, petroleum hydrocarbons/soil	Treatability study complete; bioremediation ineffective; phase II feasibility study in progress	PAHs 10 ppm; petroleum hydrocarbons 1000 ppm	Undetermined
II	Reynolds Metals Massena, NY	Lisa Carson 212-264-6857 FTS 264-6857	PCBs/river sediments	Currently in RI stage	Not yet established	Undetermined
II	Syracuse* UST lead	Chris O'Neill NYSDEC 518-457-2462	Gasoline, fuel oil/soil, groundwater	In discussion phase	Groundwater standards; proposed draft soil standards	Undetermined
III	ARC Gainesville, VA RCRA lead	Robert Stroud 215-597-8214 FTS 597-8214	Chlorobenzene/soil	Treatability study conducted 6/90; planning pilot study	Unknown	Bioremediation unit on-line since 10/89
III	Atlantic Wood* Portsmouth, VA PRP lead	Drew Lausch 215-597-1727 FTS 597-1727	PAHs from wood preserving/soil, groundwater	RI/FS ongoing; ROD scheduled for 6/91	Not yet established	Undetermined
III	Avtex Fibers Front Royal, VA PRP lead	Bonnie Gross 215-597-9023 FTS 597-9023	Arsenic, zinc, lead, carbon disulfide, hydrosulfide, phenol, cadmium/ groundwater	Treatability study planned	.05 mg/l arsenic; 5 mg/l zinc; .05 mg/l lead; .7 mg/l carbon disulfide; .3 mg/l phenol; .01 mg/l cadmium (not yet established for hydrosulfide)	Biological waste water treatment
III	Drake Chemical Lock Haven, PA Fund lead	Roy Schrock 215-597-0913 FTS 597-0913	Pesticides, DCE/soil, groundwater	Planning treatability study	MCLs	BACT
III	L.A. Clarke & Son* VA Enforcement lead	Gene Wingert 215-597-0517 FTS 597-0517	Creosote/soil	Treatability study and RI/FS ongoing; ROD signed 1/92	10 ppm carcinogenic PAHs	In situ (surface and subsurface)
III	Leetown Pesticides Leetown, WV Federal lead	Andy Palestini 215-597-1286 FTS 597-1286	DDT, lindane/soil	Treatability study conducted Spring 1990; now re-evaluating remedial action	300 ppb DDT; not yet established for lindane	Undetermined

▲ Indicates a new site in the Table.
 * Information regarding this site has been updated for this issue.
 Shading depicts a non-CERCLA site.

CERCLA/RCRA/UST SITES CONSIDERING, PLANNING, OR OPERATING FULL-SCALE BIOREMEDIATION SYSTEMS

Rgn	Site/Location/Lead	Contact/Phone Number	Contaminants/Media	Status	Clean-up Levels	Treatment
III	Ordinance Works Disposal Areas, WV* Enforcement lead	Drew Lausch 215-587-1727 FTS 587-1727	PAHs/soil	ROD signed 9/29/89; currently conducting treatability studies; unilateral administrative order issued 6/20/90	45 ppm carcinogenic PAHs	Land treatment
III	Whitmore Labs* Myerstown, PA Fund lead	Tony Dappolone 215-587-3153 FTS 587-3153	Arsenic, aniline, still bottom wastes/soil, groundwater, sludges (only certain soils are targeted for bioremediation)	Limited treatability study completed 6/90; ROD signed	Arsenic above background levels; Saturated soils: benzene .002 mg/kg; trichloroethene .004 mg/kg; tetrachloroethene .012 mg/kg; aniline .002 mg/kg; Unsaturated soils: benzene .009 mg/kg; trichloroethene .017 mg/kg; tetrachloroethene .051 mg/kg; aniline .009 mg/kg	Biological treatment (treated soils will be disposed of offsite); clay and soil capping
IV	Alabama State Docks* Mobile, AL RCRA lead	Jason Darby 404-347-3433 FTS 257-3433	PCP, creosote/groundwater, soil	Preparing to do treatability study	Not yet established	Undetermined
IV	American Creosote Works* Jackson, TN Unit 1 Fund lead	Tony DeAngelo 404-347-7791 FTS 257-7791	Creosote/soil	Treatability study planned	100 ppm for 6-8 indicators	Land treatment
IV	American Creosote Works* Jackson, TN Unit 3 Fund lead	Tony DeAngelo 404-347-7791 FTS 257-7791	Creosote/soil	Remedial study planned	100 ppm for 6-8 indicators	Land treatment
IV	American Creosote Works* Pensacola, FL Fund lead	Natalie Ellington 404-347-2643 FTS 257-2643	Creosote, PAHs, PCP, dioxins/soil	ROD 9/89 - unit 1; bench-scale treatability study completed 9/90 by Gulf Breeze Labs; ROD 6/91 - unit 2	Surface soils: 30 ppm PCP; 50 ppm carcinogenic PAHs; 2.5 ppb dioxins	Soil washing, bioreactor
IV	Brown Wood Preserving Live Oaks, FL Enforcement lead	Martha Berry 404-347-2643 FTS 257-2643	PAHs, creosote/soil	Last load of contaminated soil in surface treatment area (about finished); will monitor 3 years; treatability study conducted	100 ppm PAHs total	Land treatment; surface treatment lined with clay berms 5-6'
IV	Cape Fear Wood Preserving* Fayetteville, NC Fund lead	Jon Bornholm 404-347-7791 FTS 257-7791	PAHs, arsenic, creosote, chromium/soil, groundwater	Treatability studies ongoing	Soil: 94 mg/kg arsenic, 2.5 mg/kg carcinogenic PAHs, 100 mg/kg total PAHs; Groundwater: 10 ug/l carcinogenic PAHs, 14,350 ug/l noncarcinogenic PAHs; Surface water: 12 ug/l arsenic; Sediments: 94 mg/kg arsenic, 3 mg/kg total PAHs	Soil washing followed by treatment in bioreactor
IV	Carolawn* Carolawn, SC Enforcement lead	Al Cherry 404-347-7791 FTS 257-7791	VOCs/groundwater	Planning bench-scale studies; ongoing remedial design	Acetone 710 ug/l; cis-DCE 70 ug/l; trans-DCE 120 ug/l; TCA 200 ug/l; TCE 5 ug/l; Pb 5 ug/l	
IV	Celanese Fibers Operations* Shelby, NC PRP lead	Ken Mallary 404-347-7791 FTS 257-7791	Ethylene glycol, benzene, acetone chromium/groundwater; bis(2-ethylhexyl)phthalate/ sediments; chromium, antimony, acetone/soil	Bioreactor on-line since 8/2/89; treatability studies complete	State of North Carolina MCLs	Sequencing batch reactor
IV	City Industries* Winter Park, FL Fund (for treatability studies and ROD); Enforcement lead for RA	Diane Scott 404-347-2643 FTS 257-2643	Acetone, MEK, TCE, TCA/groundwater	Treatability study to be initiated 2nd quarter FY 91	Varied, based on Reference Dose Limits and Federal and State drinking water standards: 700 ug/l acetone; 200 ug/l MEK; 3.0 ug/l TCE	Pump and treat, air stripping, carbon adsorption, and/or biological oxidation
IV	Coleman-Evans White House, FL Fund lead	Tony Best 404-347-2643 FTS 257-2643	PCP/soil, groundwater	Remedial design underway; pilot study planned	25 ppm sediments, soil; 1 ppm groundwater	Bioreactor

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CERCLA/RCRA/UST SITES CONSIDERING, PLANNING, OR OPERATING FULL-SCALE BIOREMEDIATION SYSTEMS

Rgn	Site/Location/Lead	Contact/Phone Number	Contaminants/Media	Status	Clean-up Levels	Treatment
IV	Dubose Oil Cantonment, FL* Enforcement lead	Martha Berry 404-347-2643 FTS 257-2643	Oil, minimal PCP/soil	Currently in technology selection phase; treatability study within a year	Total TPNA 50mg/kg; PCPs 50 mg/kg; xylene 1.5 mg/kg; benzene 10 mg/kg; TCE .05 mg/kg; DCE .07 mg/kg	Land treatment
IV	Koppers* Florence, SC RCRA lead	Mike Arnet 404-347-7803 FTS 257-7803	Creosote, PCP, arsenic (CCA)/soil, groundwater	Treatability study to be conducted early 1991	Unknown	Land treatment
IV	Langdale Facility Sweetwater, TN RCRA lead	Charles Burroughs 615-741-3424	Creosote (K001 waste)/soils, sludges	Contaminated soil and sludge excavated; site capped after biotreatment	Not yet established	Land treatment using bacteria, nutrients, and cometabolites
IV	Shavers Farm* Shelby County, GA Removal lead	Chuck Eger 404-347-3931 FTS 257-3931	Dicamba, benzoic acid, dichlorosalicylic acid, benzonitrile/soil	Pilot bench-scale treatability studies being reviewed; workplans in place, comments to go over 30 days	25 ppm for all contaminants	Undetermined
IV	Stallworth Timber* Beatrice, AL RCRA lead	Jason Darby 404-347-3433 FTS 257-3433	PCP, creosote/groundwater, soil	Assessing extent of contamination	Not yet established	Land treatment
IV	White House Waste* White House, FL Fund lead	Tony Beet 404-347-2643 FTS 257-2643	Acids, PCB, waste oil, creosote/groundwater	Bench treatability study completed; risk assessment and treatability study ongoing	Not yet established	Possible bioremediation
V	Allied Chemical* Ironton, OH Enforcement lead	Jim Van der Kloot 312-353-9309 FTS 353-9309	PNAAs/soil	Conducting pilot studies; ROD signed 12/90	1 ppm carcinogenic PAHs	In situ and prepared pad
V	Allied Signal/Bendix St. Joseph, MI PRP lead	John Kuhns FTS 353-6556	TCE, DCE, VC/groundwater	Pilot scale field demonstration scheduled for 3rd quarter 1991; pilot bench-scale tests have been completed off-site	Not yet established	In situ treatment using indigenous methanotrophs
V	Aristech Chemicals Haverhill, OH RCRA lead	Jim Sario 312-886-0982	Cumene, phenols/soil, groundwater	Conducting treatability studies	4.1 mg/kg phenol 4.67 mg/kg cumene	Undetermined
V	B & F Trucking Company* Rochester, MN UST lead	Pat Hanson MPCA 612-643-3428	BTEX, gasoline/soil, groundwater	Currently conducting bioremediation	Unknown	In-situ pump treatment; reinfiltration gallery
V	BP Oil Company Toledo, OH UST lead	Stephen Bouchard 312-886-7566	Petroleum/soil	Discussing bioremediation as an option; no studies underway	Not yet established	Land treatment
V	BP Oil Company* Lima, OH	Don Heller 312-353-1248	Petroleum/soil	Discussing bioremediation as an option; no studies underway	Not yet established	Land treatment
V	Burlington Northern, MN* State/Federal lead (split lead)	Amy Blumberg 312-353-9308 MPCA contact: J. Todd Goets 612-298-7710	Creosote/soil	Currently conducting bioremediation; ROD signed 6/4/86	Groundwater: 28 mg/l carcinogens; 300 mg/l non-carcinogens Soil: detoxification levels	In situ
V	Citi/Dow Dump, MI PRP lead	Lida Tan 312-886-1842	Wood tar, acetic acid, phenol, benzene, PAHs	Conducted treatability studies; currently in pre-design stage	Not yet established	Forced aeration
V	Duell and Gardner* Muskegon, MI Fund lead	Karla Johnson 312-886-5993	Volatiles, semi-volatiles, PCBs and/or inorganic metals/soil, groundwater	Conducting treatability studies	Not yet established	Undetermined
V	Fisher-Calo LaPorte, IN Lead pending (probably PRP)	Brad Bradley 312-886-4742	TCE, DCE, DCA, PCBs/soil, groundwater	ROD signed 8/7/90; currently in design stage	5 ppb TCE; 70 ppb DCE; 200 ppb DCA; drinking water standards used where possible	Undetermined

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CERCLA/RCRA/UST SITES CONSIDERING, PLANNING, OR OPERATING FULL-SCALE BIOREMEDIATION SYSTEMS

Rgn	Site/Location/Lead	Contact/Phone Number	Contaminants/Media	Status	Clean-up Levels	Treatment
V	Galesburg/Koppers, IL* State lead	Brad Bradley 312-886-4742	Phenols, chlorophenol, PNAs, PCP, PAHs/soil	Conducting pilot study; ROD signed 7/89; have not yet started design phase	Not yet established	Land treatment; in situ with amendments - amendments and applications not yet determined
V	Hentchells* Travers City, MI UST lead	Bob Kettner 616-776-8728	Gasoline/soil, groundwater	Bioremediation activity ended; some contamination remains; Agency requested further cleanup	Non-detection levels	Air sparging; nutrient addition; in situ pump and reinfiltration gallery
V	Joslyn MFG, MN* State enforcement lead	Cliff Twarowski 612-296-7827	PAHs, PCP, dioxin, furans/soil	MN declaration 1988 - no concurrence by EPA; design completed	150 ppm total PAHs; 100 ppm total PCP	Land treatment using irrigation and addition of nutrients and microbes
V	Marathon Station Kentwood, MI UST lead	Bonnie White 616-456-5071	gasoline/groundwater	Conducting bioremediation	Background non-detection levels or risk-based levels	Fixed film bioreactor with submerged plate
V	Mayville Fire Department Mayville, MI UST lead	Sue Kaelber Matiok 517-771-1731	BTEX/soil, groundwater	Conducting bioremediation	Groundwater: 1 ppb BTEX Soil: 10 ppb BTEX	Bioremediation using oxygen with no addition of nutrients
V	McGill's Gbb, MN* Fund lead	Darryl Owens 312-886-7089	PAHs, PCP/groundwater	Treatability and pilot studies completed 12/89; report due 3/91	Not yet established	Fixed film aerobic reactor
V	Moss American Milwaukee, WI Fund lead	Betty Lavis 312-886-4784	PAHs/soil, sediments	Pilot study completed; ROD signed 9/27/90; design stage Summer 1991	6.1 ppm PAHs	Slurry bioreactor using indigenous bacteria
V	New Lyma, OH Fund lead	Darryl Owens 312-886-7089	Ethyl benzene; methylene chloride; phthalates/groundwater	Conducted pilot study 1/88; final process to begin operation by 11/90	68 ug/l ethyl benzene; 473 ug/l methylene chloride; 9.2 ug/l phthalate	Rotating biological reactors
V	Organic Chemical, MI Fund lead	Tom Williams 312-886-6157	Oil, TCE, toluene/groundwater	Waiting for feasibility study to do remediation on TCE and toluene; working on additional workplan for oil	Not yet established	Undetermined
V	Parke-Davis Holland, MI RCRA lead	Dave Petrovski 312-886-0997	Benzene, methanol, isopropenol, fuel/soil, groundwater	Approaching design phase	Not yet established	Undetermined
V	Reilly Tar, IN* Enforcement lead	Dion Novak 312-886-4737	Creosote, PAHs, metals, semi VOAs/soil; benzene, ammonia, pyridine/groundwater	RI completed; draft treatability study workplan under review	Not yet established	Undetermined
V	Reilly Tar & Chemical* St. Louis Park, MN Enforcement lead	Darryl Owens 312-886-7089 MPCA contacts: Doug Beckwith 612-296-7301 Mike Scott 612-296-7297	Creosote, PAHs/soil, groundwater	Planning treatability study	Not yet established	In situ (surface and subsurface) using additional nutrients (N, P)
V	Seymour Recycling, IN* Unit 1 PRP lead	Jeff Gore 312-886-6552	VC, TCE, DCE/groundwater	Preliminary stages; ROD signed 9/87	Drinking water standards	Proposed bioremediation of tetrahydrofurans in groundwater
V	Seymour Recycling, IN Unit 2 PRP lead	Jeff Gore 312-886-6552	VC, TCE, DCE/soil	ROD signed 9/87; bioremediation of soil completed; no treatability studies conducted	None established	Biodegradation of heavy volatiles hydrocarbons and non-volatiles
V	Sheboygan River and Harbor* Sheboygan, WI PRP lead	Bonnie Elder 312-886-4885	PCBs/sediment	Treatability and pilot studies to be completed end of 1991;	Not yet established	Natural and enhanced biodegradation in enclosed facility; in situ study in capped sediments

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CERCLA/RCRA/UST SITES CONSIDERING, PLANNING, OR OPERATING FULL-SCALE BIOREMEDIATION SYSTEMS

Rgn	Site/Location/Lead	Number	Contact/Phone Contaminants/Media	Status	Clean-up Levels	Treatment
V	Sleeping Bear Dunes National Lakeshore UST lead	Phil Durgin 702-798-2100 John Wilson 405-332-8800	Gasoline/groundwater	Site investigation completed	Not yet established	Natural biodegradation - no amendments
V	St. Louis River, MN State lead	Debbie Siebers 312-353-9299 Cliff Twaroski 812-298-7827	PAHs/soils, sediments	Planning treatability study	Not yet established	Undetermined
V	Union Carbide, OH* Enforcement lead	Kathleen Warren 312-353-6756	VOCs, dioxin, mono- dichlorinated biphenyls/soil, groundwater	Remedial investigation completed	Not yet established	Undetermined
VI	Atchinson* Santa Fe, NM Enforcement lead	Susan Webster 214-655-6730 FTS 255-6730	Hydrocarbons, diesel/soil	Some treatability studies completed; ROD signed 9/23/88; planning pilot project; starting in situ 8/91	Not yet established	In situ (surface and subsurface); sludges treated separately
VI	French Limited Crosby, TX	Judy Black 214-655-6735 FTS 255-6735	Benzene, vinyl chloride, DCE, PCBs/sludges, soil, and groundwater	ROD signed 3/88; project under design	Soils and sludges: BAP 9 ppm; PCB 23 ppm; VOCs 43 ppm; arsenic 7 ppm; benzene 14ppm; Groundwater: MCLs	Treatment in a lagoon for sludges and soils; pump and treat and/or in situ for groundwater
VI	Hudson Refining Co.* Cushing, OK RCRA lead	Keith Phillips 214-655-6480 FTS 255-6480	Oil, grease, PAHs/soil; groundwater	Operational since 4/88	Varied	Three phases of land application with varied applications of nutrients: 1) active - requires monthly application of nutrients and monthly tilling; 2) enhanced - annual application of nutrients and no tilling; and 3) augmented - no addition of nutrients or tilling.
VI	North Cavalcade* Houston, TX State lead	Deborah Griswold 214-655-6715 FTS 255-6715	Carcinogenic PAHs, benzene/groundwater; carcinogenic PAHs/soil	Design stage; planning bioremediation pilot project for FY91	.04 ppm benzene; 1 ppm carcinogenic PAHs	Groundwater: pump and carbon adsorption treatment Soil: bioremediation method - specifics undetermined
VI	Old Inger* Darrow, LA Fund lead	Paul Sieminski 214-655-6710 FTS 255-6710	Hydrocarbons/soil, groundwater	Pilot studies completed; ROD signed 9/84; design completed 1988; finalizing construction with remediation to begin 9/91; supplemental groundwater RI being conducted		Land treatment
VI	Sheridan Disposal Services* Houston, TX Enforcement lead	Ruth Israel 214-655-6735 FTS 255-6735	Benzene, toluene, ethyl benzene, phenols, PCBs/soil, sludge, surface water	Beginning pilot study; ROD signed 12/88; currently in design stage	PCBs as an indicator of other organics (25 ppm PCBs)	Aqueous bioreactor
VII	Amoco Refinery* Sugar Creek, MO RCRA lead	Frank Dolan 314-751-3178	Oil, PAHs, refinery sludges, metals/sludges, soil	Treatability studies completed 1988-89; treatment facility on-line since 7/90	Less than 300 mg/kg total PAHs; less than 160 mg/kg potentially carcinogenic PAHs	Land treatment and liquid solids reactor
VII	Conservation Chemical Kansas City, MO Enforcement lead	Steve Auchterlonie 913-551-7778 FTS 278-7778	Phenols/groundwater	Treatability study conducted; ROD signed 9/30/87; operational since 4/90	MO drinking water standards	Fixed film bioreactor (2 in series)
VII	Fairfield Coal & Gas ^Δ Fairfield, IA Enforcement lead	Steve Jones 913-551-7755 FTS 278-7755	Benzene, ethyl benzene, toluene, xylene, PAHs/groundwater	RD phase	Benzene 1 ppb; carcinogenic PAHs 0.2 ppb	In situ (subsurface) using nutrient enhancement

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CERCLA/RCRA/UST SITES CONSIDERING, PLANNING, OR OPERATING FULL-SCALE BIOREMEDIATION SYSTEMS

Rgn	Site/Location/Lead	Number	Contact/Phone Contaminants/Media	Status	Clean-up Levels	Treatment
VII	International Paper [*] Joplin, MO Unit 1 RCRA lead	Frank Dolan 314-751-3178	24 organic constituents from creosote, including PAHs, PCP/soil	Under construction; pilot studies to be conducted concurrently with treatment operations	Sum of the concentrations of 24 aromatic compound is less than 600 ppm	Land treatment (covered facility)
VII	International Paper [*] Joplin, MO Unit 2 RCRA lead	Frank Dolan 314-751-3178	24 organic constituents from creosote, including PAHs, PCP/soil	Under construction; pilot studies to be conducted concurrently with treatment operations	Not yet determined	Land treatment (covered facility)
VII	International Paper [*] Joplin, MO Unit 3 RCRA lead	Frank Dolan 314-751-3178	24 organic constituents from creosote, including PAHs, PCP/soil	Under construction; pilot studies to be conducted concurrently with treatment operations	Not yet determined	Land treatment (covered facility)
VII	International Paper [*] Joplin, MO Unit 4 RCRA lead	Frank Dolan 317-751-3178	24 organic constituents from creosote, including PAHs, PCP/soil	Under construction; pilot studies to be conducted concurrently with treatment operations	Not yet determined	Land treatment (covered facility)
VII	Park City, Kansas [△]	John Wilson RSKERL 405-332-8800 FTS 743-2259	Refined petroleum products/water table aquifer in a municipal well field	Full scale cleanup will start 3/91	Drinking water standards for benzene	Subsurface treatment using nitrate as electron acceptor
VII	Scott Lumber [*] Alton, MO Removal lead	Bruce Morrison 913-236-3881 FTS 757-3881	Creosote compounds (PAHs, benzo-a-pyrene)/soil (no PCP)	Conducted treatability study 1988; operational since 8/89; 9,200 tons of soil treated	500 ppm total PAHs; 14 ppm benzo-a-pyrene	Land treatment using irrigation, no nutrient addition
VII	Vogel Paint & Wax, IA [*] State lead	Steve Jones 913-551-7755 FTS 276-7755	Benzene, ethyl benzene, xylene, toluene, MEK/soil	Bench-scale studies complete; ROD signed 9/89; design complete, currently in RA phase	TCLP test for leachwater organics; 100 mg/kg organic hydrocarbons; EPA toxicity test	Land treatment
VIII	Burlington Northern Somers, MT Enforcement lead	Jim Harris 406-449-5414 FTS 585-5414	PAHs, zinc, phenol/soil, sediments, groundwater	Land treatment demonstration 11/90; pilot studies planned for groundwater in 11/90; ROD signed 9/27/89; full scale 1992	Soil: 36 mg/kg carcinogenic PAHs; Groundwater: .030 ug/l carcinogenic PAHs	Soils: land treatment Groundwater and sediments: in situ
VIII	Chemical Distribution Site [*] Billings, MT State lead	Jim Morrison ECOVA 206-883-1900	Herbicides (chlorinated phenol)/groundwater	Operational since 4/88	.5 ppm 2,4-D	In situ (subsurface, using nutrients and oxygen)
VIII	Libby Groundwater Site Libby, MT Enforcement lead	Julie Daisoglio 406-449-5414 FTS 585-5414	PAHs, PCP/soil, groundwater	ROD signed 12/88; consent decree 10/89; bench-scale demonstration project for land treatment unit, bioreactor and in situ treatment completed; full-scale remedial action to begin Summer 1991	Soil: 88 mg/kg total carcinogenic PAHs; 8 ppm non-carcinogenic PAHs; 7.3 ppm pyrene; 37 mg/kg PCP; 1 ppb dioxin; 8 mg/kg naphthalene; 8 mg/kg phenanthrene; 7.3 mg/kg pyrene Groundwater: 400 ug/l carcinogenic PAHs; 40 ug/l non carcinogenic PAHs; 1.05 mg/l PCP; 5 mg/l benzene; 50 mg/l arsenic; other compounds not greater than 10 ⁴	Soil: land treatment Groundwater: in situ treatment of groundwater in fixed film bioreactor
VIII	Pesticide Distribution Facility Minot, ND RCRA lead	Jim Morrison ECOVA 206-883-1900	Pesticides (2,4-D)/soil	Full-scale bioremediation completed 1988	5 ppm 2,4-D	Above ground and slurry phase biotreatment
VIII	Public Service Denver, CO UST lead	Suzanne Roll 303-293-1511	Benzene, xylene, toluene/soil, groundwater	Operating unit for one year	Not yet established	

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CERCLA/RCRA/UST SITES CONSIDERING, PLANNING, OR OPERATING FULL-SCALE BIOREMEDIATION SYSTEMS

Rgn	Site/Location/Lead	Contact/Phone Number	Contaminants/Media	Status	Clean-up Levels	Treatment
VIII	Union Pacific Laramie, WY CERCLA/RCRA enforcement lead	Felix Flechas 303-330-1524 FTS 330-1524	Creosote, PCP/soil, groundwater	Treatability and pilot studies completed 9/90	Based on human health or agricultural standards, whichever is more stringent (to be decided in next 6 months)	Undetermined
IX	BKQ Landfill [▲] West Covina, CA Enforcement lead	Carman Santos 415-744-2144	Arsenic, cadmium, chromium, lead, mercury, dichloromethane, chloroform, 1-2 dichloropropane, carbon tetrachloride, TCE, benzene, phenol, toluene, cyanide, heavy metals/groundwater	Remedial study still in progress; full-scale bioremediation in operation since 1987	.1 ppm cadmium; .05 ppm chromium, lead, arsenic; .002 ppm mercury; heavy metals 1.5 ppm; 150 ppb dichloromethane, chloroform, TCE; 700 ppb 1-2 dichloropropane; 5 ppb carbon tetrachloride; 550 ppb benzene; not established for phenols, toluene and cyanide (total VOCs 2 ppm)	Bioreactor - leachate treatment plant with metal removal system using complexation with EDTA
IX	CALTRANS Lakewood & Garderville, CA CA lead	Ken Smarke CA Dept. of Health Svcs. 916-322-3610	Oil/soil	Field work began 11/8/88; bioremediation completed	Approximately 100 ppm total petroleum hydrocarbons	Land treatment
IX	Citrus Heights Irrigation Citrus Heights, CA PRP lead	Ken Smarke CA Dept. of Health Svcs. 916-322-3610	Diesel fuel/soil	Bioremediation completed	Approximately 100 ppm total petroleum hydrocarbons	Bioreactor
IX	Converse [®] Montabellito Corp. Yard Montabellito, CA	Paul Hadley CA Dept. of Health Svcs. 916-322-3623	Gasoline/soil	Conceptual workplan submitted for review	Not yet determined	In situ bioremediation of contaminated soil; moisture/nutrient addition controlled and monitored in the subsurface; oxygen supplied via vacuum wells
IX	CWYX Freight Lines [®] Santa Rosa, CA CA lead	Mark Berscheid CA Dept. of Health Svcs. 916-322-3294	Diesel fuel/soil	No treatability studies conducted; demonstration started 10/22/90; pre-treatment samples completed resulting in non-detect	Not yet determined	Sprinkler system to apply bioculture formulation; collected leachate treated in an aerobic biological reactor before recirculation
IX	Equipment Manufacture [®] San Francisco, CA RCRA lead	Jim Morrison ECOVA 208-883-1900	Diesel fuel/soil	Remediation completed 1988; 17,000 cubic yards of soil treated	100 ppm TPH in soil	Above-ground biological treatment; solid phase biological treatment
IX	Food Processor Ripon, CA CA lead	Jim Morrison ECOVA 208-883-1900	TCE/soil, groundwater	Pilot studies completed; currently in design stage	.5 ppb TCE in groundwater	In situ biological treatment with above-ground bioreactor
IX	Former Service Station [▲] Los Angeles, CA State lead	Tony Palagyi 818-505-2701	Petroleum hydrocarbons/soil, groundwater	Remediation complete	100 ppm TPH in soil; drinking water standards	In situ bioremediation, closed loop system; hydrogen peroxide as oxygen source; above ground holding tank for nutrient addition
IX	Former Tank Farm [®] Torrance, CA CA lead	Jim Morrison ECOVA 208-883-1900	Petroleum hydrocarbons/soil	Treatment completed 1/81; 300,000 cubic yards of soil treated	1,000 ppm total petroleum hydrocarbons	Above ground biological treatment
IX	Fort Ord Army Base [®] Monterey, CA Federal facility enforcement lead	Jim Chesnut 415-744-2389 Vance Fong 415-744-2362	MEK, VOCs/soil, groundwater	Bioremediation currently being used as an interim measure; pilot testing completed; moving into ROD phase	Not yet established for soil; MCLs for groundwater	Pump and treat carbon adsorption for groundwater, followed by land treatment for MEK

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CERCLA/RCRA/UST SITES CONSIDERING, PLANNING, OR OPERATING FULL-SCALE BIOREMEDIATION SYSTEMS

Rgn	Site/Location/Lead	Contact/Phone Number	Contaminants/Media	Status	Clean-up Levels	Treatment
IX	Growers Air Service* UC Davis Medlock Field Woodland, CA State lead	John Wencowsky CA Dept. of Health Svcs. 916-322-2543	Pesticides: atrazine, BRAYO, chlorothalonil, decthal, thiodane 1 and 2, DDT, thiodane sulfate, trifluralin, methyl parathion, malathion, parathion, methyl trithion, thion, thitron, parathion/soil	Bioremediation completed - report available	Not yet determined	In situ with addition of nutrients
IX	Harmon Field* Tulare County, CA State lead	Tony Luan CA Dept. of Health Svcs. 916-322-6872	10 organic pesticides/soil	Pilot project completed; evaluating field study results	Not yet determined	Land treatment
IX	Hercules Incorporated* Hercules, CA State lead	Tony Luan CA Dept. of Health Svcs. 916-322-6872	TNT, trinitrobenzene, DNT, nitrobenzene/soil	Pilot scale field study completed; evaluating field study results	30 ppm TNT; 5 ppm DNT; 5 ppm nitrobenzene	Land treatment
IX	JASCO* Mt. View, CA Fund lead	Rose Marie Caraway 415-744-2235	VOCs/soil, groundwater	Final RI complete; FS due 3/1/91	Not yet established	Bioremediation or land treatment - composting
IX	J.H. Baxter* Weed, CA Enforcement lead	Mary Masters 415-744-2370 FTS 484-2370	Arsenic, chromium, PCP, PAHs, dioxins, furans/soil, sediments, groundwater; benzene/groundwater; zinc, TCP/sediments	Treatability studies conducted; ROD signed 9/27/90	Groundwater: arsenic 5 ppb; chromium 8 ppb; benzene 1 ppb; PCP 2.2 ppb; PAHs 5 ppb; dioxin .000025 ppb. Surface soils: arsenic 8 ppm; chromium 500 ppm; PCP 17 ppm; carcinogenic PAHs .51 ppm; dioxin .001 ppm; furans .001 ppm. Leachate: arsenic 5 ppm; chromium 5 ppm; PCP 1.7 ppm; carcinogenic PAHs .005 ppm; non-carcinogenic PAHs .15 ppm; dioxin .001 ppm. Sediments: arsenic 8 ppm; chromium 18 ppm; zinc 26 ppm; carcinogenic PAHs .5 ppm; PCP 1 ppm; TCP 1 ppm.	Land treatment for organics using imported microbes for soils and sediments (still unclear as to need to import microbes - indigenous microbes may work); cement fixation for inorganics in soils; bioreactor for organics in groundwater; chemical precipitation for inorganics in groundwater
IX	Koppers Oroville* Plant, CA Enforcement lead	Fred Schauflier 415-744-2365 FTS 484-2365	Arsenic, chromium, PCDD/PCDF, PAHs, PCP, creosote/soil; arsenic, chromium, PCDD/PCDF, PAHs, PCP/groundwater	ROD signed 9/89; currently in the last stage of the consent decree for RD/RA; treatability studies to be done late 1991	Background levels for arsenic soil and Cr in soil and groundwater; .007 ug/l PAHs in groundwater; .19 mg/kg in soil; PCP 17 mg/kg in soil, 2.2 ug/l in groundwater; dioxin 30 ppt in soil, 0.53 ppq in groundwater	In situ bioremediation of soil with PCP; soil washing for soil with PAHs; fixation of metal contaminated soil; groundwater treatment with carbon
IX	Liquid Gold* Richmond, CA State lead	Rose Marie Caraway 415-744-2235	Waste oils, metals (lead, zinc, phenol)/soil, groundwater	Second phase of feasibility study completed; RI approved by State lead agency	Not yet established	Undetermined
IX	Montrose Chemical Corp. of California* Torrance, CA Enforcement lead	Johanna Miller 415-744-2404	DDT, monochlorobenzene/soil, groundwater	Bench-scale treatability study on soil and groundwater completed 8/90; currently planning follow-up bench-scale study for groundwater only; bench-scale study proved not effective for DDT	Not yet established	In situ enhanced by injection of nutrients
IX	Naval Civil Engineering Laboratory Port Hueneme, CA	Taj Pahwa CA Dept. of Health Svcs. 916-322-6224	Jet fuel, gasoline, diesel fuel, transmission fluid, aviation fluid/soil, groundwater	Bench scale tests completed in 10/89; final consultant report submitted to Navy for approval; pilot tests are being planned; working on pilot design	Not yet determined	Hydrocarbon oxidation
IX	Oil Co. Visalia, CA CA lead	Jen Morrison ECOYA 206-883-1900	Petroleum, hydrocarbons/soil	Conducting full-scale bioremediation	5 ppm TPH in groundwater	In situ

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CERCLA/RCRA/UST SITES CONSIDERING, PLANNING, OR OPERATING FULL-SCALE BIOREMEDIATION SYSTEMS

Rgn	Site/Location/Lead	Contact/Phone Number	Contaminant(s)/Media	Status	Clean-up Levels	Treatment
IX	Protek Carson City, CA PRP lead	Ken Smarkei CA Dept. of Health Svcs 916-322-3610	Diesel fuel/soil	Bioremediation completed	Approximately 100 ppm total petroleum hydrocarbons	Land treatment
IX	Refinery Los Angeles, CA CA lead	Jim Morrison ECOVA 206-883-1900	Petroleum hydrocarbons/soil	Conducting full-scale bioremediation	10,000 ppm TPH in soil	In situ
IX	Romco Chemicals* E. Palo Alto, CA RCRA lead	Jesse Barker 415-744-2006 FTS 484-2036	MEK, YC/sol, groundwater, DCE/surface water	Treatability studies planned for end of FY91; now in investigation stage	Not yet determined	In situ; possibly pump and treat
IX	San Diego Gas and Electric* Main Street Facility San Diego, CA PRP lead	Paul Hadley CA Dept. of Health Svcs 916-322-3823	Petroleum fuels/soil, groundwater	Project is underway; monitoring is ongoing	Not yet established	In situ
IX	Seaside High School* Seaside, CA	Dick Erickson CA Dept. of Health Svcs 916-322-7046 Alan Ingham 916-322-6629	Diesel fuel/soil	Bioremediation completed 1988	500 ppm hydrocarbons in soil	Land treatment
IX	SEGS Solar Project* Kramer Junction, CA CA lead	Bruce La Belle CA Dept. of Health Svcs 916-324-2958	Heat transfer fluid (biphenyl, diphenyl ether)/soil	Pilot test completed; full scale field work began 7/90; periodic site visits will be used to oversee/monitor progress	1,000 ppm total biphenyl and diphenyl ether	Waste pit treatment using added nutrients, water and bifling
IX	Southern California Edison* Visalia, CA State lead	Dave Roberts 415-744-2227	PCP, VOCs/groundwater	R/VFS currently in progress for groundwater	Not yet established	Undetermined - bioremediation possible
IX	Southern Pacific Transportation Co.* SPTC Maintenance Yard Roseville, CA State lead	David Wright CA Dept. of Health Svcs 916-332-3910	Hydrocarbons, diesel fuel/soil	Treatment completed 1/31/91	5,000 ppm hydrocarbons	Land treatment - nutrients added to contaminated soil to enhance biological degradation
IX	Studio Hollywood, CA State lead	Jim Morrison ECOVA 206-883-1900	Petroleum hydrocarbons/soil, groundwater	Conducting full-scale bioremediation	Drinking water standards	In situ
X	American Crossarm* Fund lead	Lee Marshall 206-553-2723	PCP/soil	Currently conducting remedial investigation	Not yet established	Undetermined
X	Former OE Storage Terminal* Seattle, WA UST lead	Jim Morrison ECOVA 206-883-1900	Petroleum hydrocarbons/soil, groundwater	Full-scale bioremediation ongoing until 1992; 100,000 cubic yards of soil being treated	Soil: 200 ppm petroleum hydrocarbons Groundwater: 5 ppb benzene	In situ and above ground biological treatment
X	Former PCP Blending Facility* Portland, OR RCRA lead	Jim Morrison ECOVA 206-883-1900	PCP/soil	Full-scale bioremediation ongoing since 1989	To be established in 1991	Slurry phase bioreactor
X	Former Service Station* Vancouver, WA State Lead	Jim Morrison ECOVA 206-883-1900	Diesel fuel	Treatment complete 8/89; 1,000 cubic yards of soil treated	200 ppm in soil	Above ground biological treatment

▲ Indicates a new site in the Table.

* Information regarding this site has been updated for this issue.

Shading depicts a non-CERCLA site.

CERCLA/RCRA/UST SITES CONSIDERING, PLANNING, OR OPERATING FULL-SCALE BIOREMEDIATION SYSTEMS

Rgn	Site/Location/Lead	Contact/Phone Number	Contaminants/Media	Status	Clean-up Levels	Treatment
X	School District Maintenance Facilities [▲] Seattle, WA State lead	Jim Morrison ECOVA 206-883-1900	Diesel fuel	Treatment ongoing until 6/91; 2,000 cubic yards of soil treated	200 ppm in soil	Above ground biological treatment
X	Utah Power and Light [*] Idaho Falls, ID State lead	Andrew Pentony 208-334-5879	Creosote/soil phenols/groundwater	Final plan for bioremediation not yet submitted	50 ppb creosote in soil; EPA Region 10 groundwater protection standards for groundwater	Part of upgradient portion not capped - bioremediation being used (white rot fungus)
X	Wickoff [*] Eagle Harbor, Puget Sound, WA PRP lead	Rene Fuentes 206-553-1599 FTS 399-1599	Creosote, PCP/soil, groundwater, surface water	R/VFS not conducted yet	Not yet established	Bioreactor - activated sludge for treatment of groundwater; possible soil and sludge bioremediation

▲ Indicates a new site in the Table.

* Information regarding this site has been updated for this issue.

Shading depicts a non-CERCLA site.

Bioremediation Field Initiative Contacts

If you have information on a site using bioremediation that is not identified in Table 1, please submit this information in writing to Nancy Dean at TIO. Additionally, if you have laboratory-, pilot- or full-scale treatability data on a site, please have a copy sent to TIO at the address listed below.

Fran Kremer
Coordinator, Bioremediation Field Initiative
U.S. Environmental Protection Agency
Center for Environmental Research Information (CERI)
26 W. Martin Luther King Drive
Cincinnati, OH 45268

Nancy Dean
Technology Innovation Office (TIO)
U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response (OSWER)
Mail Code: OS-110
401 M Street, S.W.
Washington, D.C. 20460

Upcoming Conference/Publications

Biotechnology for Wastewater Treatment - Conference sponsored by the American Chemical Society National Meeting, April 14-19, 1991, Atlanta, GA. Contact: Rakesh Govind, University of Cincinnati, Department of Chemical Engineering, 697 Rhodes Hall (ML 171), Cincinnati, OH 45221-0171, (513) 556-2761.

Microbial Processes in the Degradation of Groundwater Contamination - Short Course, June 18-20, 1991, Tampa, FL. Contact: The Association of Ground Water Scientists and Engineers, division of the National Water Well Association, 6375 Riverside Drive, Dublin, OH 43017, (614) 761-1711.

Proceedings available from Bioremediation: Fundamentals and Effective Application - Symposium, February 21-22, 1991, Lamar University, Beaumont, TX. \$35.00/complete papers in proceedings. Contact: Tom Pinson, (409) 880-8768.

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SUPERFUND TECHNICAL SUPPORT PROGRAM (TSP)

The Superfund Technical Support Program has been designed to facilitate communication and coordination between EPA's Superfund site managers (On Scene Coordinators-OSCs and Remedial Project Managers-RPMs) and EPA Headquarters, Regions, State environmental agencies and the EPA Office of Research and Development. The purpose of the TSP is to ensure the consistent application of remedial technologies and the timely transfer of pertinent technical information. Through the program, EPA has established a network of technical support resources available to EPA's OSCs and RPMs that includes six technical Support Centers and two Forum Representatives from each Region, one in the area of ground-water fate and transport and the other in engineering/treatment. Technical experts participating in the TSP can assist field personnel with several different types of technical projects:

- *Evaluations of the feasibility of technologies as treatment options;*
- *Feasibility study reviews or workplan evaluations;*
- *Remedial design reviews;*
- *Implementation of treatability studies;*
- *Development or review of sampling plans; and*
- *Analysis of operational data.*

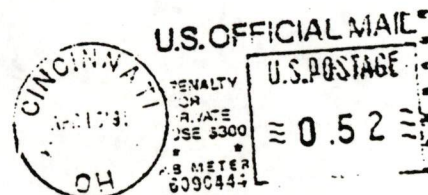
For immediate assistance on technical questions, RPMs and OSCs can call one of the six Support Centers:

- *Ground-Water Fate and Transport Center, Ada, Oklahoma;*
- *Monitoring and Site Characterization Center, Las Vegas, Nevada;*
- *Environmental Response Center, Edison, New Jersey;*
- *Exposure and Ecorisk Assessment Center, Athens, Georgia;*
- *Engineering and Treatment Center, Cincinnati, Ohio; and*
- *Health and Risk Assessment, Cincinnati, Ohio.*

To request on-site assistance or to initiate a technical assistance project, OSC's or RPM's should contact their Regional Forum representative. For projects requiring funding, written requests must be submitted to the appropriate Support Center. For further information on activities of the Regional Forums or the TSP call Rich Steimle at FTS: 382-7914 or 202/382-7914.

United States
Environmental Protection
Agency

Center for Environmental Research:
Information
Cincinnati, OH 45268



Box 85000
Cincinnati, OH 45268

A Review of Treatment Alternatives for Dioxin Wastes

Harry M. Freeman and Robert A. Olexey
Hazardous Waste Engineering Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, Ohio

The 1984 Amendments to the Resource Conservation and Recovery Act (RCRA), called the Hazardous and Solid Waste Amendments, (HSWA) direct the EPA to determine if dioxin bearing wastes should be prohibited from landfills. This determination is to be made by November 1986. Barring a determination by the Agency that the land disposal of dioxin wastes does not represent a threat to the environment, or that appropriate alternative treatment technology is not available, a land disposal prohibition would go into effect at that time.¹ The purpose of this paper is to discuss the state of the art for several treatment processes for dioxin wastes that have been proposed to be used instead of land disposal for disposing of solid and liquid wastes containing dioxins.

A dioxin is any of a family of aromatic compounds known chemically as dibenzo-*p*-dioxins. Each of these compounds has as a nucleus a triple ring structure consisting of two benzene rings interconnected to each other through a pair of oxygen atoms. Shown in Figure 1 is the structural formula for the dioxin nucleus.²

Most environmental interest in dioxin has centered on chlorinated dioxins in which a chlorine atom occupies one or more of the eight positions on the benzene rings. There are eight chlorinated dioxin homologs and, within these families of homologs, a theo-

retical possibility of 75 chlorinated dioxin isomers, each with different physical and chemical properties. Most of the interest has been directed toward the isomer 2,3,7,8-TCDD, which is among the most toxic compounds in existence. The compound exists as a colorless crystalline solid at room temperatures and is only sparingly soluble in water and most organic liquids.³

Dioxin compounds are apparently not constituents of any normal growing environment, but are formed through manufacturing or combustion processes involving precursor compounds.² Dioxins are usually formed in very low yield, i.e. in the ppb and ppt range. Although no definitive studies have determined the exact temperatures of formation, several studies have reported dioxin formation in the range of 180–400°C.^{4,5}

Once formed, the dioxin molecule is quite stable. An EPA report on the subject states:

"Laboratory tests have shown that it is not decomposed by heat or oxidation in a 700°C incinerator, but pure compounds are

largely decomposed at 800°C. A recent report states that the nucleus survives intact through incineration up to 1150°C if it is bound to particulate matter. Chlorinated dioxins lose chlorine atoms on exposure to sunlight or to some types of gamma radiation, but the basic dioxin structure is largely unaffected. In comparison with almost any other organic compound, the biological degradation rate of chlorinated dioxins is slow, although measured rates differ widely."²

Waste Characterization

Hazardous wastes grouped under the term "dioxin wastes" for the purposes of the RCRA evaluation cover wastes from the production of certain chlorophenols and chlorophenoxy pesticides, manufacturing use of tetra-, penta-, and hexachlorobenzene under alkaline conditions, as well as discarded unused formulations containing tri-, tetra-, or pentachlorophenol and their derivatives.⁶ These are listed below, by RCRA classification number.

F020 Wastes (except wastewater and spent carbon from hydrogen chloride purification) from the production or manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of tri-, or tetrachlorophenol, or of intermediates used to produce their derivatives. (This listing does not include wastes from the production of hexachlorophene from highly purified 2,4,5-trichlorophenol.)

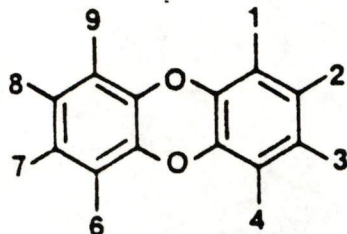


Figure 1. The dioxin nucleus.

Reprinted from JAPCA 36: 87-75 (1986)

HAZARDOUS WASTE MANAGEMENT

F021 Wastes (except wastewater and spent carbon from hydrogen chloride purification) from the production or manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of pentachlorophenol, or of intermediates used to produce its derivatives.

F022 Wastes (except wastewater and spent carbon from hydrogen chloride purification) from the manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of tetra-, penta-, or hexachlorobenzene under alkaline conditions.

F023 Wastes (except wastewater and spent carbon from hydrogen chloride purification) from the

F027 Discarded unused formulations containing tri-, tetra-, or pentachlorophenol or discarded unused formulations containing compounds derived from these chlorophenols. (This listing does not include formulations containing hexachlorophene synthesized from pre-purified 2,4,5-trichlorophenol as the sole component.)

F028 Residues resulting from incineration of soil contaminated with EPA hazardous waste Nos. F020, F021, F022, F023, F026, and F027.

These designations include reactor residues, still bottoms, brines, spent filter aids, spent carbon from product purification and sludge from wastewater treatment.⁶

A recent study carried out by EPA's

Table I. Waste quantity estimates for dioxin bearing wastes (metric tons).

Waste categories	Storage ^a	Current ^b	Future ^c
F020	4300	0	0
F021	0	350	1110
F022	ND ^d	0	0
F023	0	0	0
F026	0	0	0
F027	1000	1000	1000
F028	NA ^e	NA	NA
Total	5300	1350	2100

^a Storage—wastes that are now in storage awaiting final disposition as a result of previous EPA action. A one time quantity.

^b Current—quantity of wastes presently generated.

^c Future—annual quantity of waste expected in near future.

^d ND—no data.

^e NA—not applicable.

production of materials or equipment previously used for the production or manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of tri-, and tetrachlorophenols. (This listing does not include wastes from equipment used only for the production or use of hexachlorophene from highly purified 2,4,5-trichlorophenol.)

F026 Wastes (except wastewater and spent carbon from hydrogen chloride purification) from the production of materials on equipment previously used for the manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of tetra-, penta-, or hexachlorobenzene under alkaline conditions.

Office of Solid Waste estimates the quantities in Table I for the subject waste streams.^{7,8}

Current EPA Regulations for Dioxin Wastes

Under existing EPA regulations, dioxin bearing wastes may be stored in tanks, placed in surface impoundments and waste piles, and placed in land treatment units and landfills. However, in addition to meeting RCRA requirements for these storage and disposal processes,⁹ the operators of these processes must operate in accord with a management plan for those wastes that is approved by the EPA Administrator. Factors to be considered by the Regional Administrator include:

1. Volume, physical, and chemical characteristics of the wastes, including their potential to migrate

through soil or to volatilize or escape into the atmosphere.

2. The alternative properties of underlying and surrounding soils or other materials.
3. The mobilizing properties of other materials codisposed with these wastes.
4. The effectiveness of additional treatment, design, or monitoring techniques.

The Regional Administrator may determine that additional design, operating, and monitoring requirements are necessary for facilities managing dioxin wastes in order to reduce the possibility of migration of these wastes to ground water, surface water, or air so as to protect human health and the environment.⁶

For incineration of dioxin bearing wastes, in addition to the RCRA operation and performance requirements,¹⁰ the incinerator must achieve a destruction and removal efficiency (DRE) of 99.9999 percent for each principal organic hazardous constituent (POHC) designated in its permit. This performance must be demonstrated on POHCs that are more difficult to incinerate than tetra-, penta-, and hexachlorodibenzo-*p*-dioxins and dibenzofurans.⁶ DRE is determined from the following equation:

$$DRE = \frac{(W_{in} - W_{out})}{W_{in}} \times 100$$

where: W_{in} = mass feed rate of one POHC in the waste stream feeding the incinerator.

W_{out} = mass emission rate of the same POHC present in exhaust emissions prior to release to the atmosphere.

Of course, the HSWA amendments contain a strong presumption against land disposal. Therefore, one would expect that the Agency's implementation of the HSWA provisions on land restrictions will place primary emphasis on incineration for disposal of dioxin bearing wastes. EPA has also stated that operators of thermal treatment devices must demonstrate that they can meet the performance requirements for incinerators in order to treat dioxin bearing wastes.

Alternative Treatment Technologies for Dioxin Wastes

As indicated in Table II, there are several thermal and nonthermal processes that appear feasible for treating dioxin wastes. While some of these processes have already been tested using dioxin contaminated waste streams, others are either under development or

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Administrator may develop design, operating requirements are managing dioxin reduce the possibility of these wastes to be water, or air so as health and the envi-

of dioxin bearing to the RCRA operation requirements.¹⁰ achieve a destruction efficiency (DRE) of each principal or constituent (POHC) permit. This performance demonstrated on the difficult to incinerate, and hexachloro- and dibenzofuran determined from the fol-

$$\frac{W_{out}}{W_{in}} \times 100$$

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VA amendments assumption against are, one would expect implementation on land re- primary emphasis disposal of dioxin has also stated thermal treatment strate that they performance requirements in order to treat

Technologies

Table II, there are nonthermal processes for treating some of these processes tested using waste streams, development or

Table II. Treatment processes for dioxin wastes.

Treatment process	EPA contact
EPA Mobile Incineration System	Frank Freestone ^a (212) 321-6632
Huber Advanced Electric Reactor	Harry Freeman ^b (513) 569-7529
Shirco Infrared System	Harry Freeman
Liquid injection incinerators	Don Oberacker ^b (513) 569-7431
Photolysis	Charles J. Rogers ^b (513) 569-7757
Rotary kiln incineration	Don Oberacker
GA Technologies Circulating Bed Combustor	Harry Freeman
Chemical dechlorination	Garry Howell ^b (513) 569-7756
UV photolysis/APEG chemical detoxification	Charles Rogers
Supercritical fluids	Robert Olexsey ^b (513) 569-7717
White rot fungus	P. R. Sferra ^b (513) 569-7618

^a Address: Hazardous Waste Engineering Research Laboratory, Edison, New Jersey 08837.

^b Address: Hazardous Waste Engineering Research Laboratory, Cincinnati, Ohio 45268.

have been tested with other chlorinated waste streams. The processes are presented in order of the availability of data for treating actual dioxin wastes. Those processes which have actually treated dioxin wastes are presented first. Those that appear to have potential but have not actually been used to treat dioxin wastes are presented in subsequent sections. Discussions of each of the processes follow. The names of the EPA contacts in Table II are individuals who are familiar with the processes.

Reference or failure to reference a particular process does not imply that the process is recommended or not recommended by the U.S. Environmental Protection Agency for treating dioxin contaminated wastes. The discussion that follows is a compilation of processes that, from a technical perspective, the authors judge to have potential to treat such wastes. To the extent that test data are available they are presented here. Each specific application of each technology is subject to EPA and state and local regulatory and permitting requirements on a case-by-case basis.

Processes Which Have Been Used to Treat Dioxin Wastes

EPA Mobile Incinerator

EPA's Office of Research and Development has developed a mobile rotary kiln incinerator capable of incinerating hazardous waste at the point of generation. The unit, called the Mobile Incineration System, consists of three major subsystems: 1) combustion and air pollution control equipment mounted on three trailers, 2) continuous flue gas monitoring equipment located in a fourth trailer, and 3) support equipment. Figure 2 describes the Mobile Incineration System.¹¹

The incineration system consists of a primary combustion chamber (rotary kiln) where solid or liquid wastes are introduced, volatilized, and partly oxidized and a clean fuel oil-fired secondary combustion chamber (SCC) for completing the combustion process initiated in the kiln. The combustion flue gases pass through a gas cleaning unit designed to collect and remove particulate matter and acid gases prior to discharge through the stack. The initial

treatment of the combustion gases is accomplished by water quenching in the quench elbow, which is then followed by particulate removal in a cleanable high efficiency air filter (CHEAF). [The primary function of the elbow is to lower the gas temperature from 1200°C (2200°F) to adiabatic saturation, at approximately 85°C (185°F), and thus reduce the gas volume; some particulate and acid gas removal does occur in the quench elbow.] The final step in the gas treatment process is the removal of acid gas in a cross-flow packed-bed mass-transfer scrubber. The pH of each process water stream is controlled by the addition of sodium carbonate to enhance acid gas removal and to minimize corrosion of the gas cleaning equipment. The prime gas mover for the incineration system is a diesel-powered induced-draft fan that maintains a negative pressure in the entire system so as to prevent the leakage of toxic vapors. The process gas is discharged through a 12-m (40-ft) stack.¹²

In 1983, trial burns were conducted in Edison, New Jersey on RCRA-listed surrogates, including dichlorobenzene, trichlorobenzene, tetrachlorobenzene, Aroclor 1260, and tetrachloromethane (CCl₄). After a solids feed system was installed and tested in December 1984, additional laboratory tests were conducted. Currently, the mobile incinerator is installed at the Denny Farm site near McDowell, Missouri, where "cold" and "hot" tests were conducted using clean soil and soil contaminated with surrogates similar to those employed in the earlier liquid waste tests (CCl₄ and hexachloroethane). Tests using dioxin-contaminated liquid wastes and soil verified the DRE and the effectiveness of the control devices. Interim delisting guidelines were established and analyses were conducted on ash, treated soils, filter materials, and process/quench water to ascertain if the guidelines were attainable.¹³

The dioxin trial burns were successful, with DREs exceeding 99.9999 percent for the POHCs burned. During these tests 3.84 pounds of 2,3,7,8-TCDD, contained in 1750 gallons of liquids and over 40 tons of soil, were

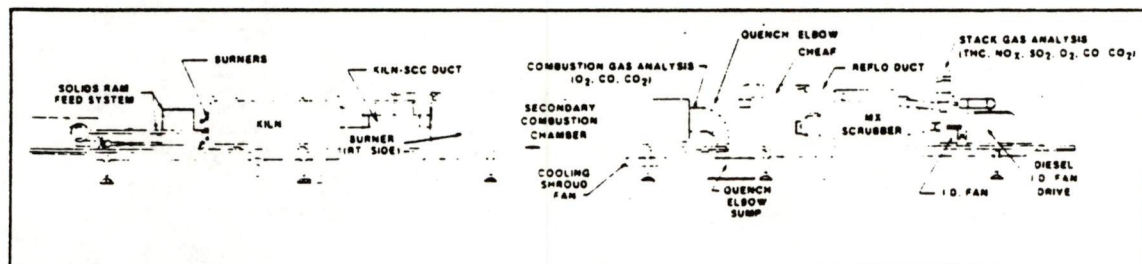


Figure 2. EPA Mobile Incineration System.

destroyed. Particulate emission permit limitations ($<180 \text{ mg/Nm}^3$ @ 7% O_2) were achieved in three of four test runs. During the fourth run, particulate emissions exceeded the prescribed limit slightly, possibly due to the accumulation of submicron-sized particles in the air pollution control system. The observed CO emission values (1.3–7.7 ppm) are equivalent to those from the best available incineration technologies and are indicative of very complete combustion (C.E. = 99.993–99.999%).¹³

Finally, the treated soil (ash) and process wastewater from the trial burn were analyzed for a series of specific constituents considered as likely contaminants. The results of these analyses were used to support an application to "delist" residues from a planned larger scale burn of similar wastes.¹⁴

Advanced Electric Reactor

The Advanced Electric Reactor (AER) is a process designed specifically for on-site detoxification of soils. It is owned by the J. M. Huber Company, Borger, Texas.

The reactor employs a new technology to rapidly heat materials to temperatures between 4000–5000°F using intense thermal radiation in the near infrared region. The reactants, which can be in gaseous, liquid, or solid form, are isolated from the reactor core walls by means of a gaseous blanket formed by flowing nitrogen radially inward through porous graphite core walls. Carbon electrodes are heated and in turn heat the reactor core to incandescence so that heat transfer is accomplished by thermal radiative coupling from the core to the feed materials. Destruction is accomplished by pyrolysis rather than oxidation.¹⁵

Figure 3 is a simplified process diagram of the AER process. For solid waste treatment, the solid feed stream is introduced at the top of the reactor by means of a metered screw feeder connecting the airtight feed hopper to the reactor. Nitrogen is introduced primarily at two points in the reactor annulus formed by the external containing vessel and the porous graphite core which creates the fluid barrier. The solid feed passes through the reactor where pyrolysis occurs at approximately 4000°F. After leaving the reactor, the product gas and waste solids pass through two post-reactor treatment zones (PRTZ). The first PRTZ is an insulated vessel to provide additional high temperature (in excess of 1100°C, 2000°F) and residence time (5 to 10

seconds) while the second PRTZ is water-cooled. It also provides additional residence time (approximately 10 seconds) but primarily cools the gas to less than 1000°F prior to downstream particulate cleanup.^{16,17}

Solids exiting the PRTZ are collected in a solids bin which is sealed to the atmosphere. Additional solids in the product gas are removed by a cyclone and routed back to the solids bin. The product gas then enters a baghouse for fine particle removal followed by an aqueous caustic scrubber for chlorine removal. Any residual organic and chlorine are removed by passing the product gas through activated carbon beds just upstream of the emission stack. The organic, particulate, and chlorine-free product gas composed almost entirely of nitrogen is then emitted to the atmosphere through the process stack.

Among the potential advantages of this process are transportability, extremely high treatment efficiencies (because of the high process temperatures and long residence times), intrinsic safety features (such as the activated carbon beds, electrically driven solids feeder, and large amount of thermal inertia in the reactor), and the ability to detoxify wastes in a pyrolytic atmosphere, thereby minimizing particulate emissions.

Huber has reported several relevant tests that have been carried out over the past two years. A test in the Spring of 1984 to determine the destruction efficiency (DE) and DRE for the pro-

cess with carbon tetrachloride over a wide range of operating conditions demonstrated greater than six nines (99.9999%) DRE.¹⁵ A September 1983 test on PCB contaminated solids demonstrated better than seven nines DRE and resulted in Huber's facility at Borger, Texas being certified to destroy PCB contaminated solids.¹⁷

In November of 1984 a mobile version of the Huber unit was used to treat soil containing 2,3,7,8-TCDD in Times Beach, Missouri. Reports of this test state that no 2,3,7,8-TCDD was detected in the treatment soil at detection limits of 0.11 ppb from the 2,3,7,8-TCDD and that no 2,3,7,8-TCDD was detected in the stack gas at detection limits of 0.55 ng/M³.¹⁸

The process' most recent test was at a U.S. Navy facility in Mississippi in which some 1000 pounds of soil contaminated with Agent Orange were pyrolyzed. Results for these tests are not yet available.

Shirco Infrared System

The Shirco unit treats waste by metering the waste streams onto a woven metal alloy conveyor belt and passing the waste under infrared heating elements and then burning combustible off-gases in a secondary chamber. The unit currently being tested by Shirco is a portable pilot scale system that is contained in a 45-ft trailer.¹⁹

The primary chamber is rectangular (2.5 ft × 9 ft × 7 ft) and is lined with multiple layers of ceramic fiber blanket insulation. Infrared energy is provided by heating elements equally spaced along the length of the furnace. The electrically powered heating element

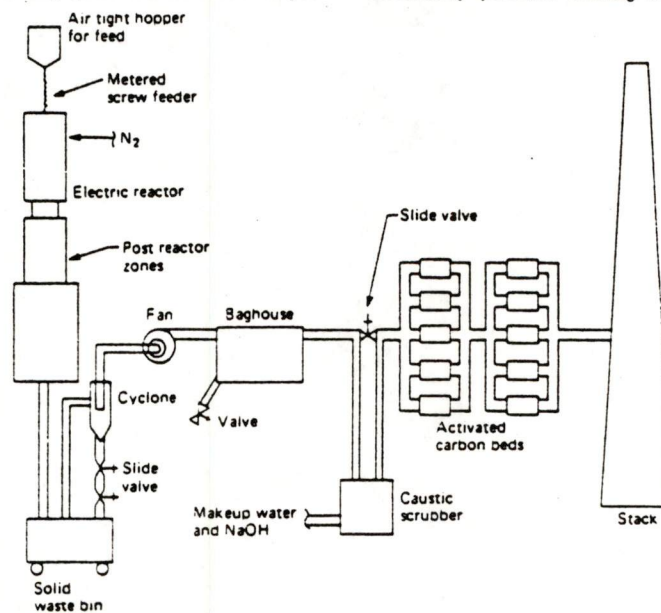


Figure 3. Huber advanced electric reactor.

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Table III. Operating conditions for decontamination of dioxin contaminated soil—Shirco system.

Test No.	Solid phase residence time (minutes)	Solid fuel rate (lb/h)	Temperature		
			Zone A (°F)	Zone B (°F)	Secondary chamber (°F)
1	30	47.68	1560	1550	2250
2	15	48.12	1490	1490	2235

can provide capabilities of 500–1850°F of process temperature with material residence times variable between 10 and 180 minutes. Oxidizing, reducing, or neutral atmospheres can be provided.¹⁹ A secondary chamber is equipped with a propane burner and is sized to provide gas residence time of up to 2.2 seconds. The process temperature capability is 2300°F. Scrubbers are provided for off-gas cleanup.^{19,20}

Shirco has reported successful use of the system to treat municipal and industrial sludges and a simulated creosote pit waste. During the week of July 3, 1985 the unit was used to treat dioxin contaminated soil at Times Beach, Missouri. A summary of the soil decontamination test results is shown in Tables III and IV.¹⁹

units include their capability to incinerate a wide range of wastes and their relatively low maintenance costs due to the few moving parts in the system. The primary disadvantage is that they can burn only pumpable liquids, and are susceptible to being shut down because of clogged nozzles. Liquid injection systems are also usually designed to burn specific waste streams and consequently are not often used for multi-purpose facilities.

These facilities have been used to destroy a variety of wastes including phenols, PCBs, still and reactor bottoms, solvents, polymer wastes, herbicides, and pesticides. They are not recommended for burning heavy metals, high-moisture content wastes, or materials with high inorganic content.

Table IV. Dioxin contaminated soil decontamination test results—Shirco system.

	Test 1	Test 2
Emissions sampling duration (h)	7	2.5
Particulate ^a at 7% O ₂ (gr/dscf)	0.0010	0.0002
Gas phase DRE of 2,3,7,8 TCDD	>99.999996 ^b	>99.999989
Detection limit (picograms)	14	8.4
Ash analysis for 2,3,7,8 TCDD	ND ^c	ND
Detection limit (ppb)	0.038	0.033

^a Particulate filter only, without train rinse.

^b (>) indicates DRE calculations at detection limit.

^c ND indicates nondetectable.

Liquid Injection Incinerators

A liquid injection system consists of a refractory-lined combustion chamber and a series of atomizing nozzles. It is capable of burning virtually any combustible waste which can be pumped. Wastes to be burned are usually blended in mixing tanks prior to atomization to improve either their pumpability or combustibility, and then are atomized and burned in suspension. The capacity will vary depending upon the energy value of the waste. Typical combustion chamber residence times and temperature ranges are 0.5 to 2 seconds and 1300°F to 3000°F respectively. In addition to being the primary part of a waste combustion system, a liquid injection incinerator is often used as an afterburner to complete the combustion of waste gases following burning in other incinerators such as rotary kilns.

The advantages of liquid injection

incinerators is a technology in daily use throughout the U.S., both at industrial locations and at central treatment facilities. It is the most commonly used incinerator for hazardous waste destruction,²¹ comprising some 64 percent of the market for incinerators.²²

The incinerators aboard the M/T Vulcanus, an incinerator ship designed to burn chemical wastes on the open ocean, are liquid injection units. The units are vertically mounted with a volume of 131 m³. Each unit has three rotary cup vortex burners firing into a cylindrical refractory-lined combustion chamber. Each incinerator is capable of burning some 1650 gallons per hour of liquid wastes.²³

In July–September 1977 the liquid injection incinerators on the Vulcanus were used to destroy Herbicide Orange, an herbicide that contains several chlorinated substances including TCDDs.

The reported DE for the TCDD was greater than 99.93 percent, which was the highest DE that could be measured given the detection limits of the TCDD concentration in the exhaust gas.²³ More recent test burns in similar liquid injection units on the Vulcanus II, a sister ship, demonstrated greater than 99.998 DE for the organochlorine CCl₄, CHCl₃, and 1,1,2-TCE.²³ The EPA concluded for its evaluation of the 1977 and earlier test burns that oceanic incineration had the potential to be an environmentally acceptable alternative to other means of disposal.²³

Although incinerator ships are currently available for use, they are neither TSCA or RCRA permitted. However, specific permits will be required by the EPA before any operation in this country can occur.

Photolysis

Photolysis is a process that involves the breakdown of a chemical by light energy. Photolysis studies have shown that chlorinated dioxins may be photolytically degraded in the environment by sunlight.²

Polychlorinated dibenzo-*p*-dioxins undergo photolysis rapidly in the presence of hydrogen donors such as alcohols, ethers, hydrocarbons, and natural oils and waxes. The photolytic degradation appears to occur in a stepwise loss of one chlorine atom at a time. Sunlight is effective in activating the reaction and, hence, of all the possible natural detoxification mechanisms, photolysis appears to be the most significant. The ultraviolet wavelengths of light have been shown to be the most effective in causing the degradation reaction.²²

Under appropriate conditions, certain wavelengths of light convert the more toxic dioxins to less toxic forms by removing halogen substituents. Applications of this principle will, therefore, be limited to decontamination and partial degradation, rather than to complete disposal.

The effectiveness of dioxin photolysis is enhanced by solution of the dioxins in a light-transmitting film, the presence of a hydrogen donor in the solution, and the use of ultraviolet light.²⁵

IT Enviroscience, Knoxville, Tennessee, has developed a solvent extraction photolysis process that was applied to dioxin-laden sludge in Verona, Missouri, in 1980. In this process the dioxin was extracted from a sludge using hexane as solvent. The resulting extract was then passed under eight 10-kW lamps to effect the desired reduction.

A report of the work states that "160 gal batches of the waste were run through the destruction process in five

two-week operating periods. Six extractions of the waste reduced the dioxin content from 34 ppm to 0.2 ppm (34 mg/L to 0.2 mg/L). Generally, photolysis reduced the dioxin concentration to less than 100 ppb (0.1 mg/L) with optimum photolysis times of about 20 hours. Air sampling at the single process vent confirmed that no dioxin (less than 0.01 $\mu\text{g}/\text{m}^3$) was emitted to the atmosphere during operation.²⁶

Processes Which Have Potential to Treat Dioxin Wastes

Rotary Kiln Incinerators

The rotary kiln system is the most nearly universal of waste disposal systems. It can be used for a wide variety of solid and sludge waste disposal, and for the incineration of liquid and gaseous wastes.²⁷

Rotary kiln incinerators are refractory-lined cylinders mounted with their axes inclined at a slight angle from the horizontal. This type of incinerator has a length-to-diameter ratio between 2 and 10; a rotational speed in the range of 1–5 fpm (measured at kiln periphery); an incline ratio between 1/16 and 1/4 in./ft; an operating temperature upper limit of 3000°F (1650°C), although typical temperatures are lower, and a residence time that can vary from seconds to hours. It can be used to dispose of solids, sludges, liquids, and gases. The speed of rotation may be used to control the residence time and mixing with combustor air.

The primary function of the kiln is to convert, through partial burning and volatilization, solid wastes to gases and ash/residue. The ash is removed and, if found to be free of unacceptable levels of hazardous wastes, is put in a landfill. An afterburner using gaseous or liquid fuels to generate a high-temperature oxidizing environment is almost always required to complete the gas-phase combustion reactions. The afterburner is connected directly to the discharge end of the kiln, where the gases exiting the kiln turn from a nearly horizontal flow path to a vertical flow path upward to the afterburner chamber. The afterburner itself may be horizontally or vertically aligned.²⁸

The system is designed so that a negative pressure can be maintained in the kiln in order to minimize emissions at the end seals of the rotating section.

Both the afterburner and kiln are usually equipped with an auxiliary fuel firing system to bring the units up to the desired operating temperatures. The auxiliary fuel system may consist of separate burners for auxiliary fuel, dual-liquid burners designed for combined waste/fuel firing, or single-liquid burners equipped with a premix system. Fuel flow is gradually turned down, and liquid waste flow is initiated after the desired operating temperature is attained.²⁸

In rotary kilns, liquid wastes may be fired either at the feed or discharge end of the unit; both cocurrent and countercurrent firing designs are used.

Rotary kilns have the advantages of being able to incinerate a wide variety of liquid and solid wastes, being able to accept drum and bulk containers, and

being able to retain waste materials sufficiently long to accomplish very high destruction rates. Rotary kilns are capital intensive and need significant maintenance to maintain seals and refractory.

There are no reported data for the combustion of TCDD in stationary rotary kilns. However, there are several rotary kilns that have been permitted to burn PCB wastes. These kilns have at least the potential for incinerating dioxin waste streams. Three commercial rotary kilns with PCB permits are:

1. ENSCO, El Dorado, Arkansas
2. Rollins, Deer Park, Texas
3. SCA, Chicago, Illinois

Each of these facilities, as part of the trial burns associated with its permit application, reported DREs for PCBs in excess of 99.9999 percent.

Circulating Bed Combustion

Circulating bed combustion technology is a modification of traditional fluidized bed incineration developed by GA Technologies, San Diego, California. Fluidized bed incinerators are vessels, usually some 20–25 ft in diameter and 30 ft high, which contain a bed of inert granular material, usually sand. The bed is kept at a temperature of 840–1560°F. Fluidizing air is passed through a distributing plate below the bed to agitate and heat the granular material. Waste materials and auxiliary fuel are injected radially in small amounts and mixed with the bed material which transfers heat to the waste. The waste in turn combusts and returns energy to the bed. Figure 4 describes the circulating bed process.²⁹

Circulating bed technology extends fluidized bed technology by increased turbulence and throughput per unit area. The incinerator uses high air velocity and circulating solids to create a highly turbulent combustion zone. Because of the high air velocity, solids are entrained and combustion takes place along the entire height of the combustion section. Solids are separated from off-gases by an integral cyclone and returned to the combustion zone through a nonmechanical seal. Temperatures are uniform with $\pm 5^\circ\text{F}$ variance throughout this loop. This uniform temperature and high solids turbulence avoids the ash slagging encountered in other types of incinerators. Turbulence is a prime factor in the zone. Nitrogen oxide (NO_x) and carbon monoxide (CO) emissions are reported to be well controlled by the good mixing, relatively low temperatures (1450–1500°F), and staged combustion achieved by injecting secondary air at higher locations in the combustor.²⁹

The unit is designed to control pollution by the efficient combustion/des-

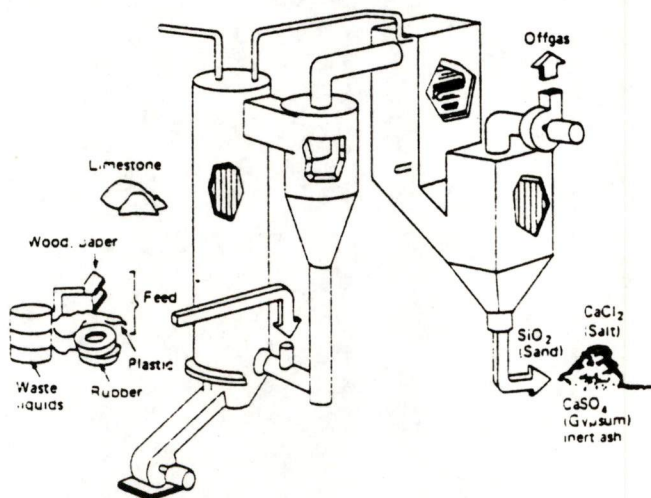


Figure 4. Circulating bed combustion.

Table V. P

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perature and pressures, have been found to be excellent solvents for organic wastes.

In the supercritical water process developed by the MODAR Company, Natick, Massachusetts, an aqueous waste stream is subjected to temperatures and pressures above the critical point of water, i.e., that point at which the densities of the liquid and vapor phase are identical. (For water the critical point is 714°F and 219 atmospheres.) In this supercritical region water exhibits unusual properties that enhance its capability as a waste destruction medium. Because oxygen is completely miscible with supercritical water, the oxidation rate for organics is greatly enhanced. Also, inorganics are practically insoluble in supercritical water. This factor should allow the inorganics to be removed from the waste streams. The ideal result is that organics are oxidized rapidly and the resultant stream is virtually free of inorganics.^{14,15}

A brief summary of this concept, described in Figure 5 is:

1. Waste is slurried with make-up water to provide a mixture of 5 percent organics. The mixture is heated using previously processed supercritical water and then pressurized.
2. Air or oxygen is pressurized and mixed with the feed. Organics are oxidized in a rapid reaction. (Reaction time is less than 1 minute.) For a feed rate of 5 weight percent organics, the heat of combustion is sufficient to raise the oxidizer effluent to 930°F.
3. The effluent from the oxidizer is fed to a salt separator where inorganics are precipitated out.
4. Waste heat from the process can be reclaimed to provide sufficient energy for power generation and high pressure steam.

Bench scale experiments with the supercritical water process have yielded organic carbon destruction efficiencies of from 99.970 to 99.996 percent for a range of chlorinated organic compounds. For PCBs in transformer oil and a methyl ethyl ketone matrix, average organic carbon destruction efficiency was 99.991 percent.³³

Another process, using supercritical CO₂, has been proposed to extract PCBs from soil particles.³⁴ In this process, which is still in laboratory development, over 90 percent of PCB contamination in soil was extracted in under one minute. Work is continuing on this medium of treatment.

Given the low levels of TCDD contamination normally found in dioxin contaminated wastes, it is unlikely that

supercritical CO₂ will prove to be viable for TCDD waste treatment. If supercritical water can demonstrate specific TCDD compound destruction efficiencies in the range of those for organic carbon in the previous laboratory work, the supercritical water process may have potential, particularly for highly aqueous dioxin contaminated wastes or leachates that present a problem for the sodium based dechlorination processes.

White Rot Fungus

Through its biodegradation research program, EPA is supporting work to identify, develop, and test microorganisms capable of degrading highly toxic and refractory organohalide pollutants, including 2,3,7,8-TCDD.

Although research has not yet identified organisms considered capable of treating 2,3,7,8-TCDD, it has identified an organism, the white rot fungus, *Phanerochaete chrysosporium*, that appears very promising. The fungus secretes a unique hydrogen peroxide-dependent oxidant capable of degrading lignin. Recent reports on this research indicate that the substrate is not only effective in degrading lignin, but also is effective in degrading organo-halides such as lindane, DDT, 4,5,6-trichlorophenol and 2,4,6 trichlorophenol.³⁵

It is proposed that the fungus may prove to be suited for use in biotreatment processes for the degradation of refractory organic pollutants. To date, work with this primary alternative has been confined to the laboratory. EPA's

HWERL is planning to test the enzyme system at several contaminated sites in the future.¹⁴

Summary

This article has identified and discussed many alternative technology options for treating dioxin wastes. As the U.S. continues to move away from land disposal toward more acceptable techniques for managing hazardous wastes, processes such as the ones discussed will become more common as waste management options. While many of the processes described here may now appear to be expensive or exotic, as EPA moves to implement the landfill restrictions imposed by Congress, these processes may assume more practicality. Most certainly, the adoption of advanced technologies such as those described here will measurably improve the quality of the environment.

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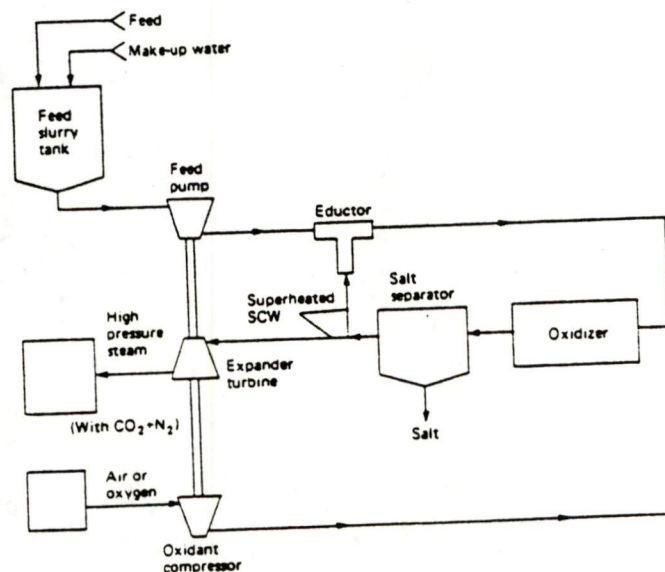


Figure 5. Supercritical water process.

*90-06610 **Vaporizing VOCs**, Neil J. Hutzler et al, Michigan Technological Univ, Houghton, *Civil Engineering-ASCE*, Apr 90, v60, n4, p57 (4) journal article

Soil vapor extraction is a cost-effective technique for VOC removal from contaminated soil. It is a relatively simple concept and can be used in conjunction with other soil decontamination procedures such as biological degradation, washing, or on- and off-site treatment and disposal. The design of such a technique involves contamination volume, groundwater depth, soil heterogeneity, contaminant location and area development, site soil characteristics, chemical properties, and operating and response variables. The typical system consists of extraction vents, air inlets, air headers, vacuum pumps, flow meters and controllers, vacuum gauges, sampling ports, air-water separator, vapor treatment, and an impermeable cap. The design and operation of these systems is flexible enough to allow for rapid changes in operation, which will optimize chemical removal. (1 diagram, 1 table)

*90-06603 **EPA's Assessment of European Contaminated Soil Treatment Techniques**, Thomas H. Pfeiffer et al, EPA, Washington, DC, *Env Progress*, May 90, v9, n2, p79 (8) journal article

An EPA-sponsored project to evaluate the most successful and innovative European technologies for contaminated site remediation is assessed. Three phases are discussed: Phase I involved the identification of these technologies, Phase II studied the most promising of those technologies discovered, and Phase III culminated in the first forum on innovative domestic and international hazardous waste treatment technologies in June 1989. Countries examined included Belgium, The Netherlands, and West Germany (FRG). The most promising technologies were developed in The Netherlands and the FRG, and included vacuum extraction of hydrocarbons from soil, in situ washing of cadmium-polluted soil, in situ steam stripping, and several landfarming and washing practices. The apparent success of this short-term technology assessment program indicates that despite the wealth of information available in the US, there is much to be learned from ongoing work in foreign countries. (2 diagrams, 8 references, 5 tables)

*90-06604 **An Overview of Solvent Extraction Treatment Technologies**, Dorothy W. Hall et al, CH2M Hill Inc, Milwaukee, WI, *Env Progress*, May 90, v9, n2, p98 (8) journal article

Several innovative solvent-extraction systems have recently become available for treatment of hazardous wastes. An overview is presented of some of the solvent-extraction systems being introduced and applied to treat hazardous materials as well as those still in the development stage. Systems profiled include: CF Systems Corp's extraction process, New York Univ's LEEP (Low Energy Extraction Process), BP Oil's solvent extraction process, Resource Conservation Co's B.E.S.T. (Basic Extractive Sludge Treatment) process, Envinte Field Services' Accurex solvent extraction process, and Sanexen Intl's Extraksol™ process. Process description, application, and availability information are presented for each system. The solvent extraction process technology appears to be a viable alternative for treating some contaminated soils and sludges. (8 diagrams, 1 table)

*91-00425 **Site Cleanup with Soil Washing Technology**, Hsin-Neng Hsieh and Dorairaja Raghu, New Jersey Inst of Technology, Newark, *Advances in Env Technology & Management*, 1990, v2, p157 (14) conf paper

The rehabilitation of sites contaminated by hazardous wastes has been facilitated by new technologies, including soil washing/soil flushing. This process extracts organic and inorganic contaminants via a liquid medium in which contaminants are mobilized through chemical reactions or the formulation of an emulsion. Extracting agents can include water, acids or bases, chelating agents, surfactants, reducing/oxidizing agents, and organic solvents. Factors affecting success rates include soil characteristics, hydrology, contaminants, extracting agents, and mixing of soil. (1 diagram, 20 references)

*90-00971 **Thermal Treatment Technologies for Haz Waste Remediation**, Nancy P. Johnson and Michael G. Cosmos, Weston Services Inc, West Chester, PA, *Pollution Engineering*, Oct 89, v21, n11, p66 (16) journal article

Thermal treatment is frequently selected as the preferred alternative for remediation of sites on the National Priorities List (NPL), as well as for non-NPL sites. Sites containing as much as 300,000 yd³ of contaminated soil have been identified as requiring thermal treatment. To avoid the high cost of transportation to a central treatment facility, on-site treatment op-

tions have been developed. On-site treatment is provided by installing modular-constructed facilities within the confines of the hazardous waste site. (2 diagrams, 8 drawings)

*91-00414 **Soil Remediation Techniques at Uncontrolled Hazardous Waste Sites: a Critical Review**, Ronald C. Sims, Utah State Univ, Logan, *Air & Waste Management Assn J*, May 90, v40, n5, p704 (29) journal article

A conceptual framework for soil remediation technique evaluation, selection, and monitoring is proposed, based on a critical review and evaluation of current information and activities used at hazardous waste sites. These processes provide the inputs into chemical mass balance that can be used for assessing the problem of mobility, for evaluating treatment techniques, and for identifying chemicals in specific phases for monitoring treatment effectiveness. Soil vacuum extraction, bioremediation, contaminant mobilization and immobilization, radio frequency heating, colloidal gas aphrons, electrokinetics, prepared bed reactors, in-tank reactors, and thermal treatment are all discussed. (5 diagrams, 2 graphs, 147 references, 16 tables)

*90-02851 **Assessment of 2,3,7,8-TCDD Emissions from Waste Disposal Sites**, Seong T. Hwang, EPA, Washington, DC, *EPA/APCA Measurement of Toxic and Related Air Pollutants Intl Sym, Research Triangle Park, NC*, May 88, p470 (16) conf paper

The significance of 2,3,7,8-TCDD emissions from soil and disposal sites is assessed by comparing the exposure to the emissions with the exposures associated with other multimedia pathways. The potential for human health risk is examined for various scenarios of environmental conditions and disposal design at different levels of waste contamination. Vapor inhalation, dust inhalation, and soil ingestion are a few of the exposure pathways described. (1 diagram, 10 references, 1 table)

190-155807/REB PC A08/MF A01
Environmental Protection Agency, Cincinnati, OH. Risk
Reduction Engineering Lab.
Handbook on In situ Treatment of Hazardous
Waste-Contaminated Soils. Rept. for May 88-Jul 89.
Associates, Inc., Cincinnati, OH.
D. Chambers, J. Willis, S. Giti-Pour, J. L.
Seleniewski, and J. F. Rickabaugh. Jan 90, 158p EPA/
90/002
EPA-68-03-3413
Prepared in cooperation with Cincinnati Univ., OH.
Sponsored by Environmental Protection Agency, Cin-
cinnati, OH. Risk Reduction Engineering Lab.

The handbook is intended to assemble state-of-the-art
information on in situ treatment technologies for haz-
ardous waste - contaminated soils. Extensive refer-
ences are provided for those who wish to seek more
detail on a given topic. The Risk Reduction Engineer-
ing Laboratory is continuing with its research on in situ
treatment to improve on technologies discussed in the
handbook and to explore new technologies.

Keywords: "Soils, "Hazardous materials, "Waste treat-
ment, "Reviews, Handbooks, Legislation, Soil stabili-
zation, Solidification, Degradation, Vaporizing, Photol-
ysis, Freezing, Cooling, Electrokinesis, Ultrasonics,
soil flushing.

PB90-263229/REB PC A03/MF A01
NATO/CCMS Pilot Study on Demonstration of Re-
medial Action Technologies for Contaminated
Land and Groundwater: 1988 Activities.
Environmental Protection Agency, Cincinnati, OH. Risk
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D. E. Sanning, M. A. Smith, and R. M. Bell. c1988, 12p
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The paper describes the nature, structure and content
of the NATO Committee on the Challenges of Modern

Society (CCMS) Pilot Study 'Demonstration of Remed-
ial Action Technologies for Contaminated Land and
underwater' and the associated CCMS Fellowship
program. To date, twelve projects in six countries have
been selected for inclusion in the program which will
involve periodic expert review during the five years for
which the project will run. The paper draws special at-
tention to the work on microbial clean up techniques
included in the program, and the outcome of the first
international meeting held in Washington, D.C. in
1987.

Keywords: "Hazardous materials, "Water pollution
control, Ground water, Research projects, Perform-
ance evaluation, Site surveys, Meetings, Reviews,
International relations, Reprints, "Foreign technology,
"Remedial action, "Soil contamination, "Waste man-
agement, NATO, Technology utilization, Technology
transfer, Cleanup operations, Demonstration pro-
grams, Microbial processes.

PB90-274093/REB PC A04/MF A01
Compendium of Technologies Used in the Treat-
ment of Hazardous Wastes.
Environmental Protection Agency, Cincinnati, OH.
Center for Environmental Research Information.
C. A. Clemons. Sep 87, 55p EPA/625/8-87/014

The document is intended to serve as an introduction
to technologies which can be used in the treatment of
hazardous wastes. While the contents of this docu-
ment are not exhaustive, it is believed that most treat-
ment processes are discussed. Each technology dis-
cussion includes a description of the basis of the tech-
nology, a brief discussion of the applicability and limita-
tions of that technology, the status of the technology, a
non-exhaustive listing of vendors, suppliers or devel-
opers and when appropriate, a process diagram for a
typical application of that technology. Furthermore, for
many of the technologies, a tabular listing of specific
data needed by an engineer designing a treatment
system is included. Technologies are categorized on
the basis of whether they are considered physical
treatment, chemical treatment, biological treatment,
thermal treatment (incineration) or stabilization/fixa-

Keywords: "Hazardous materials, "Waste treatment,
Process charting, Stabilization, Biodegradation,
"Technology utilization, Physical chemical treatment,
Chemical treatment, Biological treatment, Encapsulat-
ing, Physical treatment, Incineration, Waste forms.

PB90-191750/REB PC A07/MF A01
Environmental Protection Agency, Cincinnati, OH. Risk
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Technology Evaluation Report: SITE Program
Demonstration Test, Soliditech, Inc., Solidifica-
tion/Stabilization Process. Volume 1.
PRC Environmental Management, Inc., Chicago, IL.
W. E. Grube. Feb 90, 138p EPA/540/5-89/005A
Contract EPA-68-03-3484
See also Volume 2, PB90-191768. Sponsored by Envi-
ronmental Protection Agency, Cincinnati, OH. Risk Re-
duction Engineering Lab.

The primary objective of the Soliditech, Inc. solidifica-
tion/stabilization demonstration was to develop reli-
able performance and cost information. The demon-
stration took place at the Imperial Oil Company/Cham-
pion Chemical Company Superfund site in Morganville,
New Jersey. Contamination at this site includes PCBs,
various metals, and oil and grease. The Soliditech
process mixes the waste material with Urchem, a prop-
rietary reagent; proprietary additives; pozzolanic ma-
terials or cement (cement was used for the demonstra-
tion); and water, in an open-topped concrete mixer.
The technical criteria used to evaluate the effective-
ness of the Soliditech process were contaminant mo-
bility, based upon leaching and permeability tests; and
the structural integrity of the solidified material, based
upon physical and morphological tests. The treated
wastes had significant structural integrity, low perme-
ability, and higher bulk density than the untreated
wastes. pH values of the treated wastes were highly in-
fluenced by alkalinity of the portland cement added
during treatment. Documentation will consist of two re-
ports. This one is the Technology Evaluation Report
that describes the field activities and laboratory re-
sults.

Keywords: "Waste treatment, "Hazardous materials,
"Solidification, "Stabilization, Performance evaluation,
Cost analysis, Cements, Leaching, Greases, Oils,
Metals, Permeability, Physical tests, Morphology,
Density(Mass/volume), pH, Chemical tests, Site sur-
veys, "Technology utilization, "Superfund Innovative
Technology Evaluation Program, "Soliditech process,
Polychlorinated biphenyls, Urchem, Encapsulation,
Environmental transport.

PB90-191768/REB PC A99/MF A04
Environmental Protection Agency, Cincinnati, OH. Risk
Reduction Engineering Lab.
Technology Evaluation Report: SITE Program
Demonstration Test, Soliditech, Inc. Solidifica-
tion/Stabilization Process. Volume 2.
PRC Environmental Management, Inc., Chicago, IL.
W. E. Grube. Feb 90, 675p EPA/540/5-89/005B
Contract EPA-68-03-3484
See also Volume 1, PB90-191750. Portions of this docu-
ment are not fully legible. Sponsored by Environmen-
tal Protection Agency, Cincinnati, OH. Risk Reduction
Engineering Lab.

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terials or cement (cement was used for the demonstra-
tion); and water, in an open-topped concrete mixer.
The technical criteria used to evaluate the effective-
ness of the Soliditech process were contaminant mo-
bility, based upon leaching and permeability tests; and
the structural integrity of the solidified material, based
upon physical and morphological tests. The treated
wastes had significant structural integrity, low perme-
ability, and higher bulk density than the untreated
wastes. pH values of the treated wastes were highly in-
fluenced by alkalinity of the portland cement added
during treatment. Documentation will consist of two re-
ports. This one is the Application Analysis Report that
provides an interpretation of the data, and discusses
the potential applicability of the technology.

Keywords: "Waste treatment, "Hazardous materials,
"Solidification, "Stabilization, Performance evaluation,
Data processing, Tables(Data), Quality assurance,
Quality control, Field tests, Cements, Leaching, Per-
meability, Physical tests, Chemical tests, Experimental
design, Metals, Greases, Oils, "Technology utilization,
"Superfund Innovative Technology Evaluation Pro-

gram, "Soliditech process, Polychlorinated biphenyls,
Urchem, Encapsulation, Environmental transport.

PB90-183799/REB PC A15/M
Forum on Innovative Hazardous Waste Treat-
ment Technologies: Domestic and International. H...
Atlanta, Georgia on June 19-21, 1989. Techni-
cal Papers.
Environmental Protection Agency, Washington, D.C.
Office of Solid Waste and Emergency Response.
Sep 89, 328p EPA/540/2-89/056

As a result of the high level of interest in innovat-
ive hazardous waste control technologies, U.S. EP-
A, Office of Solid Waste and Emergency Response &
Risk Reduction Engineering Laboratory jointly or-
ganized this conference. The conference consisted
of presentations of technical papers and posters by in-
ternational and domestic vendors of technologies for
treatment of waste, sludge, and contaminated soils
uncontrolled hazardous waste disposal sites. The pur-
pose of the 2 1/2 day conference was two-fold: to in-
troduce promising international technologies through
technical paper and poster displays; and to show the
results of the U.S. EPA Superfund Innovative Technol-
ogy Evaluation program technologies in addition to
other domestic innovative technologies. Both were
aimed at increasing awareness of the user commu-
nity in technologies ready for application. The compen-
dium does not include all papers that were presented
only those that were made available by authors &
their institutions are included.

Keywords: "Meetings, "Hazardous materials, "Wa-
ster treatment, Waste disposal, Sludge, Water pollut-
ion control, United States, "Pollution control, "Technol-
ogy utilization, "Land pollution, Foreign technology, Su-
perfund Innovative Technology Evaluation, Cleanup op-
erations, Remedial action, Incineration.

PB90-108507/REB PC A87/MF A01
Environmental Protection Agency, Research Triangle
Park, NC. Air and Energy Engineering Research Lab.
Experimental Investigation of Critical Fundamen-
tal Issues in Hazardous Waste Incineration. F
rept. Jan 84-Apr 85.
Energy and Environmental Research Corp., Irvine, CA.
J. C. Kramlich, E. M. Poncelet, R. E. Charles, W. R.
Seeker, and G. S. Samuels. Sep 89, 130p EPA/
600/2-89/048
Contract EPA-68-02-3633
Sponsored by Environmental Protection Agency, Re-
search Triangle Park, NC. Air and Energy Engineering
Research Lab.

The report gives results of a laboratory-scale program
investigating several fundamental issues involved in
hazardous waste incineration. The key experiment for
each study was the measurement of waste destruction
behavior in a subscale turbulent spray flame. Atomiza-
tion quality: the performance of subscale nozzles was
directly measured in terms of droplet size by laser dif-
fraction. Secondary atomization: test results showed
that, when atomization quality was the limiting process,
secondary atomization markedly improved both waste
destruction efficiency and overall combustion efficien-
cy, as measured by CO and total hydrocarbon emis-
sions. Compound concentration: test results support
the hypothesis that varying secondary atomization in-
tensity with compound concentration in the feed ex-
plains most of the variation in laboratory-scale studies.
A mechanism involving mixing limited equilibrium
chemistry is proposed to explain the field data. Forma-
tion of products of incomplete combustion: the broad
spectrum of volatile organic compounds from a simpli-
fied flame were measured. Test results show that most
of the organic compounds present were from the fuel.

Keywords: "Hazardous materials, "Waste disposal,
"Organic compounds, "Combustion efficiency, "Air
pollution abatement, "Atomizing, Experimental design,
Performance standard, Design criteria, Combustion
products, Carbon monoxide, Hydrocarbons, "Inciner-
ation, Compliance, Air pollution standards, Pollution
regulations, Afterburning.

PC A01/MF A01
Innovative Technology: Soil Washing. Fact sheet (Final).
Environmental Protection Agency, Washington, DC.
Office of Emergency and Remedial Response.
Nov 89, 5p EPA/9200.5-250/FS

The fact sheet provides technology description, site characteristics affecting treatment feasibility, technology considerations, and technology status for soil washing. The fact sheet describes how soil washing can be potentially beneficial in the separation/segregation and volumetric reduction of hazardous materials in solids, sludges, and sediments.

Keywords: *Hazardous materials, *Decontamination, Technology innovation, Technology assessment, Waste treatment, Site surveys, Feasibility, Performance evaluation, Separation, Sediments, Sludge disposal, Process charting, Dewatering, Portable equipment, Washing, *Superfund, *Waste management, *Office of Solid Waste and Emergency Response, *Soil treatment, Cleanup operations, Remedial action.

PC A01/MF A01
Innovative Technology: In-situ Vitrification. Fact sheet (Final).
Environmental Protection Agency, Washington, DC.
Office of Emergency and Remedial Response.
Nov 89, 5p EPA/9200.5-251/FS

The fact sheet provides technology description, site characteristics affecting treatment feasibility, technology considerations, and technology status for In-Situ Vitrification (ISV). The sheet describes how ISV can be used to treat soils and sludges contaminated with mixtures of various waste types (e.g. radioactive, inorganic and/or organic).

Keywords: *Hazardous materials, *Vitrification, Waste treatment, Site surveys, Feasibility, Radioactive materials, Organic compounds, Inorganic compounds, Technology innovation, Technology assessment, *Superfund, *Waste management, *Office of Solid Waste and Emergency Response, *In-situ processing, Soil treatment, Sludge treatment, Remedial action.

PC A01/MF A01
Innovative Technology: Slurry-Phase Biodegradation. Fact sheet (Final).
Environmental Protection Agency, Washington, DC.
Office of Emergency and Remedial Response.
Nov 89, 5p EPA/9200.5-252/FS

The fact sheet provides technology description, site characteristics affecting treatment feasibility, technology considerations, and technology status for Slurry Phase Biodegradation (SPB). The sheet describes how SPB is potentially effective in treating various organic contaminants.

Keywords: *Hazardous materials, *Biodegradation, *Sludges, *Waste treatment, Site surveys, Organic compounds, Aeration, Process charting, Microorganisms, Technology assessment, Technology innovation, *Superfund, *Waste management, *Office of Solid Waste and Emergency Response, *Remedial action, Feasibility studies, Soil contamination.

PC A04/MF A01
Environmental Protection Agency, Cincinnati, OH. Risk Reduction Engineering Lab.
Operations and Research at the U.S. EPA Incineration Research Facility: Annual Report for FY89.
Acurex Corp., Jefferson, AR.
L. R. Waterland, Mar 90, 73p EPA/600/9-90/012
Contract EPA-68-03-3267
Sponsored by Environmental Protection Agency, Cincinnati, OH. Risk Reduction Engineering Lab.

The Environmental Protection Agency's Incineration Research Facility in Jefferson, Arkansas, is an experimental facility which houses two pilot-scale incinerators and the associated waste handling emission control, process control, and safety equipment, as well as onsite laboratory facilities. During Fiscal Year 1989, a major facility expansion and reconfiguration construction effort was completed. Upon completion of the construction, incineration testing at the Facility was resumed. Hazardous waste incinerator trace metal emission regulation development for the Office of Solid Waste and a Superfund site remediation treatability study for Region I and the Office of Emergency Response were major program support activities in Fiscal Year 1989.

Keywords: *Research projects, *Test chambers, *Hazardous materials, *Waste disposal, *Air pollution control equipment, *Soils, Incinerators, Performance evaluation, Scrubbers, Design criteria, Particle size distribution, Kilns, Tables(Data), Concentration(Composition), *US EPA, *Incineration, *Air pollution sampling, Superfund program, Land pollution.

PC A01/MF A01
Innovative Technology: BEST Solvent Extraction Process. Fact sheet (Final).
Environmental Protection Agency, Washington, DC.
Office of Emergency and Remedial Response.
Nov 89, 5p EPA/9200.5-253/FS

The fact sheet provides technology description, site characteristics affecting treatment feasibility, technology considerations, and technology status for the BEST solvent extraction process. The sheet describes the BEST process as using one or more secondary or tertiary amines to separate toxic wastes and oils from sludges or soils.

Keywords: *Hazardous materials, *Solvent extraction, Technology assessment, Technology innovation,

Waste treatment, Site surveys, Performance evaluation, Separation, Amines, Feasibility, *Superfund, *Waste management, *Office of Solid Waste and Emergency Response, *Best technology, Soil treatment, Land pollution, Sludge treatment, Remedial action.

PC A01/MF A01
Innovative Technology: Glycolate Dehalogenation. Fact sheet (Final).
Environmental Protection Agency, Washington, DC.
Office of Emergency and Remedial Response.
Nov 89, 5p EPA/9200.5-254/FS

The fact sheet provides technology description, site characteristics affecting treatment feasibility, technology considerations, and technology status for Glycolate Dehalogenation. The sheet describes the process as being potentially effective in detoxifying specific types of aromatic organic contaminants, particularly dioxins and PCBs.

Keywords: *Hazardous materials, Waste treatment, Process charting, Pesticides, Technology innovation, Technology assessment, *Superfund, *Waste management, *Office of Solid Waste and Emergency Response, *Dehalogenation, *Glycolic acid, Dioxins, Polychlorinated biphenyls, Soil treatment, Remedial action.

PC A03/MF A01
Bioremediation of Contaminated Surface Soils.
Robert S. Kerr Environmental Research Lab., Ada, OK.

J. L. Sims, R. C. Sims, and J. E. Matthews. Aug 89, 28p
EPA/600/9-89/073
Prepared in cooperation with Dynamac Corp., Ada, OK, and Utah State Univ., Logan.

Biological processes, including microbial degradation, have been identified as critical mechanisms for attenuating organic contaminants during transit through the vadose zone to the groundwater. On-site soil remedial measures using biological processes can reduce or eliminate groundwater contamination, thus reducing the need for extensive groundwater monitoring and treatment requirements. On-site remedial systems that utilize the soil as the treatment system accomplish treatment by using naturally occurring microorganisms to treat the contaminants. Treatment often may be enhanced by a variety of physical/chemical methods, such as fertilization, tilling, soil pH adjustment, moisture control, etc. The development of a bioremediation program for a specific contaminated soil system includes: (1) a thorough site/soil/waste characterization; (2) treatability studies; and (3) design and implementation of the bioremediation plan. Biological remediation of soils contaminated with organic chemicals has been demonstrated to be an alternative treatment technology that can often meet the goal of achieving a permanent clean-up remedy at hazardous waste sites.

Keywords: *Soils, *Microorganisms control(Water), *Water pollution control, Ground water, Contamination, Monitoring, Fertilizing, Cultivation, pH, Soil water, Organic compounds, Waste treatment, Clean up.

PC A03/MF A01
Pilot-Scale Evaluation of Incinerating Listed Wastes from Specific Sources. Rept. for 1986-88.
Environmental Protection Agency, Cincinnati, OH. Risk Reduction Engineering Lab.
C. R. Dempsey, and R. C. Thumau. 1990, 14p EPA/600/D-90/141

Pilot-scale incineration testing was conducted at the United States Environmental Protection Agency's Incineration Research Facility (IRF) to support the development of best demonstrated available technology (BDAT) standards for the treatment of several hazardous wastes from specific sources (K-Wastes). All testing was conducted in the IRF's rotary kiln system. The paper summarizes the results of this testing for four of these wastes. The objective was to determine if these wastes could be incinerated by a well designed, well operated incinerator based on compliance with the hazardous waste incinerator regulations and to characterize the incineration residuals for hazardous constituents. It was found that these wastes could generally be incinerated in compliance with these regulations. However, the mist carryover from the air pollution control device would have to be more effectively controlled to meet the particulate standard in some cases. No detectable amounts of principle organic hazardous constituents (POHC's) were found in either the kiln ash or scrubber blowdown.

Keywords: *Hazardous materials, *Waste disposal, *Combustion efficiency, Pilot plants, Performance evaluation, Waste treatment, Standards, Air pollution control, Particles, Kilns, Organic compounds, *Best technology, *Incineration, Source Classification Codes, Pollution regulations, Standards compliance, Resource Conservation and Recovery Act, Physical chemical treatment.

PC A07/MF A01
Environmental Protection Agency, Cincinnati, OH. Risk Reduction Engineering Lab.
Development of Electro-Acoustic Soil Decontamination (ESD) Process for In situ Applications.
Battelle Columbus Labs., OH.
H. S. Muralidhara, B. F. Jirjis, F. B. Stulen, G. B. Wickramanayake, and A. Gill. Apr 90, 141p EPA/540/5-90/004
Sponsored by Environmental Protection Agency, Cincinnati, OH. Risk Reduction Engineering Lab.

The technical feasibility of electro-acoustic soil decontamination process through lab experiments demonstrated the removal/concentration of heavy metals such as cadmium and zinc. Results of the decane contaminated soils were, however, inconclusive. The ESD process is based on the application of a d.c. electric field and acoustic field in the presence of a conventional hydraulic gradient to contaminated soils to enhance the transport of liquid and metal ions through the soils. Electrodes (one or more anodes and a cathode) and an acoustic source were placed in contaminated soils to apply an electric field and an acoustic field to the soil. This process works especially well with clay-type soils having small pores or capillaries, where hydraulic permeability is very low. The development program included a literature review, soil characterization, design and construction of the laboratory ESD unit, and lab scale experiments with soils contaminated with decane, zinc and cadmium. Evaluation of the experimental results indicated that application of the field sources reduced the heavy metals zinc and cadmium more than 90% in the treated cake. Tests yielded 10-20% decane removal.

Keywords: *Soils, *Pollution control, Experimental design, Water pollution, Ground water, Performance evaluation, Soil surveys, Reviews, Tables(Data), Osmosis, Design criteria, Laboratory equipment, Zinc, Cadmium, Clay soils, Electrolysis, Superfund Innovative Technology Evaluation Program, *Remedial action, *Heavy metals, *Electroacoustic waves, Environmental transport.



Project Summary

Treating Chlorinated Wastes with the KPEG Process

M. L. Taylor, J. A. Wentz, M. A. Dosani, W. Gallagher, and J. S. Greber

The two reports summarized here describe development of the alkali metal polyethylene glycolate (APEG) chemical technology to dechlorinate hazardous hydrocarbons in soils and its application at four demonstration sites: field-scale application to contaminated soils on the island of Guam; pilot-scale demonstration in Moreau, New York; and drum-stored contaminated materials at the Bengart & Memel site in New York and in Omaha, Nebraska. The Omaha site involved tetrachlorodibenzo-p-dioxin (TCDD) in waste herbicides.

Equipment for the field-scale application on Guam included a steam-jacketed mixer, a steam-generating plant, and a condensate collection system. Approximately 15 yd³ of contaminated soil (with concentrations averaging 3635 ppm Aroclor 1260) were batch treated with potassium polyethylene glycolate (KPEG). The polychlorinated biphenyl (PCB) concentrations were reduced by more than 99%, with no individual PCB congener exceeding 2 ppm.

The reports provide detailed information about preparation of contaminated soils before treatment, equipment and reagents used during treatment, and analyses done before, during, and after treatment. Potential users are given sufficient information of the KPEG process to ascertain which version of the process is best suited for a particular site.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the

research projects that are fully documented in two separate reports (see Project Report ordering information at back).

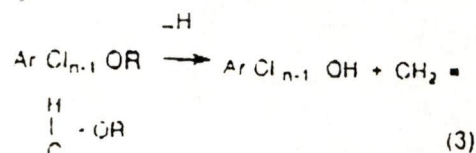
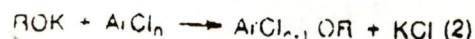
Introduction

The two reports concern a chemical dechlorination process that employs a reagent, typically prepared by reacting a base (e.g., potassium hydroxide) with one of several polyethylene glycols (e.g., PEG 400). Early laboratory- and drum-scale studies are described that proved the feasibility of the KPEG technology to treat PCB-contaminated soils. In-depth descriptions are given of the KPEG-process demonstrations that have been done to date.

A typical laboratory-scale procedure for dechlorinating polychlorinated dibenzo dioxins (PCDD)- and PCB-contaminated soil involves mixing potassium hydroxide (KOH) and polyethylene glycol-400 (PEG-400, average molecular weight of 400 Daltons) to produce the reagent KPEG. This KPEG reagent is mixed with the contaminated soil, heated to approximately 150°C (302°F), and maintained at that temperature while being continuously stirred for 1 to 4 hr. Excess reagent is then decanted, the soil is neutralized with acid and rinsed two or three times with water, and the decontaminated soil is discharged.

The reaction of the KOH and PEG-400 produces an alkoxide (ROK) (Equation 1), which in turn reacts with one of the chlorine atoms on the aryl ring to produce an ether (ArCl_{n-1}OR) and potassium chloride (KCl) salt (Equation 2). Replacement of the chlorine atom on the aryl ring with an ether-linked PEG

removes the compound. The dechlorination process is described in Equations 1, 2, and 3:



Pilot-Scale and Field-Scale KPEG Treatment Demonstrations

Four site demonstrations of the KPEG process are discussed. A pilot-scale demonstration was conducted at the Moreau, New York, site, and a field-scale demonstration was conducted at the Guam site. At the Bengart & Memel site in New York and a site in Omaha,

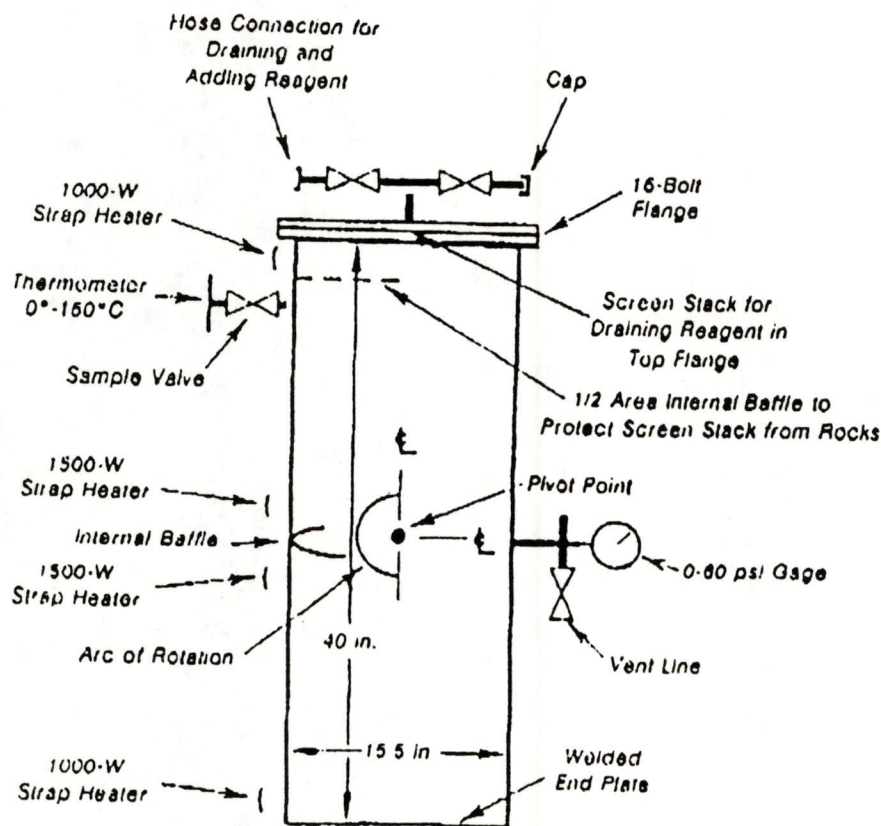
Nebraska, drum-treatment demonstrations of the KPEG process were conducted. Discussions of these four site demonstrations should assist potential users of the KPEG process with sufficient information to assess which of the four versions of the KPEG process is best suited for implementation at a particular site.

Pilot-Scale Demonstration of KPEG Process in Moreau, New York

The objectives of the demonstration at the Moreau site were to document that the KPEG reagent could effectively dechlorinate PCBs to acceptable levels at the 40-gal scale (from hundreds and thousands of parts per million to less than 3 to 4 ppm) and to gather process data that would subsequently be used to design a larger (2-yd³ or 400-gal) reactor. The test at Moreau was not intended to be a site cleanup; only a small portion of the contaminated soil was treated as part of the test.

The Moreau site was formerly a drag strip. The drag strip was oiled periodically, and some of the oil used for this purpose was transformer oil containing PCBs. The PCB concentrations in the soil at the site ranged from nondetectable up to tens of thousands parts per million. The pipe reactor (Figure 1) used during the pilot-scale tests was constructed from a 40-in. length of 16-in. steel pipe. It was mounted on a stand that allowed it to rotate about the indicated pivot point, and because it rotated through an arc of 180° in about 10 sec, mixing inside the pipe was gentle. A baffle along the side of the pipe (midway down its length) redirected the flow of slurry along the pipe wall and enhanced mixing.

Four electric heating straps heated the reactor. One 1000-watt heating strap was wrapped around the top of the reactor, and another was wrapped around the bottom. Both straps were about 10 in. wide. Two 3-in.-wide 1500-watt straps were wrapped around the center portion of the reactor.



Removable insulation is used during operation

Figure 1. Reactor detail for the Moreau, New York pilot-scale demonstration.

During the reactor operation, temperature and pressure were recorded every 15 min. The reactor motion and its direction were controlled by a hand-held switch; therefore, during the entire time the reactor was operating, someone held the switch and manually reversed the reactor's direction at the end of each 180° turn.

Vapor from the reactor was vented through a small fan-cooled condenser (Figure 2). The condenser condensate was collected in Condensate Drum No. 1, which was vented to an ice condenser consisting of a coil submerged in an ice bath that drained to Condensate Drum No. 2. Condensate Drum No. 2 was vented through an activated carbon canister to remove any trace volatiles before atmospheric discharge.

The treatment procedure involved preparing the solvent PEG mixture—dimethylsulfoxide (DMSO), triethylene glycol methyl ether (TMH), and PEG-400 (ratio 2:1:1)—in a 55-gal drum. The soil, solvent mixture, and 45% KOH solution were then loaded into the reactor and mixed. The reactor was heated to 150°C, and the samples were withdrawn by removing the thermometer and pouring the slurry (~50 g) out of the thermometer insertion port.

Altogether, four runs were made with this reactor. Table 1 lists the reactor contents for each of these runs. After the samples were taken out of the reactor, both soil and reagent were analyzed for PCBs. The reductions in PCB concentration in the soil achieved during Run No. 1 ranged from 93.9% to 99.8% and averaged 96.3%. The PCB reduction in the remaining three runs (Runs 2 through 4) was greater than 99%. PCBs were also found in the recovered reagents, generally at higher concentrations than those in the soil; this indicated that although the PCBs were being extracted from the soil into the liquid phase, chemical dechlorination was not yet complete. The PCB concentrations in the reagent were 0.16 ppm in Run 1, 74.8 ppm in Run 2, 72.4 ppm in Run 3, and 4.25 ppm in Run 4.

Field-Scale Demonstration of KPEG Process in Guam

The U.S. Navy Public Works Center on Guam was selected for the field-scale demonstration of the KPEG chemical dechlorination system. The PCB concentrations in the soil at the site averaged 3535 ppm, with "hot-spots" as high as 45,860 ppm (4.59%). Soil contamination (found primarily in a nearby storm

drainage ditch) was the result of leachate from a transformer rework building waste PCB stored outside the building. Excavated, contaminated soil was stored in a 12.2- by 18.3-m (40- by 60-ft) building with a heavy rubber liner on a concrete pad. Also another 30.5- by 30.5-m (100- by 100-ft) concrete pad poured for the installation of the full-scale KPEG treatment system.

Soil and particles smaller than 1/2 mm were passed through the screens collected separately so that particles would not be jammed in the mixer.

Laboratory studies of contaminated samples from Guam determined the soil's potential for KPEG treatment, established the reagent formulation, and other operating parameters. Figure 3 is a simplified mechanical flow diagram of the KPEG system at Guam. As illustrated, the mixer was the primary component of the system in which the chemical dechlorination process occurred. An extensive pipe network connected the ancillary equipment with each other and with the mixer.

The principal components of the Guam KPEG treatment system (mixer, platform liquid reagent loading system, heating system, nitrogen system, condensate collection system, process cooling system, reagent collection system, and ventilati-

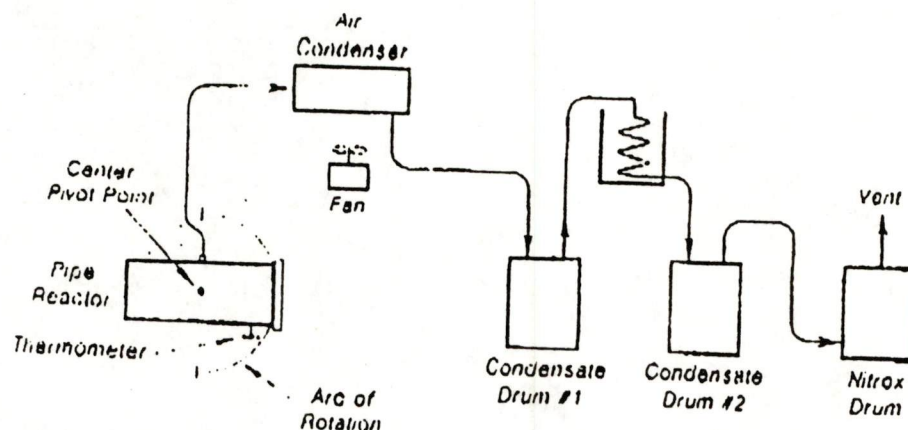


Figure 2. Equipment arrangement for the Moreau Test.

Table 1. Material Charged to Reactor, in Pounds

Run	Soil	Sulfolane	DMSO	TMH	PEG-400	45% KOH	Total Liquid
1	33.5	0.0	11.0	5.5	5.5	11.0	32.9
2	32.5	0.0	10.0	5.0	5.0	10.0	30.0
3	34.0	0.0	12.0	6.0	6.0	12.0	35.9
4	39.0	15.0	0.0	7.5	7.5	13.0	43.0

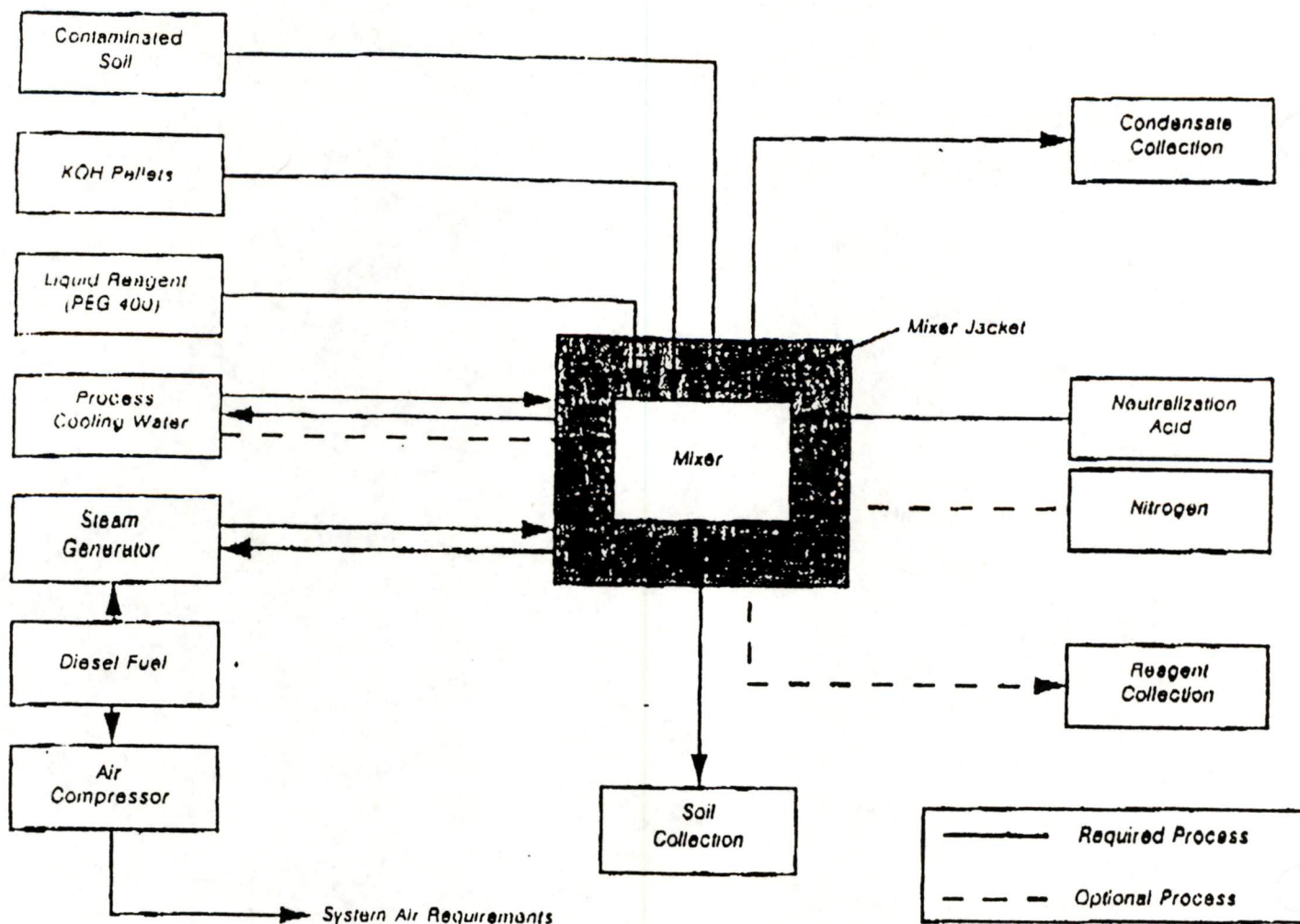


Figure 3. Mechanical flow diagram of KPEG field-scale treatment system.

system) are described in detail in the full report.

Six 55-gal drums were placed on a metal pallet, the pallet was positioned in the metal building next to the stockpiled soil, and the soil was shoveled into the drums. The six drums of soil were relocated to the scale, where a small forklift with a drum-lifting attachment placed them on the scale. A grab sample was collected from each of the six drums of soil. These samples were placed in a container and mixed thoroughly to provide a homogeneous sample for PCB analysis.

A crane hoisted the drums of soil, and two persons on the platform used the manual chainfall on the drum lifter to dump the drum contents into the mixer. After every second drum of soil was loaded, the mixer was turned on for a short time to disperse the soil evenly throughout the mixing cylinder.

After all the soil was loaded into the mixer, the components of this KPEG (PEG 400 and KOH) formulation were added. The mixer was run at low speed (30 rpm) while the PEG-400 was pumped into it; this allowed thorough dispersion of the PEG-400 and KOH to initiate the first reaction shown in Equation 1. When the reagents and soil were completely mixed, the mixer was switched to high speed (60 rpm). The vent line from the mixer to the condensate collection system was opened, and the fan condenser was turned on.

The steam-generating plant was ignited and 80-psi steam was circulated through the mixer jacket. The mixer contents reached 150°C in approximately 2 hr, and the temperature and mixing were maintained for 4 hr. At the end of 4 hr, the steam generator and mixer were shut down, the fan condenser was turned off,

and the contents were allowed to cool overnight.

After cooling overnight, all the treatment batches of soil were neutralized with concentrated sulfuric acid and discharged. Samples were collected from the sample-collection port, and the soil pH was measured. If the collected sample had a pH in the 6 to 8 range was also used as the posttreatment sample. The treated soil and reagent used in the treatment process were discharged into the soil-collection hopper pending analytical results.

A high-pressure (2000-psi) washer was used to decontaminate process equipment, and the resulting water was collected in 55-gal drums. The collected condensate and water was passed through a series of cartridge filters and activated-carbon canisters. The treated water was then collected, sampled, and held until results

Analyses for PCB contamination were obtained. Treated waters with nondetectable PCB concentrations were either collected by a liquid transport truck and discharged into the sanitary sewer treatment plant or pumped back onto the site.

PCB analyses employed an EPA-developed field-screening method, which is followed with a more vigorous, corroborative analysis. A review of water and soil analytical data from both analyses indicated that the destruction of a total PCB concentration exceeded 99%. In both sets of data, however, analysis of each of the congener peaks showed that a tetrachlorobiphenyl congener concentration in a portion of the treated batches was slightly above the RCRA permit requirement of 2 ppm or lower per PCB peak. The batches containing greater than 2 ppm of the tetracongener were loaded back into the mixer, mixed with the new KPEG formulation of 1.3 moles KOH and 1.0 mole EG-400, and retreated. Analytical results of the retreated batches indicated the tetracongener in each batch was well below 1 ppm.

Drum Treatment Demonstration of KPEG Process at Bengart & Memel Site, New York

The preceding two KPEG demonstrations were performed to prove the effectiveness of the KPEG process at larger scales and to promote the development of a full-scale system. The demonstrations described in this section and the one that follows concern the in situ treatment of smaller quantities of contaminated materials that may have already been placed into drums for storage. This process offers an alternative to the costly and hazardous process of emptying drums of hazardous materials.

When Bengart & Memel, Inc., a wholesaler of nonferrous scrap metals, dismantled PCB transformers and capacitors, PCBs were released into the soil. In the mid-1970's, soil samples from this site contained PCB concentrations exceeding 50 ppm. Soil sampling and analysis indicated that PCB concentrations were excessive in seven locations on the property. As part of the remedial program, the contaminated soil was excavated and placed in 166 55-gal steel drums. Because of a consent order deadline, only 51 drums of soil were treated in this demonstration. All the remaining drums were shipped, unprocessed, directly to a landfill.

During the KPEG treatment process, a weighed quantity (typically 150 to 170 lb) of a single-phase reagent mixture (2:2:4:9:5—PEG:TMH:DMSO:45% KOH: water) was added to each of the soil drums. A bimetal thermometer was inserted into the 3/4-in. bung on each drum cover, and the drums were heated from the bottom to ensure that all of the soil contaminants would react. The soil temperature was monitored 9 to 12 in. below the top of the drum, and the soil temperatures were typically maintained between 105° and 110°C for several hours.

The drums were vented to a central condenser system with a capacity of 16 drums (see Figure 4). During heating, vapors exited from the drum through an insulated flexible line connecting the 2-in. drum bung with the main header. Because part of the header was ice-jacketed, much of the water vapor was condensed and drained directly into a 55-gal holding drum. The remaining vapor was drawn through an air-cooled radiator (used as a condenser), which also drained liquid to the 55-gal holding drum. An ice-jacketed scrubber containing a dilute sodium hypochlorite solution (for odor control) trapped most of the remaining condensables. From the scrubber, the vapor passed through a 55-gal drum filled with a mixture of activated carbon and containing a molecular sieve. A vacuum pump provided negative pressure for the vapor control system.

A 30-in. auger attached to a hand drill was used to collect treated soil samples from the drums. Four samples (one from the center, one close to the drum wall, and two spaced between the center and wall) were collected from the drum by penetrating the soil as deeply as possible with the auger.

After the treated soil had been decontaminated, the soil had to be brought from a highly alkaline to a neutral pH by the addition of dilute acid.

Soon after the KPEG treatment (October 1986), EPA determined the concentrations of PCBs in selected drums. A second group of drums was sampled and analyzed in February 1987 after the reagent had been in contact with the soil for 5 mo. Group 2 included fresh samples from the drums that EPA found contained PCB concentrations exceeding 50 ppm, samples from treated drums not analyzed by the EPA, and one soil sample that contained less than 50 ppm when EPA analyzed it. The low-concentration sample was analyzed to check the potential reaction progress in drums with PCB concentrations below 50 ppm. A comparison of the reduced concentrations

reported in February with the October results indicated that the reaction continued during the holding period.

A review of treated-soil analytical data indicated that PCB concentrations were reduced from 108 to 27 ppm (a 75% reduction). The PCB levels in the one drum with an initial concentration of 1300 ppm were reduced to 78 ppm (94% reduction).

Drum Treatment Demonstration of KPEG Process at an Omaha, Nebraska, Site

This 1987 EPA study was designed to demonstrate the effectiveness of the KPEG process for treating drummed, contaminated herbicide wastes containing dioxins. The contaminated waste contained 17,800 ppm 2,4-D, 2800 ppm 2,4,5-T, and 1.3 ppm 2,3,7,8-TCDD.

The KPEG reagent used in this demonstration was prepared with PEG and KOH. The field-scale testing of the KPEG technology was performed on one 20-gal batch of the contaminated waste.

The treatment equipment consisted of a 55-gal drum, a clamp-on heating band, and a stirring motor. The drum containing the KPEG reagent and the contaminated waste was heated to a temperature of 70° to 85°C for 2 days while being continually stirred. After 2 days, the heat was turned off and the reaction mixture was allowed to cool to ambient temperature. The treated waste samples were then analyzed to determine the posttreatment concentration of the contaminated waste.

Table 2 presents the analytical results of samples collected before treatment and after the first and second treatments. The KPEG treatment reduced the concentration of 2,3,7,8-TCDD in the waste to less than the detectable range. The concentrations of both 2,4-D and 2,4,5-T were reduced by 98%.

Conclusions

The pilot-scale KPEG demonstration in Moreau, New York, represented the first attempt to dechlorinate PCBs in a reactor/mixer at a scale larger than that used in the laboratory. Results of the demonstration indicated that PCBs could be reduced by an average of 98.3% (reductions ranged from 93.8% to 99.8%).

The field-scale demonstration at Guam proved the effectiveness of the KPEG technology for treating soils with initial PCB concentrations averaging 3535 ppm

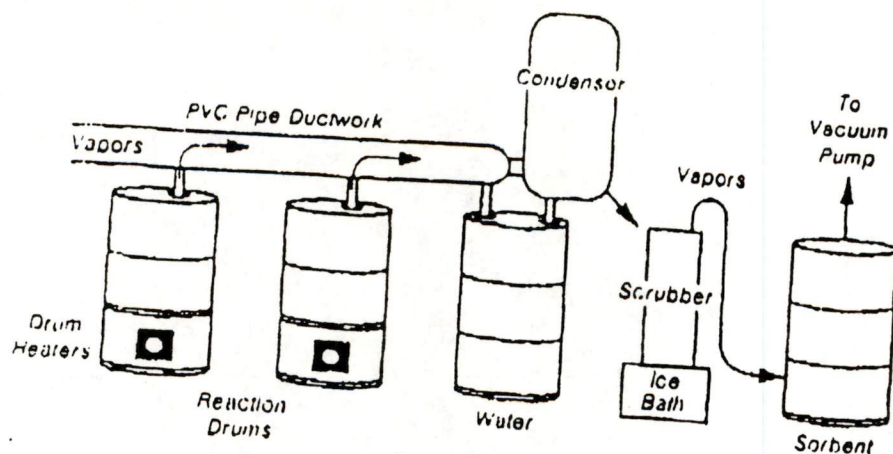


Figure 4 Central condenser system. KPEG drum treatment demonstration, Bengart & Memel, Buffalo, New York.

Table 2. Drum Scale Treatment of TCDD, 2,4-D and 2,4,5-T

Contaminant	Conc. in Untreated Waste, ppm	Concentration in Treated Waste		Percent Reduction of Contaminants
		First Treatment, ppm	Second Treatment, ppm	
TCDD (2,3,7,8)	1.3	0.086	ND*	99.99
2,4-D	17,800	9,000	334	98.12
2,4,5-T	2,800	1,700	55	98.04

*ND = None Detected

(3260 to 3828 ppm). PCB concentrations were reduced to an average concentration of 6.74 ppm (1.01 to 13.9 ppm), which represents an average reduction of 99.84% (99.58% to 99.98%) with no resolvable PCB congener exceeding 2 ppm (after retreatment). The process implemented in Guam was successful in its treatment of PCB-contaminated soil without the use of DMSO or TMH.

The KPEG process used at the Bengart & Memel site successfully reduced PCB levels in soil contained in 55-gal drums to below the 50-ppm control limit set for the oil at the site.

The drum-scale KPEG process at the Maha site proved to be capable of degrading 2,3,7,8-TCDD, 2,4-D, and 2,4,5-T. Initial concentrations of 1.3 ppm 2,3,7,8-TCDD, 17,800 ppm 2,4-D, and 300 ppm 2,4,5-T were reduced to concentrations of none detectable, 334 ppm,

and 55 ppm, respectively. The demonstration also proved the effectiveness of KPEG without the use of DMSO or TMH.

Recommendations

The following recommendations were made concerning the field-scale KPEG system:

1. The system should be used at additional sites to provide more background data on the technology.
2. Additional field-scale demonstrations should be done in an attempt to optimize the reagent formulation and operating parameters.
3. The labor intensity of the system should be reduced by modifying it with materials handling equipment and automation.

4. Attempts should be made to identify alternative equipment manufacturers that may be capable of further increasing the efficiency of the system.
5. Design of a full-scale, fully portable, self-supportive KPEG treatment system should be initiated for soils contaminated with halogenated aromatic compounds.
6. Efforts should be initiated to delist the KPEG-treated soil judged to be "clean" per the requirements of the R&D permit.

The full report was submitted in fulfillment of Contract No. 68-03-3413, Work Assignment No. 1-2, and IAG RW17933910 by PEI Associates, Inc., under the sponsorship of the U.S. Environmental Protection Agency.

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T. D. Ferguson and C. J. Rogers are the EPA Project Officers (see below).

The complete reports entitled "Field Applications of the KPEG Process for Treating Chlorinated Wastes" (Order No. PB 89-212 724/AS; Cost: \$17.00, subject to change), and "Comprehensive Report on the KPEG Process for Treating Chlorinated Wastes" (Order No. PB 90 163 843; Cost \$23.00, subject to change)

will be available only from:

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HAZARDOUS WASTE MANAGEMENT

TREATMENT TECHNOLOGIES FOR HAZARDOUS WASTES: PART IV

A Review of Alternative Treatment Processes for

Metal Bearing Hazardous Waste Streams

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The U.S. Congress and the U.S. Environmental Protection Agency believe that treatment and recovery techniques should be given maximum priority when considering methods for managing the nation's generated hazardous waste. A prohibition for the disposal of certain categories of hazardous wastes either directly onto or into the land without being treated to an accepted degree prior to such disposal practice has been promulgated.¹ Wastes containing toxic metals and cyanide complexes have been selected as a group to be restricted. Due to the high generation rate associated with this category, a large capacity of waste treatment processing will be required. Existing and emerging treatment alternatives which are or have the potential to be employed for waste treatment of metal bearing wastes are presented in this paper.

An estimated 7.9 billion gallons of metal bearing wastes, 4.7 billion gallons of cyanide wastes and 0.8 billion gallons of reactive wastes containing cyanides were generated in the United States in 1983.² Currently, 85 percent of all metal and cyanide bearing wastes that are subjected to land disposal are aqueous (≤ 1 percent total solids). A listing of the principal number of waste generators are listed by SIC code in Table I.²

The purpose of this review is to describe current treatment practices that are being used or considered for use at on-site or commercial hazardous waste treatment, storage and disposal facilities (TSDF) to treat metal and cyanide wastes conventionally land disposed.

Waste Characterization

Hazardous wastes which can be categorized as metal and cyanide bearing wastes are included in each of the five source designations for hazardous

wastes as designated by EPA (40 CFR). The source categories are:

- D Wastes which are hazardous because they exhibit a particular hazardous characteristic, such as toxicity;
- F Wastes from non-specific sources;
- K Wastes from specific sources;
- P Acutely hazardous constituents; and
- U Toxic constituents

As is illustrated by Table II, the majority of metal/cyanide wastes generated in this country are characteristic toxic metal wastes (D) and wastes that result from electroplating and metal treating processes (F). These wastes are specified by the following RCRA codes:

- D002 Corrosive metal wastes which are aqueous and have a pH less than or equal to 2 or greater than or equal to 12.5.

D003 A solid waste that exhibits the characteristics of reactivity in the presence of the cyanide ion, but is not listed as a hazardous waste in Part 2613.

- D004 Arsenic
- D005 Barium
- D006 Cadmium
- D007 Chromium
- D008 Lead
- D009 Mercury
- D010 Selenium
- D011 Silver

F006 Wastewater treatment sludges from electroplating operations except from the following processes: 1) sulfuric acid anodizing of aluminum; 2) tin plating on carbon steel; 3) zinc plating (segregated basis) on carbon steel; 4) aluminum or zinc-aluminum plating on carbon steel; 5) cleaning/stripping associated with tin, zinc and aluminum plating on carbon steel; and 6) chemical etching and milling of aluminum.

F007 Spent cyanide plating bath solutions from electroplating operations (except for precious metals electroplating spent cyanide plating bath solutions).

F008 Plating bath sludges from the bottom of plating baths from electroplating operations where cyanides are used in the process (except for precious metals electroplating plating bath sludges).

F009 Spent stripping and cleaning bath solutions from electro-

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Table I. Number of waste generators by SIC code.

No. of facilities (Dun's 1983)	SIC description	Weighted No. of facilities			
		SIC	CN	Metals	Metals +CN
4,287	Plating and polishing	3471	750	263	1013
2,145	Paints and allied products	2851	20	212	232
2,902	Metal coating and allied products	3479	46	149	195
4,151	Motor vehicle parts and accessories	3714	62	107	169
2,183	Industrial inorganic chemicals	2819	3	131	134
876	Metals, nonferrous, secondary	3341	37	93	130
55,380	Fabricated metal products	3400	51	73	124
393	National security	9711	16	84	100
966	Motors and generators	3721	40	61	100
32,867	Misc. manufacturing industries	3900	23	68	91
384	Metal, nonferrous, rolling, drawing	3356	30	60	90
609	Printing ink	2893	0	89	89
1,229	Blast furnaces, steel mills	3312	11	78	89
1,229	Foundries, gray iron	3321	0	82	82
2,614	Electric services	4911	0	81	81
1,160	Industrial organic chemicals	2869	5	80	85
1,529	Plastics material	2821	7	76	83
4,656	Radio and TV communication equipment	3662	30	49	79
5,392	Electronic components	3679	35	42	77
1,040	Motor vehicle bodies	3711	41	34	75
3,432	Machine tool accessories	3545	40	0	40

plating operations where cyanides are used in the process (except for precious metals electroplating bath sludges).

F010 Quenching bath sludge from oil baths from metal heat treating operations where cyanides are used in the process (except for precious metals heat treating quenching bath sludges).

F011 Spent cyanide solutions from salt bath pot cleaning from metal heat treating operations (except for precious metals heat treating spent cyanide solutions from salt bath pot cleaning).

F012 Quenching wastewater treatment sludges from metal heat treating operations where cyanides are used in the process (except for precious metals heat treating quenching wastewater treatment sludges).

Other hazardous wastes containing metals and/or cyanide constituents are generated from specific industrial sources (RCRA Code K), such as inor-

ganic chemicals and pigments (K002-8), petroleum refining (K052), iron and steel (K061, K062), secondary lead (K069, K100), and ink formulations (K086). Salts of the various metal ions and cyanide complexes are listed in Part 261.33 (e) and (f) as discrete chemical constituents of discarded commercial chemical products, off-specification species, container residues and spill residues of acutely hazardous (P) and toxic (U) wastes respectively. Metal ions are prevalent in

Table II. Generated waste distribution.

Hazardous waste group	Metals			Cyanides		
	Annual volume (million gals.)	Percent of total metals	No. of generators	Annual volume (million gals.)	Percent of all CN	No. of generators
D wastes	3,685	46.9	3,860	Est. 750	—	Not available
F wastes	3,920	49.9	2,091	3,920	83	2,091
K wastes	219	2.8	402	572	12.1	10
P wastes	28.3	.36	405	226	4.8	800
U wastes	5.2	.07	365	3.92	.08	306
Total	7,858		6,586	4,723		2,781

many forms based upon the type of industrial processes and uses employed.

Alternative Treatment Technologies for Metal Bearing Wastes

The U.S. EPA is interested in defining available technologies for each of the relevant hazardous waste codes. Technologies to be considered as alternatives to land disposal practices must demonstrate an acceptable level of treatment before these processes are permitted for operation. Treatment standards for many waste codes are being established through case studies, demonstration projects and pilot studies. A review of some of the existing alternative treatment options for metal/cyanide bearing wastes will be presented.

Discussions of how various treatment processes can achieve acceptable treatment objectives can be generalized by the approach presented in Figure 1. Although this simplification and reduction of waste treatment options does not account for all metal bearing wastes, a majority of these wastes will incorporate some aspect of the presented waste treatment strategy.

Due to the wealth of information found in the literature describing pretreatment practices associated with specific waste discharges, the following discussion is limited to two basic waste management approaches:

- Waste treatment processes
- Waste reduction and recovery

Processes are listed and synopsisized for each main category with a description of their capabilities, advantages, limitations, significant results and relevance to standards and regulations. Discussion of a particular technology should not be construed as an endorsement by EPA. Likewise, absence of discussion for a particular technology does not imply a lack of confidence by

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Waste Tr

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- Precipitation
- Reduction
- Stabilization
- Cyanide
- Bioremediation

Table current. tive n for each gory. will be section.

Prec treatment toxic h-wastew

EPA in treating a particular waste stream. Rather, in the judgement of the author, the processes listed are to have potential for use to treat the subject waste. Regulatory and permitting requirements for installation and operation of the technologies presented may vary among local, state and federal authorities.

approximately 75 percent of the electroplating facilities treating aqueous metal bearing wastes. The bulk of electroplating wastewater treatment sludges are usually in the form of metal hydroxides.⁴ Precipitation techniques currently being practiced on spent process waters include hydroxide, lime and/or sulfide treatment.

tween 9.5 and 12.⁶ Some of the hazardous wastes currently being treated by lime precipitation include corrosives (D002), metal finishing wastewaters and sludges (F006-12) after cyanide destruction, spent pickle liquor from steel finishing operations (K062) and leachates from secondary lead smelting (K100).⁷

Disadvantages encountered when employing lime precipitation are: limitation of metals removal due to solubility constraints of the metal hydroxides for variable wastewater matrices; interferences associated with complexing agents, e.g., cyanide, ethylenediaminetetraacetic acid (EDTA) etc., and difficulty encountered when stabilizing metal hydroxide sludges.

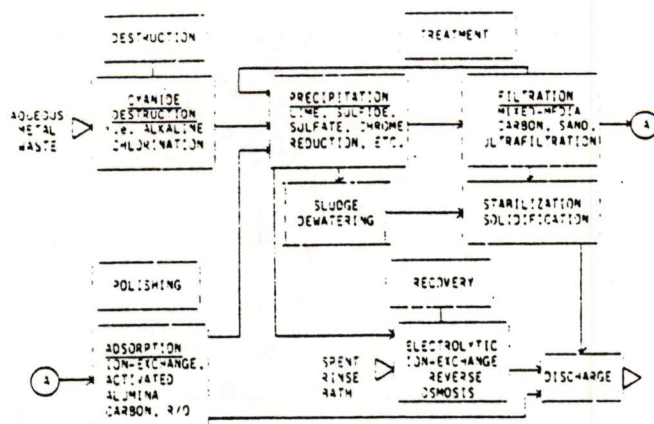


Figure 1. A general treatment approach for aqueous metal/cyanide bearing waste streams.

Waste Treatment Processes

Traditional approaches used to treat aqueous metal bearing wastes, other than land disposal, include:

- Precipitation: alkali, sulfide magnesium oxide
- Reduction: chromate, selenites, selenates and osmium tetroxide
- Stabilization/solidification
- Cyanide destruction
- Biological treatment

Table III shows treatment practices currently employed to treat representative metal bearing hazardous wastes for each major hazardous source category.² Cyanide treatment processes will be discussed separately in a later section.

Precipitation

Precipitation is the most preferred treatment process employed to remove toxic heavy metals from electroplating wastewaters. This method is used by

(1) *Lime Precipitation.* Lime precipitation is a well-established process, perhaps the most commonly used process for treatment of aqueous metal bearing wastes. Lime (in slurry or solution) or caustic soda is added to the waste as a source of hydroxide ion raising the pH to a suitable level for optimum precipitation of the metal hydroxides.⁵

The metal hydroxide precipitate forms a floc which is afterwards removed from the water by gravity settling or filtration. Effluents and residual wastewaters containing excess hydroxide may require neutralization before discharge. Sludges precipitated from treatment may require fixation or encapsulation to ensure post disposal non-leachability. Because the optimum pH for hydroxide precipitation is different for each metal ion, treatment of mixed-metal aqueous wastes may require some adjustment. However, this adjustment must stay within the limits of regulation. Typically, hydroxide precipitation is optimum at a pH be-

(2) *Magnesium Oxide Precipitation.* One precipitation agent which has shown promise for removal of heavy metal ions is magnesium oxide. To improve technology for treating process waters Schiller *et al.*, of the U.S. Bureau of Mines have shown in a research study that magnesium oxide (MgO) has many advantages over lime or caustic soda for precipitating metal hydroxides.⁸ Due to the MgO's propensity for insolubility, lower sludge volumes are produced as the hydroxide sludge becomes more compact. The MgO-metal hydroxide sludge also cements together upon standing, thus hindering resuspension of the metal ions. One factor contributing to this phenomenon is the positive surface charge on MgO complementing the negative surface charge on most heavy metal hydroxides. Hence, water is expelled from the spaces between the particles yielding a more condensed solid. Also, MgO-hydroxide sludge is more easily dewatered.

Although the cost of MgO is greater than the cost of lime, for aqueous wastes with lower dissolved metals concentrations, the savings in sludge handling may outweigh the precipitant costs. Results from treating a spent process water sample comparing final metal concentrations after MgO and lime addition are presented in Table IV.⁸

From three- to fourfold stoichiometric excess of MgO is required to reach adequate pH values which range from 8 to 9. Lower residual metals concentrations can be observed for both settled and filtered MgO addition as compared to lime addition.

(3) *Sulfide Precipitation.* Sulfide precipitation is a process that produces

HAZARDOUS WASTE MANAGEMENT

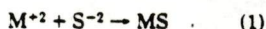
Table III. Alternative treatment processes for representative metal bearing wastes.^a

Hazardous waste	Source	Code	Waste treatment class				
			Precipitation	Reduction		Stabilization/solidification	
			Sulfide	Lime	Cr ^b	Selenite, selenate	
1. EP toxic (D)		D002	X	X	X		
		D004					X
		D005		X			X
		D006	X	X			X
		D007		X	X		X
		D008	X				X
		D009	X				X
		D010				X	
		D011	X				X
		F006	X	X	X		X
		F007	X				X
2. Nonspecific (F)		F008	X				X
		F009					
		F019			X		X
		K002-6			X		X
		K008		X	X		X
3. Specific industrial (K)		K021	X				X
		K044	X				X
		K046	X				X
		K059	X				X
		K061		X			X
		K062		X			X
		K071	X		X		X
		K086			X		X
		K100	X				X
		K106	X				X
		P013		X			X
		P087				X	
4. Toxic (U) and acutely hazardous (P) constituents, salts of:		U032			X		X
		U204				X	
	mercury		X				X
	lead		X				X
	thallium		X				X
	arsenic		X				X
	cadmium		X				X
	silver		X				X
	antimony		X				X
	vanadium		X				X

^a This table does not include cyanide treatment processes which will be presented in a later section.

^b Insoluble chromates with low solubilities require longer reaction times followed by subsequent treatment.

the precipitation of a metal ion as a metal sulfide (MS) through contact between a metal ion (M²⁺) and a sulfide ion (S²⁻):



Most heavy metals associated with electroplating wastes will form relatively stable metal ions. Exceptions to this rule include the trivalent chromic and ferric ions. The two processes currently employed to precipitate metals as sulfides are soluble sulfide precipitation (SSP) and insoluble sulfide precipitation (ISP).

SSP processes use water-soluble sulfide compounds, such as NaHS, which yield relatively higher concentrations

of dissolved sulfide than the ISP process. As a result rapid precipitation of dissolved metals occurs. This rapid precipitation reaction induces discrete particle settling rather than nucleation precipitation of a particle from solution onto an existing substrate. SSP

precipitation tends to result in a poor settling or filtering floc. However, this tendency can be reversed when additional coagulant and/or flocculant aids are used to enhance settling. Another disadvantage of the SSP process is that under certain pH conditions (pH <9), H₂S can evolve from dissolved sulfide ions. The rate of H₂S formation in a water solution is a direct function of pH and sulfide ion concentration. The H₂S creates an odor problem which can be mitigated by enclosing and venting process vessels.

The ISP process mixes the wastewater with a slurry of slightly soluble FeS which dissociates to satisfy its solubility product. This has the effect of controlling the level of dissolved sulfide at concentrations low enough to eliminate any detectable emission of H₂S. One advantage of the ISP process is the ability of combined sulfide and ferrous ions to reduce hexavalent chromium to its trivalent state. This eliminates the need to segregate and treat chromium wastes separately. A generalized treatment scheme for the ISP process is illustrated by Figure 2.⁹

There are numerous examples where specific applications of sulfide precipitation have been used to treat aqueous metal bearing hazardous wastes. One commercial facility used a two-stage precipitation process in which initial pH adjustment to 11 was followed by alum addition to pH 9.5 and final dosing with sodium bisulfite. Influent wastewaters (without chelating agents) contained up to 300 ppm Cd, 15,000 ppm Cr, 10,000 ppm Cu, 120,000 ppm Fe, 10,000 ppm Pb and 10,000 ppm Ni. After flocculation and clarification, the effluent met NPDES requirements for discharge to the municipal sewer.⁶

In another demonstration, the U.S. Army Belvoir R&D Center constructed and operated an SSP treatment system which was designed by JRB Associates. This SSP treatment system achieved a level of treatment comparable to that of lime precipitation coupled with filtration. Performance data are summarized in Table V.¹⁰

Sulfide precipitation of heavy metals

Table IV. Results from treating sample process water with MgO and lime.

Sample process water	pH	Chemical analysis, ppm							
		Fe	Cu	Zn	Ni	Mn	Co	Cd	Pd
Pretreatment	4.2	ND	8.7	ND	12.0	ND	11.1	ND	ND
0.4 g/l MgO, filtered	8.9	ND	<0.1	ND	<0.2	ND	<0.2	ND	ND
0.4 g/l MgO, filtered	8.9	ND	0.5	ND	0.2	ND	0.2	ND	ND
0.1 g/l lime, settled	9.4	ND	0.7	ND	1.2	ND	1.6	ND	ND

Figure 2

Figure 2

can be influencing agents, although not precipitation. precipitation. high degree retention time for due to the sludge thick at pH 5 com sludge.¹²

Chemical acceptance is complexed metal hexavalent lead, silver and mercury most effective wastes are compound reduced by dioxide and reducing borohydride shown in moving lead salts facturing

(1) Chromate

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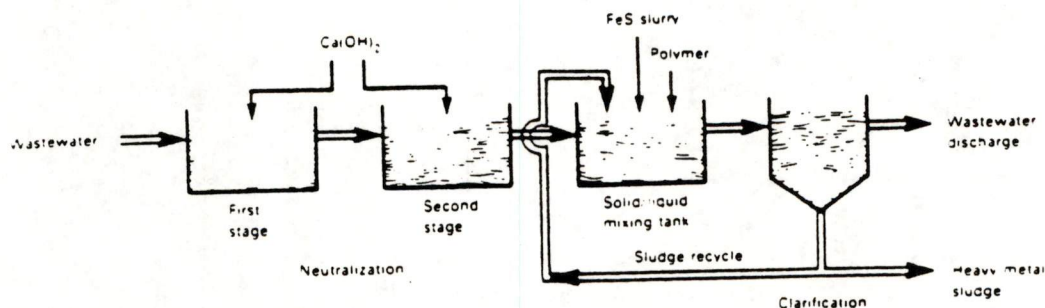


Figure 2. Insoluble sulfide process.

can be influenced adversely by chelat-
ing agents, such as EDTA, citrate, etc.,
however not as much as with hydroxide
precipitation.¹¹ Advantages of sulfide
precipitation include attainment of a
high degree of metal removal; low de-
tention time requirements in the reac-
tor due to the high reactivities of sul-
fide; selective metal recovery; better
sludge thickening and less leachability
at pH 5 compared with the hydroxide
sludge.¹²

chromium may be reduced from a va-
lence state of (+6) to the less toxic tri-
valent chromium salts (+3). Some of
the RCRA wastes which have been
treated by chromate reduction are list-
ed in Table VI.²

Several aqueous based processes
which are commercially practiced are
listed below:²

1. *Hydrosulfide reduction.* A sulfide
ion is added to the chromate waste

2. *Sulfur dioxide reduction.* Gaseous
sulfur dioxide is added under pres-
sure to the chromate containing so-
lution, whereby the pH is lowered to
an acidic level. Chromic hydroxide
is precipitated after alkali addition
and filtered.

3. *Ferrous ion precipitation.* Waste
pickle liquor is frequently used to
initiate a rapid reaction with ferrous
ions under acidic conditions. Chro-
mic hydroxide is formed with iron
hydroxides and is precipitated un-
der alkaline conditions. The resul-
tant precipitate is filtered for re-
moval.

Wastewaters generated by the above
three treatment processes will require
secondary treatment to remove sul-
fides and/or sulfites.

Chemical reduction is very efficient,
with ≥ 90 percent reduction achieved
in only 1-2 hours for continuous pro-
cesses. However, it is limited to treat-
ing only aqueous wastes due to the ease
of surface contact between reducing
agent and hazardous constituent.
Treatment of slurries, tars and sludges
is more difficult due to reduced surface
contact. Another limitation of the re-
duction process is the interference en-

Table V. Soluble sulfide treatment system performance.

Compound	Average concentration		Metals limits (30 day average) (mg/L)
	Influent (mg/L)	Effluent (mg/L)	
Cd	2.06	0.10	0.26
Cr	2.61	0.32	1.71
Cu	1.82	0.04	2.07
Pb	1.04	0.19	0.43
Ni	3.50	0.07	2.38
Zn	5.8	0.41	1.48

Reduction

Chemical reduction has gained ac-
ceptance in industry for reducing com-
plexed metals, such as nickel, copper,
hexavalent chromium waste, soluble
lead, silver, metal-containing cyanide
and mercury. Chemical reduction is
most effective when the aqueous metal
wastes are relatively devoid of organic
compounds. Chromium is usually re-
duced by sodium sulfite salts, sulfur
dioxide and sulfuric acid. Iron, alumi-
num and zinc have shown potential for
reducing chromium wastes. Sodium
borohydride (NaBH₄) has recently
shown promise for reducing and re-
moving soluble lead, including organo-
lead salts, from tetra-alkyl lead manu-
facturing wastes.⁶

with pH adjustment to 7. After al-
lowing a few hours for reaction the
pH is adjusted to the alkaline side
where chromic hydroxide is precipi-
tated and filtered.

Table VI. Hazardous wastes treated by chromate reduction.

Waste code		Description
Soluble	U032	Calcium chromate
	D007	Chromium (hexavalent with chromic acid)
	F019	Sludges from chemical conversion coatings
Insoluble	K002	Production sludges from: chrome yellow
	K003	molybdate orange
	K004	zinc yellow
	K005	chrome green oxide
	K006	chrome green oxide
	K008	Oven residues from chrome green oxide
	K086	Pigments and inks
	F006	Insoluble chromates

(1) *Chromium Reduction.* Hexavalent

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Table VII. Summary of treatment levels reported for hexavalent chromium wastes.

Treatment process	Chromium (VI) concentration (mg/L)	
	Initial	Final
Reduction		
Sulfur dioxide	1300	"zero"
Sulfur dioxide	0.23-1.5	0.1
Bisulfite	140	0.7-1.0
Bisulfite plus hydrazine	8-20.5	0.1
Metabisulfite	70	0.5
Ion exchange	8-10.7	0.0-0.9
Cementation	16.3	0.09
Activated carbon*	0.09-0.19	0.017 (ave.)
Activated carbon*	5.0	0.006-0.087
Activated carbon*	100-820	5.05-195
Freeze concentration*	100	0.225

* Pilot plant results.

countered with organic compounds and complexes, causing a decrease in reduction efficiency with a potential for H₂S emission. Furthermore, a large volume of metal hydroxide sludge can be generated.⁶

A two-stage chromate reduction process has been employed for treating chromium plating rinsewater at several waste treatment facilities. In the first stage either sulfur dioxide, sodium bisulfite or metabisulfite are added as reducing agents. In the second "polishing" stage, hydrazine combined with soda-ash is added to precipitate chromic hydroxide. Chromate concentration in the influent ranging from 8 to 20.5 mg/L, was reduced to less than 0.1 mg/L in the effluent.¹³

One study claimed to have successfully reduced chromate by combining two hazardous wastes, chromate and waste pickle liquor, to reduce chromate in the presence of ferrous sulfate. This chemical agent has the purported advantage of being effective, independent of pH.¹⁴

Several recovery processes have been utilized to recover chromium as a reusable resource. Ion exchange, electrochemical reduction, evaporative recovery, activated carbon and reverse osmosis have all been reported to have some application for hexavalent chromium treatment. Table VII summarizes treatment levels based upon pilot plant results for treating hexavalent chromium wastes.¹³

(2) *Other Reduction Processes.* Reduction of selenites, selenates and osmium tetroxide typically involves reaction with sulfur dioxide. It is reported that selenium precipitates can be recovered. This process was used to remove selenium from copper smelter process wastes. However, this process

was only used to recover elemental selenium and was not used for waste treatment. Few established processes have been reported for treatment of osmium tetroxide wastes (RCRA P087). Since osmium tetroxide is an oxidizing agent it has the potential to be reduced by reducing agents such as sulfites.²

Stabilization/Solidification

The basis upon which stabilization/solidification (S/S) processes are used is to limit the mobility of pollutants to the groundwater, making land disposal a viable treatment option. Materials are mixed with wastes to chemically

The process is generally used to treat concentrated waste solids, sludges, slurries and liquid wastewaters.

Malone *et al.*, of USAE Waterways Experiment Station have conducted many studies concerning the application of and factors affecting S/S technology. One study was explicitly devoted to electroplating wastes (RCRA F006-F009).¹⁶ Since the chemical characteristics of electroplating sludges are highly variable, some exhibit varying mixtures of fine grained metal hydroxides, organic chelating agents and salts from materials added for neutralization purposes. These amorphous metal hydroxides of cadmium, chromium, copper, lead, nickel and zinc can become significant pollutants if improper disposal techniques are utilized.

There are two types of S/S agents employed: organic and inorganic additives. Some organic agents presently used are chemical grouts, (e.g. cement) thermoplastic agents (e.g. bitumen, asphalt, paraffin and high temperature polyethylene), organic polymers (e.g. urea-formaldehyde, polyester resins and polyvinyl chloride) and glassification agents (e.g. molten glass). Common inorganic materials used for S/S processes include cement, lime and pozzolan-based agents combined with a mixed kiln dust, soluble silicates, fly ash, blast furnace slag and flue gas sludge. Organic processes are expensive and have limited applications.

Table VIII. Concentrations of cyanide in plating wastewaters.

Process	Range (mg/L)
Plating rinse	1.4-256 (56 avg)
Bright dip	15-20
General (separate cyanide)	9-115 (72 avg)
General (combined stream)	1-103 (28 avg)
Alkaline cleaning bath	4,000-8,000
Plating bath	45,000-100,000
Plating bath	
Brass	16,000-48,000
Bronze	40,000-50,000
Cadmium	20,000-67,000
Copper	15,000-52,000
Silver	12,000-80,000
Tin-zinc	40,000-50,000
Zinc	4,000-64,000

and physically immobilize wastes. S/S processes have two different goals. Stabilization functions to reduce the solubility and/or chemical reactivity of a waste, while solidification processes convert the waste into a fixed, easily transported solid with reduced hazard from leaching into the environment.¹⁵

while inorganic processes tend to be less expensive with wider application. However, the inorganic S/S processes are limited by the organic content of the waste.⁶

Some S/S applications lead to the development of chemically stable insoluble silicates which are specific for

the metal of low-temperature encapsulation and no trices. Typical hydroxides

1. Macro: polymer jacketed lent con
2. Micro: organic able for acidific
3. Therm which tail
4. Poi capsule ment p

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1. Lime tion

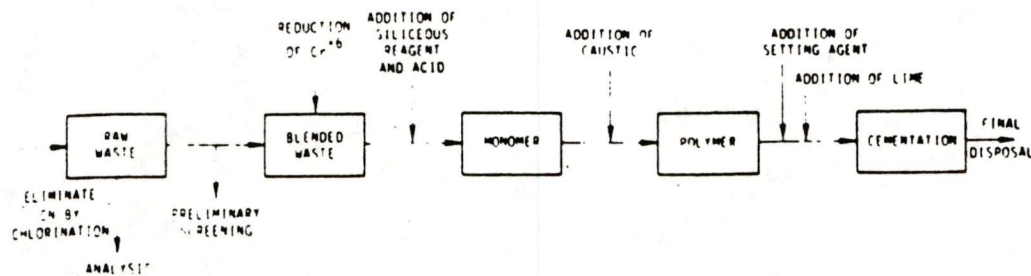


Figure 3. Soliroc process flow diagram.

the metal of interest. Gel-like systems of low-temperature silicate polymers encapsulate the metals in both crystalline and non-crystalline polymeric matrices. Typical encapsulates of metal hydroxides are:

1. Macroencapsulates produced from polymer-bonded and polyethylene jacketed wastes which exhibit excellent containment properties;
2. Microencapsulates produced from organic polymers that are not suitable for electroplating wastes under acidification procedures;
3. Thermoplastic microencapsulates which have shown excellent containment characteristics; and
4. Portland-pozzolan and pozzolan encapsulates exhibiting poor containment properties.

Several studies have shown promising results in stabilizing and solidifying electroplating wastes. One engineering study conducted by Rousseaux and Craig evaluated the "soliroc fixation process" for immobilizing industrial metal wastes.¹⁷ Results indicated that the soliroc process substantially immobilized the metal constituents of sulfuric acid pickle liquor (RCRA K062). Furthermore, the addition of Portland cement in the cementation step improved the structural stability of the hardened material. Figure 3 represents a flow diagram of the process. Compressive strength conducted in this study indicated that the addition of Portland cement in the cementation step improved the stability of the solidified waste.¹⁷

The U.S. Army Engineer Waterways Experiment Station funded by the EPA has conducted extensive studies on fixation and encapsulation techniques for a variety of industrial wastes including electroplating wastes. Some of the significant findings resulting from these studies have shown that:

1. Lime-fly ash pozzolanic solidification produced a solid soil/cement-

like product with good structural integrity but exhibited significant leaching problems;

2. Cement/soluble-silicate techniques produced a semifrable material with soil-like consistency containing 60-70 percent of the metal constituent prevalent in the untreated sludge;
3. Urea-formaldehyde polymerization monomers applied to electroplating waste and paint production sludges failed to contain leaching of the toxic metal constituents; and
4. Encapsulation systems (especially macro-) proved to be the most effective in containing toxic pollutants from electroplating wastes.

Apparent disadvantages encountered with encapsulation techniques are that they tend to be costly and limited to certain waste categories. It is important to note that S/S processes are generally applied to wastewater sludges which cannot be further treated by another means prior to disposal.^{18,19}

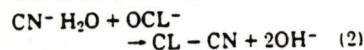
Cyanide Destruction

One of the major sources of generated cyanide waste is the electroplating industry. Cyanide baths are used to hold metallic ions such as zinc and cadmium in solution. When the "drag-out" of plating solution containing cyanide ions contaminates rinsing baths, a wastewater is generated for treatment. Table VIII lists concentrations of cyanide for representative plating wastewaters.¹³

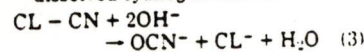
Cyanide appears in waste residuals in two forms: as an "ionizable cyanide" in the form of sodium cyanide (NaCN) and hydrocyanic acid (HCN) or as a complex with heavy metals, e.g. ferrocyanide, nickel cyanide or copper cyanide. Other cyanide species come in the form of inorganic compounds such as thiocyanates and cyanates which are

easily removed from waste streams by using an assortment of treatment processes. Various methods for treating cyanide wastes have been employed, with cyanide destruction via alkaline chlorination being used most frequently. Unit processes reported to successfully treat cyanide and cyanide complexes include incineration, alkaline hydrolysis of cyanohalides, pyrolysis of copper cyanide, peroxide oxidation (Kastone®) and iron cyanide pyrolysis.² Although natural degradation including volatilization, oxidation biodegradation and photo decomposition will reduce cyanide concentrations in aqueous wastes given enough time, a recent study has reported successes with ozonation, ion-exchange, activated carbon, reverse osmosis, electro dialysis, electrolytic hydrolysis and titanium oxide/UV.²⁰

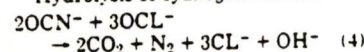
(1) *Alkaline Chlorination.* As the most prominent, widely used treatment option employed to date, alkaline chlorination may be accomplished by direct addition of sodium hypochlorite or by addition of chlorine gas with sodium hydroxide. This process cannot effectively treat simple or complex copper cyanides, zinc cyanide and iron cyanides due to their low solubilities. Hypochlorite, perhaps the most widely used oxidizing agent, reacts with cyanide in the following manner:



Conversion of CN^- to dissolved cyanogen chloride



Hydrolysis of cyanogen chloride



Conversion to CO_2 and chlorine

If thiocyanates are present the demand for chlorine is preferential, therefore, requiring more oxidant.

The following cyanide bearing

HAZARDOUS WASTE MANAGEMENT

Table IX. Treatment levels for cyanide wastewaters.

Treatment process	Cyanide concentration (mg/L)		Percent removal
	Initial	Final	
Alkaline chlorination ^a		1.7	
Alkaline chlorination ^a		0.1	
Alkaline chlorination ^b		0.4	
Alkaline chlorination ^b	700	0.0	100
Alkaline chlorination ^c	32.5	0.0	100
Alkaline chlorination ^c	5.1	0.1	98
Ferro-ferrocyanide precipitation		5-10	
Electrolysis	45,000-100,000	0.1-0.5	99.99+
Electrolysis	20	0.5	97.5
Ozonation	25	0	100
Kastone process	350-400	0.3	99.9+

^a Single-stage chlorination.

^b Two-stage chlorination.

^c High pH-high temperature process.

wastes are amenable to alkaline chlorination:

RCRA Waste

Code	Waste
P106	Sodium cyanide
P098	Potassium cyanide
P021	Calcium cyanide
P013	Barium cyanide (the treated waste requires subsequent treatment by the sulfate precipitation process)
P083	Hydrogen cyanide (in aqueous solution)
P074	Nickel cyanide
P099	Potassium silver cyanide (sludges generated may be reprocessed to recover silver)
P104	Silver cyanide (sludges generated are reprocessed for silver recovery)
K060	Lime sludge from coking operations
F006-12	Cyanide bearing plating solutions and sludges (some treated sludges may be reprocessed to recovery metals; sludges of no value may require subsequent treatment by the encapsulation process)
P030	Miscellaneous cyanides

(2) Incineration. Incineration has been used to destroy gaseous hydrogen cyanide, gaseous cyanogen, organonitriles and organic isocyanates at elevated temperatures. Several types of incinerators such as liquid injection, rotary kiln and fluidized bed are capable

of treating these wastes. Isocyanates are converted to CO₂, N₂, and H₂O leaving little if any toxic residuals. The following cyanide wastes may be treated by incineration.²

RCRA Waste

Code	Waste
P083	Hydrogen cyanide (as gas)
U003	Acetonitrile
U152	Methyl acrylonitrile
U149	Propane nitrile
U009	Acrylonitrile
P101	Propionitrile
P064	Methyl isocyanate
P069	2-Methylacetone nitrile
P027	3-Chloropropanenitrile
P069	2-Hydroxy-2-methylpropanenitrile
P031	Cyanogen
K011-14	Waste streams for acrylonitrile and acetonitrile production
K087	Tar sludges from coking operations

Table X. Summary of observed metals removals.

Metal	Influent (mg/L)	Primary effluent (mg/L)	Removal by pri. clar. (percent)	Activated sludge effluent (mg/L)	Removal by activated sludge (percent)	Total removal (percent)
Ag	8.0	9.0	0.0	5.0	44.0	37.5
As ^a	20.6	16.0	22.3	16.7	0.0	18.9
Ca	86.0	81.0	5.8	81.0	0.0	5.8
Cd ^a	20.9	17.0	18.7	7.9	53.5	62.2
Cr	0.63	0.51	19.0	0.34	33.3	46.0
Cu	0.80	0.57	28.8	0.16	71.9	80.0
Fe	4.29	2.44	43.1	1.01	58.6	76.5
Hg ^a	2.0	2.0	0.0	2.0	0.0	0.0
Mg	17.6	28.0	0.0	17.9	0.0	0.0
Mn	0.65	0.55	15.4	0.40	27.3	38.5
Ni	0.45	0.27	40.0	0.18	33.3	60.0
Pb	0.88	0.58	34.1	0.11	81.0	87.5
Zn	1.24	1.28	0.0	0.46	64.1	62.9

^a Micrograms/liter.

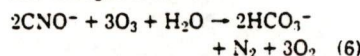
U223 Toluene diisocyanate

(3) Other Cyanide Processes. Since iron cyanides, such as ferric cyanide (RCRA P055), chrome green (RCRA K005), iron blue (RCRA K007) and paint/ink formulation sludges (RCRA K086) are not easily treated by chlorination processes due to the stability of the iron ion, decomposition of the complex to yield free cyanide ions is a prerequisite. Ultraviolet (UV) radiation has been reported to be effective in converting complex cyanides to cyanate.²⁰

Ozonation has been demonstrated to show potential for treating relatively dilute cyanide wastes, e.g., rinse water plating wastes or "carryover" from electrolytic decomposition.¹³ The free cyanide reaction with ozone can be represented as:



with the reaction proceeding rapidly. Conversion of cyanate to bicarbonate and nitrogen is slower:



Thiocyanate reacts rapidly with ozone, hence requiring a much greater demand for ozone to complete the reaction. Ultraviolet light can be used in conjunction with ozone to treat wastes generated from electroplating and color photographic processes. One of the disadvantages of using ozone and/or ozone/UV treatment is the high energy consumption.²⁰

The Kastone[®] process purportedly removes free cyanide from wastewaters generated by an electroplating industry. Free cyanide is converted to a mixture of ammonia, sodium cyanate and

Table XI. In:

Metal (no. observation)
Zinc
Cadmium
Copper

^a S.D.—standard

glycolic acid formaldehyde, mulation coride, stabilizthough free resultant inc sediments we water treatr tage of the p dehyde, a su Although carbon, reve alysis have t treatment o: wastes, thes removal nide. Th another sec and recover treatment l ters is prese

Although wastes con has tradit: POTWs tre taining low ions, recent treat highe wastes, suc arsenic. M convert me als into les Hg⁺).

In a stud EPA's Te Cincinnati system wa tration me als were c ances esta al ions i Results a The avera based upx was 42 pe

Table XI. Influence of heavy metals on cyanide biodegradation.*

Metal (no. of observations)		Metal conc. (mg/L)		Cyanide as CN, mg/l	
		Influent	Effluent mean (S.D.)	Influent mean (S.D.)	Effluent mean (S.D.)
Zinc	(8)	10	0.07 (N.C.)	98.6 (6.63)	0.20 (0.01)
	(8)	25	0.04 (N.C.)	97.4 (2.67)	0.18 (0.01)
	(8)	50	0.12 (0.19)	98.2 (6.96)	0.19 (0.02)
Cadmium	(9)	5	0.13 (0.02)	95.6 (3.50)	0.17 (0.02)
	(5)	10	0.60 (0.50)	97.4 (7.00)	0.18 (0.02)
	(5)	20	0.56 (0.09)	100.0 (0.76)	0.18 (0.01)
Copper	(7)	5	4.06 (1.28)	96.7 (2.45)	2.00 (0.40)
	(6)	10	8.50 (0.56)	96.1 (2.00)	16.20 (3.60)
	(6)	20	17.60 (1.00)	97.0 (1.00)	28.50 (2.00)

* S.D.—standard deviation; N.C.—not calculated.

glycolic acid amide in the presence of formaldehyde and a proprietary formulation containing hydrogen, peroxide, stabilizers and flocculants. Although free cyanides are destroyed, a resultant increase in BOD/COD and sediments would require further wastewater treatment. Another disadvantage of the process is the use of formaldehyde, a suspected carcinogen.²¹

Although ion exchange, activated carbon, reverse osmosis and electrodialysis have been mentioned as feasible treatment options for treating cyanide wastes, these processes are directed at removal, not destruction of the cyanide. These processes will be covered in another section addressing reduction and recovery techniques. A summary of treatment levels for typical wastewaters is presented in Table IX.¹³

Biological Treatment

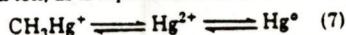
Although biological treatment of wastes containing metal constituents has traditionally been reserved for POTWs treating municipal wastes containing low concentrations of metal ions, recent studies have attempted to treat higher strength aqueous metal wastes, such as cyanide, mercury, and arsenic. Microbes may be utilized to convert more toxic forms of heavy metals into less toxic forms (e.g., $Hg^{2+} \rightarrow Hg^0$).^{22,23}

In a study conducted by Petrusek, at EPA's Test and Evaluation Facility, Cincinnati, Ohio, an activated sludge system was monitored for low concentration metals removal. Metals removals were computed and material balances established for 13 prevalent metal ions in a municipal wastewater. Results are presented in Table X.²⁴ The average removal of the 13 metals, based upon mass balance calculations was 42 percent. The best removal effi-

ciency of all 13 metal ions monitored was exhibited by Pb with 87.5 percent removal.

Data on the biological treatment of higher strength metal wastes are more limited. It has been documented by Silver and Misra²² that certain bacteria can carry out chemical transformations of heavy metals. Transformations can occur via intra- and extracellular metabolism of the various elements. These transformations include oxidation, reduction, methylation and demethylation of certain metal ions. However, these transformations are sometimes byproducts of normal metabolism with. These transformations can constitute a mechanism for resistance which are often determined by plasmids.

The mercury cycle represents the best known example of how microbes metabolize the chemical form of a metal ion; as is represented below:



The enzymatic mechanism responsible for mercurial detoxification volatilizes the mercury as metallic Hg^0 by an enzyme called mercuric reductase (R100). Although work has been done on other select material (e.g. silver, cadmium, and zinc) little is known for other toxic

metals. However, there is some preliminary evidence that certain microbes can be fooled into accumulating toxic metals.²²

Another study on the biological treatment of an industrial wastewater containing toxic cyanide was conducted by Shivaraman and Parhad.²⁵ Although alkaline chlorination is the preferred method for cyanide destruction, biological treatment systems have shown some cost advantages in treating cyanide and cyanide-complexed wastewaters. It has been demonstrated that "simple" cyanide can be degraded by activated sludge systems and trickling filters when these systems have been acclimated prior to full loading. Moreover, zinc and cadmium cyanide complexes were shown to be degraded via acclimated trickling filters. Results are shown in Table XI. As evidenced, good removal efficiencies were observed for Zn, Cd and their respective cyanide complexes; however, Cu exhibited poor treatability.

Waste Reduction and Recovery

Interest in establishing centralized treatment and recovery systems for treating heavy metal wastes in large metropolitan areas has spurred many studies to demonstrate waste reduction and recovery technologies. With the high cost of raw materials and pending land disposal restrictions (HSWA), reclamation of raw materials from waste streams can be the treatment option of choice. EPA studies indicate that a large part of the operational costs would be subsidized by the sale of the recovered metals.²⁶ An estimate of metal values lost in 1980 is presented in Table XII. Using the same amount of metals discarded and adjusting for inflation, the 1985 estimate would increase to \$58 million.²⁷

Economic feasibility of metals recovery operations are primarily dependent upon three factors:

Table XII. Annual loss of minerals in electroplating wastes.

Mineral	Amount (metric tons)	Value/ton	Total value
Iron	3,460	\$ 77	\$ 266,420
Copper	2,560	791	2,024,960
Zinc	3,718	748	2,781,064
Nickel	5,000	4,000	20,000,000
Aluminum	1,651	1,060	1,750,060
Chromium	6,357	2,000	12,714,000
Lead	756	462	349,272
Total	23,502		\$39,885,776

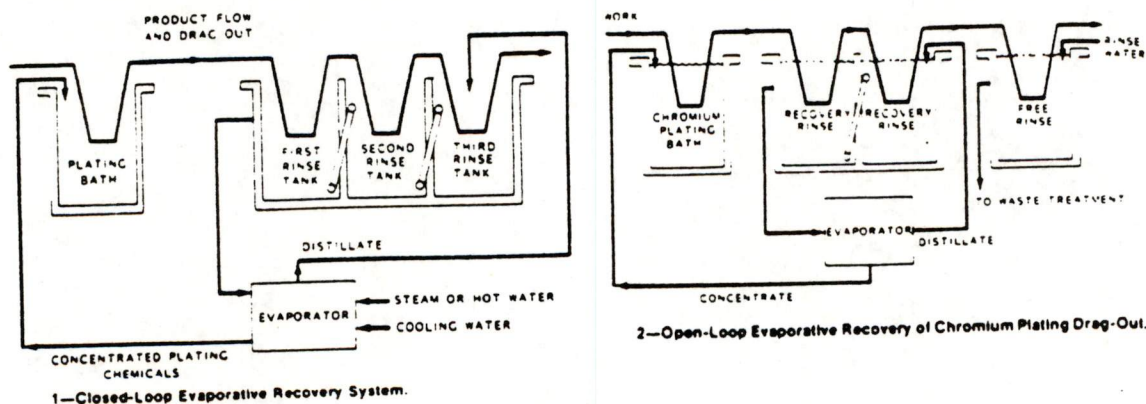


Figure 4. Evaporative recovery systems.

1. Metal type and concentration;
2. Availability of material quantity within close proximity; and
3. Economical (profitable) recovery process.

Justification for recovery processes is not exclusive to raw material savings. Reduced operating costs for "end-of-pipe" pollution control can be a significant factor. Four reduction and recovery processes will be discussed here: evaporation processes, ion-exchange systems, membrane technology, and electrolytic deposition.

Evaporation

Evaporators have traditionally been used to concentrate rinse water and recycle "drag-out" back to the plating bath. This in-plant separation process represents a sound waste minimization practice. Figure 4 illustrates two types of systems which have been employed: 1) a closed-loop system, which totally eliminates a water discharge from the plating process and requires substantial make-up water to satisfy rinsing requirements and 2) an open-loop system with lower operating costs as a result of less make-up water. However, with the open-loop system a wastewater discharge is generated.

Ion Exchange

Ion exchange (I/E) and resin adsorption systems offer a versatile separation process with wide application to the metal finishing industry. I/E has all the advantages of evaporative processes for recovery. In addition, it can serve as a polishing step after conventional wastewater treatment and purification

of liquids (acids, bases, water, etc.). By definition, I/E is a separation technology which removes various ionic species from solution via interchanging reversible ions between the solution (aqueous waste) and the exchanger (e.g. resin). The I/E process can be manifested as a resin system, membrane selection process (Donnan Dialysis) or a liquid-liquid extraction procedure. Exchangers may be comprised of synthetic resins, insoluble salts, molecular sieves or even liquid membranes. Liquid ion exchange, where organic polar molecules are added to complexed metal ions, appears to have some promise.²⁸

Many applications for ion-exchange systems have been demonstrated. The development of reciprocating flow and countercurrent exchange systems have enhanced the potential application of I/E for plating "drag-out" recovery by 1) providing reduced equipment cost (due to small resin volumes), 2) automatic regeneration of resin, and 3) their compact size. These systems are currently being used for drag-out recovery from chromium, copper and nickel plating rinses, purification of spent process acids (e.g. chromic acid) and mixed wastewater deionization. Figure 5 shows a schematic of an I/E system utilized for polishing following conventional treatment.

Several studies have been conducted to demonstrate specific application of various resins for treating synthetic and industrial aqueous metal wastewaters. Tare *et al.*²⁹ described the kinetics for metal ion removal by chelating I/E resins. The presence of strongly complexing organics (such as citrate, EDTA, and tartrate) and inorganic ligands (CL, F, PO₄, etc.) in dilute metals waste make chemical separation

processes (i.e. precipitation) not feasible. Chelating I/E resins offer an alternative to treating these complexed wastes. Results of this study have shown that rates of metal uptake were strongly influenced by solution pH and waste aging, especially for Cr (III) and Pb. Desorption from contacted resins was easily achieved by using hydrochloric acid.

In another study, Maeda³⁰ investigated the influence of porosity for several macroreticular chelating resins (RST) containing triethylene-tetramine with different porosities. Results indicated that large pore radius RSTs proved to be more practical for removal and recovery of heavy metal ions from an industrial metal bearing waste.

Liquid ion exchange is a relatively new process which combines the concepts of I/E and liquid-liquid extraction for the recovery of metal ions from wastes.³¹ This application has shown promise for treating the more dilute metal wastewaters. Like resin systems, the actual exchange takes place when the solution of metal ions, upon contact with the extractant, produces an unstable liquid-liquid dispersion. The process occurs via a three-step mechanism:

1. The complexed metal ion diffuses to the aqueous/organic interface;
2. The ion is stripped of its hydration layer and complexes with the extractant at the interface; and
3. The organic/metal complex diffuses into the bulk organic phase where, simultaneously, hydrogen ions are transferred to the aqueous phase.

Thereafter, the stripping solution (extractant) is regenerated.

Additional research is needed to further develop I/E processes. Potential areas include: the development of bet-

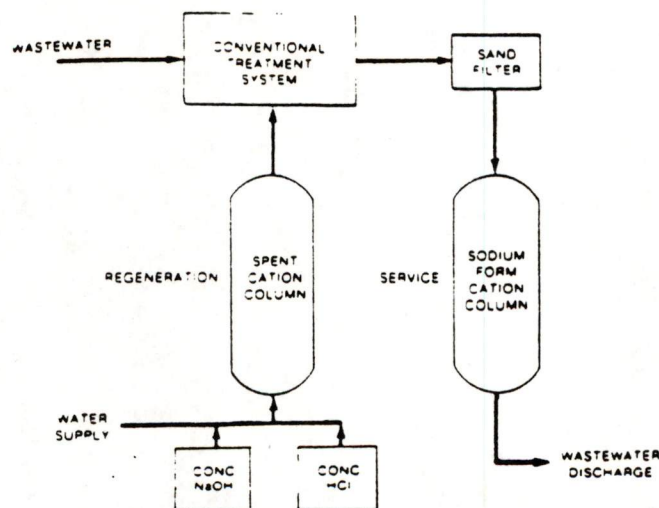
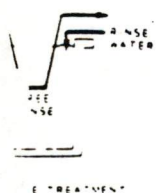


Figure 5. Ion exchange polishing after conventional treatment.

ter ion-exchange materials which do not foul as easily, investigation of the transport of ionic species through a dielectric medium, improvement of counter current processes, and further development of liquid I/E systems.

Membrane Processes

Membrane processes typically used to treat aqueous metal wastes are reverse osmosis (RO) and electrodialysis. RO is a pressure driven membrane process where water molecules are forced through the microscopic pores of a semi-permeable membrane. The production rate of an RO membrane is a function of dissolved solids concentration, temperature, pressure, pH and chemistry of the solution to be treated. No commercially available membrane polymer has demonstrated tolerance to all extreme chemical factors, such as pH, strong oxidizing agents, and aromatic hydrocarbons.

A study by Crampton²⁶ successfully demonstrated the use of a cellulose acetate membrane to concentrate the drag-out from plating solutions. Both the concentrate and purified water are recycled. However, this type of membrane is pH sensitive and is primarily used to treat Watt's nickel plating baths. Other drag-out recovery applications successfully treated copper, zinc and chromic acid baths.

Cartwright defines various membrane types and their applications.³² Some applications of RO membranes to various waste streams are listed below:

- Nickel—cellulose acetate
- Copper sulfate—hollow-film polyamide, cellulose triacetate and spiral-wound-thin film composite
- Zinc sulfate—spiral-wound-thin film composite
- Brass cyanide—polyamide cellulose, triacetate hollow fiber
- Copper cyanide—polyamide hollow fiber
- Chromium (VI)—spiral-wound-thin film composite
- Other—thin film composite (TFC)

Table XIII presents RO test data for six common plating bath rinses.³²

Potential problems with RO systems stem from membrane fouling due to suspended precipitated solids coating the membrane surface, precipitation of salts in the concentrate, membrane deterioration due to chemical attack and, for higher strength wastes, high levels of dissolved solids in the permeate.

Table XIII. RO test data for six common plating bath rinses.

Plating bath	Bath temperature °C/°F	Toxic contaminant	Percent rejection
Watts Ni	60/140	Ni ²⁺	99+
Copper cyanide	60/140	Cu ⁺	85
		CN ⁻	46
Zinc cyanide	27/80	ZN ²⁺	96
		CN ⁻	80
Brass cyanide	27/80	ZN ²⁺	98
		Cu ⁺	97
		CN ⁻	
Decorative Cr	43/110	Cr ⁶⁺	90
Hard Cr	55/130	Cr ⁶⁺	92

In electrodialysis systems an electrical potential is applied across the membranes to provide the driving force for ion passage through the membranes. Membranes used in this process are "thin sheets" of the same polymeric network used to make I/E resins. Unlike RO systems, these membranes are tolerant of most chemical environments. Another variance exhibited by electrodialysis over RO systems is the propensity to separate water from the salt by selective removal of the salt, rather than concentrating the salt from solution.

Electrolytic Recovery

Electrolytic recovery is one of the many technologies utilized to remove and concentrate metals from process waste streams. This process uses electricity to pass a current through an aqueous metal bearing solution between a cathode plate and an insoluble anode. Positively charged metallic ions cling to the negatively charged cathodes leaving behind a metal deposit which is strippable and recoverable. Initially used to recover gold and silver, its use in recovering less precious metals has been limited. However, new interest has been given to this promising recovery technology.

Walters and Vilagliana of the University of Maryland have demonstrated the electrolytic recovery of zinc from metal finishing rinse waters.³³ The deposition of copper ions after contacting diluted aqueous metals solution onto a packed graphite bed was studied. Results of the study indicated that zinc recovery from plating bath rinse waters, which consisted of a dilute zinc cyanide solution, was achievable. A batch electrochemical reactor with stainless steel electrodes was employed. The controlling factor in achieving high rates of zinc deposition appeared to be agitation. The study

cited that mechanical mixing and nitrogen gas aeration were both effective. NaCl was added to maintain a minimal conductivity level. Higher current densities elicited higher deposition rates as opposed to lower current densities. One noticeable disadvantage was that corrosion could play a significant limiting factor. Electrodes would have to be replaced frequently.

Summary

A review of applicable technologies for any given time tends to be a mere "snapshot" of the advances and development of treatment options that enable industry to keep pace with economic realities and legislative requirements. Although this review only scratches the surface of available technologies for metals treatment application, numerous innovative approaches deserve evaluation. Many options have been presented with specific application to hazardous waste treatment of metal bearing process residuals. With proper application, most processes discussed here can lead to responsible hazardous waste management.

Notice. This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names of commercial products does not constitute endorsement or recommendation for use.

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D. W. Grosse is with the Thermal Destruction Branch, Alternative Technologies Division, Hazardous Waste Engineering Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, OH 45268. Submitted for peer review February 28, 1986, the final manuscript was received March 31, 1986.

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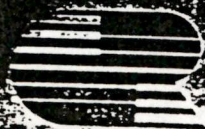
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January 1991

GALSON REMEDIATION CORPORATION

Company History and Process Description



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potassium hydroxide in a solution of mixed polyethylene glycol and dimethyl sulfoxide. The reagent mixture dehalogenates the aryl halide contaminant to form a glycol ether, which may further degrade to form a totally dechlorinated species. Tests done using PCBs in transformer oil show some 98 percent conversion of organic chlorine to inorganic chloride. This mechanism is shown below in Figure 1.

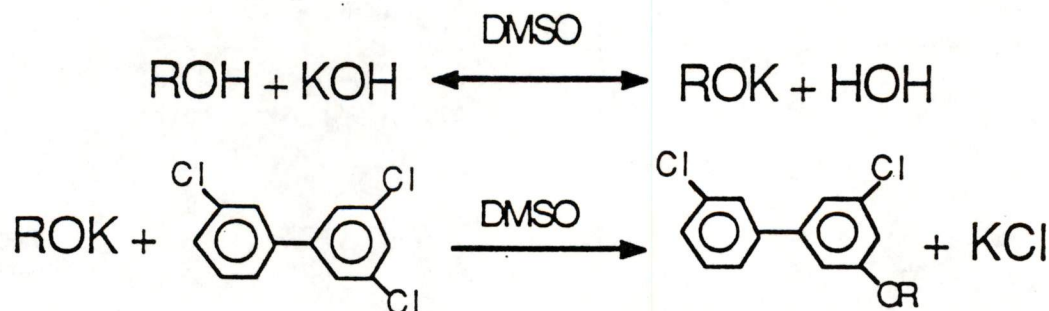


Figure 1 - Reaction Mechanism for Galson Dechlorination Treatment System

TOXICITY - BEFORE AND AFTER TREATMENT

Dimethyl sulfoxide and polyethylene glycol, reagents used in the GRC process, are essentially non-toxic materials, with LD50s less toxic than that of table salt. (LD50 is the average lethal dose that, when administered to test species, kills half of them.) The addition of the non-toxic glycol to the aromatic PCB or dioxin ring introduces an electron-donating substituent to the ring, producing a water-soluble, low-toxicity material. Toxicity testing by the U.S. Environmental Protection Agency (USEPA) demonstrates that alkaline dechlorination of 2,3,7,8-TCDD (dioxin) produces a material which is low in toxicity (LD50 > 5,000 mg/kg) and does not appear to bioaccumulate or cause mutagenic effects (11).

PROCESS DESCRIPTION

Site Preparation

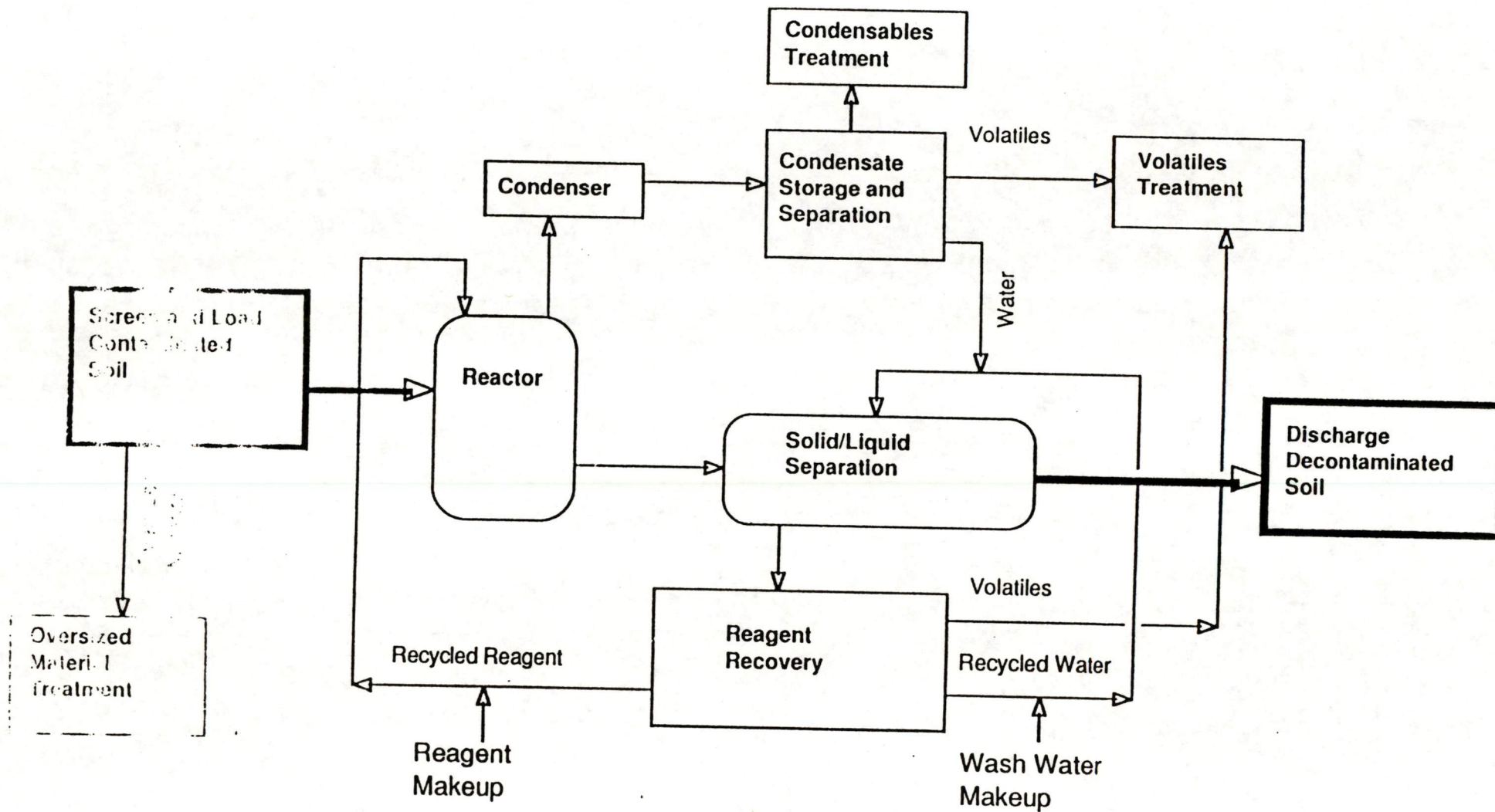
Prior to mobilization of the GRC treatment unit, the site is prepared by excavating and stockpiling contaminated soil. If it is not already present, electrical power may be brought in to the site. If electrical power cannot be readily brought into a site or is not an economic source of power, GRC would provide portable generators to supply all power needs. A concrete treatment pad of approximately 100 ft. by 150 ft. is prepared, and the APEG-PLUS™ system is transported to the site. The system components are assembled and tested with non-contaminated soils or sludges from the site.

The evaporator turns the water to steam, which is then condensed and returned to holding tanks for treatment of subsequent batches of contaminated soils. Any volatiles generated in this evaporation process are pulled off, condensed and stored for offsite disposal or onsite bioremediation.

Clean Soil

Decontaminated soil is discharged from the centrifuge onto a conveyor and handled according to specifications of the site.

PROCESS FLOW DIAGRAM



INTEGRATED SYSTEM AND COMPONENTS

Integrated Processing System

The processing unit has eight main subsystems: Sizing, Reaction, Separation, Reagent Recovery, Heating, Cooling, Electrical, and Controls. The equipment for these subsystems is set up on individual trailers, but most systems have components spread out on several trailers. The entire system is designed for maximum flexibility. Changes in component configuration can be made to optimize performance, increase safety of operation, and/or promote ease of maintenance. (See Figure 5 for example layout of soils processing system.)

Sizing Pretreatment and Loading

The sizing unit contains the equipment necessary to screen the soil to approximately .25 inch. It consists of a rotary drum mixer to mix the soil (wet or dry) and a series of screens to separate rock and other material that is over one quarter inch in diameter.

Reaction

Each reactor module contains two 3,000 gallon reactor tanks. Design of the system allows a total of five modules (ten reactor vessels). The ASME code reactors are rated for full vacuum and 40 psig. All reactor vessels have hot oil jackets for heating. Each of the tanks is fitted with an agitator system powered by a high (60-100) horsepower electric motor. A vacuum pump is used to maintain a slight vacuum, and a shell and tube heat exchanger is used to condense steam from the reaction. Electrical and Programmable Logic Control (PLC) control panels containing breakers and PLC interface specific to the centrifuge trailers are used to provide power and process sequence commands to the reactor system.

Separation

Horizontal solid bowl decanter centrifuges with a force of approximately 400 G's are used for separation of the aqueous reagent from the soil. The centrifuges, like all of the other equipment components, are trailer mounted. Electrical and PLC control panels containing breakers and PLC interface specific to the centrifuge trailers are used to provide power and process sequence commands to the separation system. Additional dewatering and solids/liquids separation devices such as filter, presses, and other centrifuges can be added to the treatment train as needed to handle the various waste matrices to be treated.

Reagent Recovery

The reagent recovery system is used to separate the liquid reagent and the water that are present in the discharge stream from the centrifuging operation. The feed stream to this recovery system consists of approximately 7,000 lb/hr of reagent and 23,000 lb/hr of water. A total of 2,000 lb/hr of water is evaporated, condensed as condensate, and reused as wash water in the centrifuges. The concentrated reagent stream, consisting of 7,000 lb/hr of reagent and 2,000 lb/hr of water, is also reused in the reactors.

CASE HISTORIES

GRC has used the APEG-PLUS dechlorination treatment system at a variety of sites, as summarized in the table below:

<u>Site</u>	<u>Dates</u>	<u>Contaminant</u>	<u>Comments</u>
Wide Beach	1988	PCB soils	Pilot test: 10 runs @ 200#/run w/recycle; 260 ppm to < 2 ppm
AmTech	1988	dioxin sludge	2500 gallons @ 11,000,000 ppb to <1 ppb
Signo Trading	1987	dioxin sludge	1 drum TCDD material to < 1 ppb
GE Moreau	1987	PCB soil	Pilot test: PCBs 7000 ppm to <10 ppm
NCBC	1987	dioxin soil	Pilot test: dioxin to 350 ppb
Montana Pole	1986	dioxin oil	9000 gallons @ 100,000 ppb to <1 ppb
Western Proc.	1986	dioxin oil	5500 gallons @ 15% water to < 1 ppb
NMPC	1986	PCB oil	6000 gallons to < 2 ppm PCBs
Bengart-Memel	1986	PCB soils	Decontamination of 12 tons PCBs
NMPC	1984-5	PCB oil	Pilot test: PCBs to < 2 ppm

Other dechlorination demonstrations have been conducted under the sponsorship of the USEPA Cincinnati laboratory.

To date, the most complete GRC demonstration of the dechlorination of PCB- contaminated soils is the pilot-scale testing conducted at the Wide Beach site under the sponsorship of the USEPA. In this testing, extensive sampling was used to support a fully functional, scaled-down reagent recycle system. The key to the economic success of dechlorination processes is the successful recycle of reagents between runs. During the Wide Beach pilot testing a series of seven recycle runs were conducted, with the results (13) shown in Figure 4.

POTENTIAL COST REDUCTIONS THROUGH PILOT STUDIES

After a treatability study has been conducted, a cost estimated to be accurate within a roughly 50 percent margin of error can be developed, based on laboratory analyses and results. It has been the experience of GRC that, as the size of the project scales up from laboratory to pilot and finally to full scale, the costs will be reduced because of increased equipment efficiencies at larger scale. To evaluate these potential cost reductions, GRC recommends that a pilot field demonstration be conducted at any hazardous waste site over 5,000 cubic yards. Listed below are some areas where costs may be reduced.

- Using a pretreatment to reduce the soil moisture content when excavating soils saturated with water;
- reducing the KOH consumption through other methods of washing; and
- increasing the amount of soil put into each reactor.

Other factors that could affect the prices include:

- cost of electricity,
- cost of fuel oil, and
- costs of chemicals.

Cost estimates do not include obtaining, preparing, or submitting permits that may be required before the cleanup could take place, nor negotiating for solid waste disposal with vendors. Further details of operation and maintenance of the APEG-PLUS™ treatment system will be offered when a proposal for the full-scale cleanup is prepared, or sooner on request of the prime contractor or the client. An approximate layout for the full scale soils processing unit is shown in Figure 5.

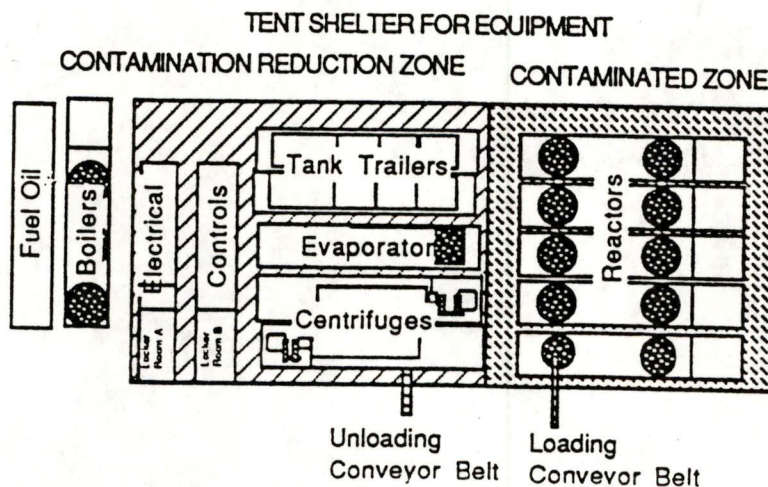


Figure 5. Layout for Full-Scale Soils Processing Unit

January 1991

GALSON REMEDIATION CORPORATION

Project Experience and Personnel

Galsen
Remediation Co., p.

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PROJECT SUMMARY TABLE

Site	Contaminant and Matrix	Original Concentration (ppm)	Final Concentration (ppm)	Date
A	PCB (soil)	4000	<2	1981
B	PCB (sludge)	150	<2	1981
C	PCB (soil)	125	<2	1981
D	PCB (oil)	69000	<2	1980
E	PCP (soil)	5000	44	1981
	Total Dioxins	38.4	0.014	1980
	Total Furans	7.12	0.0002	1980
F	Dioxin (soil)	0.476	nondetect	1989
	HCB (soil)	450	1.9	1989
	DDE (soil)	100	1.2	1989
	DDD (soil)	1600	0.9	1989
	DDT(soil)	5600	4.2	1989
G	Total Dioxins	22	nondetect	1989
	Total Furans	3.6	nondetect	1989
	PCP (soil)	1100	31	1981
H	PCB (soil lab)	690-490	6.5-3.8	1988
	PCB (soil pilot)	245	2.7	1987
I	Dioxin (sludge)	11000	<0.001	1988
J	PCB (soil)	300	<1	1983
K	PCB (soil)	790	6	1983
L	PCB (sand)	2900	<1	1987

PERSONNEL EXPERIENCE & SUMMARY SHEET

Title	Years exper. w/this firm	Years Exper. w/other firms	Education (Degrees(s)/Specialization/Year	Active Registration/ Year First Registered/ Discipline
President	1 year	15 years	MPPM, Yale School of Organization and Management, New Haven, CT B. A., cum laude, Political Science, Williams College, Williamstown, MA Boston University School of Law, Boston, MA	
Technical Director	9 years	7 years	B. S. Chemical Engineering, University of Illinois	Registered Professional Engineer, State of New York
Senior Project Manager	1 year	17 years	M. S., Civil Engineering, Syracuse University, Syracuse, NY B. S., Civil Engineering, Syracuse University, Syracuse, NY	Professional Engineering Registration in New York Mechanical Engineering Registration in California Member of National Council of Engineering Examiners Registered Environmental Assessor in California Certified Asbestos Inspector and Planner
Senior Chemist	7 years	4 years	M. S., Environmental Chemistry, State University of New York, College of Environmental Science and Forestry B. S. Chemistry, Capital University, Columbus, OH	



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Name: Richard C. Tavelli

Title: President

Education: MPPM, Yale School of Organization and Management
New Haven, Connecticut

BA, cum laude, Political Science, Williams College
Williamstown, Massachusetts

Boston University School of Law
Boston, Massachusetts

Experience: Galsion Remediation Corporation, East Syracuse, NY
President - January 1990 to present
Responsible for overall financial and management control of the company.
Participates actively in the development, management and oversight of field
remediation programs.

Texas Eastern Gas Pipeline Co. Inc., Houston, TX
Senior Environmentalist - 1988 to January 1990
Created and managed \$2.5+ million PCB remediation technology
development program, including field demonstrations. Developed
remediation strategy, including technology alternatives, contracts for
vendors, and insurance provisions.

Enron Interstate Pipeline Company, Houston, TX
Director, Administration and Environment - 1984-1987
Saved over \$40 million of cost of closure of RCRA facility. Reduced costs of
multi-site PCB remediation program 200% by site investigations, including
risk assessments, and by renegotiating TSCA consent agreement with
USEPA.

Empak, Inc., Houston, TX
Director, Management Budget - 1982-1984
Managed remediation projects in Texas and New Jersey including
completion of Superfund contract with USEPA and US Army Corps of
Engineers.
Directed all management/financial operation for hazardous waste disposal
service company, including contract drafting and capital budget program.



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Name: Russell Dionne, P.E.

Title: Senior Project Manager

Education: M.S., Civil Engineering, Syracuse University, Syracuse, NY
B. S., Civil Engineering, Syracuse University, Syracuse, NY

Certifications: Professional Engineering Registration on New York, Mechanical Engineering Registration in California, Member of National Council of Engineering Examiners. Registered Environmental Assessor in California. Certified Asbestos Inspector and Planner.

Experience: Galson Remediation Corporation, East Syracuse, NY
Senior Project Manager- 1989 to Present
In charge of design, construction and cost control for full-scale equipment.

McLaren Environmental Engineering
Project Manager - 1988-1989
Responsible for asbestos survey for major aerospace firm in Southern California. Includes operations and maintenance plan, maintenance staff training and presentation of results. Also project manager on environment assessment for oil field to be developed for single family housing.

Galson Technical Services
Project Engineer - 1987-1988
Project Engineer for multimillion dollar asbestos abatement renovation project. Responsibilities included contract design drawing, specifications, scheduling and cost estimating.

Galson & Galson Consulting Engineers
Project Manager and Principal in Charge - 1973-1987
Project Manager and Principal in Charge of many projects for asbestos abatement, power conversion, investigative modification and upgrades.



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Name: Edwina Milicic

Title: Laboratory Manager

Education: Master's Degree in Environmental Chemistry, 1983
State University of New York
College of Environmental Science and Forestry
Thesis research: Developed a new method for determining kinetic and equilibrium constants for the association of hydrophobic pollutants with dissolved humic substances using a C-14 labeled PCB as a test compound.

Bachelor's Degree: Capital University, Columbus, OH, 1978
Major: Chemistry, ACS Certified

Experience: Galson Remediation Corporation, East Syracuse, NY
1984 - present
Provided technical and research support for projects involving removal of PCBs from transformer oil and destruction of chlorinated toxic compounds in soil and other matrices. Developed more rapid analytical methods for PCBs and APEG reagent components. Assists with field operations at contaminated sites. Current manager of laboratory operations.

Galson Technical Services, East Syracuse, NY
1982-1984

Primarily responsible for PCB analysis of oil, soil, water, and air. Performed other GC analyses associated with Industrial Hygiene and other environmental applications. Adapted wet methods for specific applications. Performed glove permeability testing.

State of Ohio Health Department
1978-1984

Started in Manual Procedures Unit, transferred to Autoanalyzer Unit and advanced to head of Autoanalyzer Unit. Performed and supervised routine water analyses.



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Name: Jeffrey Ahrens

Title: Shift Manager

Education: B. S., Metallurgical Engineering, Purdue University

Experience: Galson Remediation Corporation, East Syracuse, NY

Shift Manager - August 1990 to Present

Responsible for working with a multidisciplinary team to develop, test, and operate innovative hazardous waste remediation treatment plants. Work includes development of pilot scale and prototype units as well as processing with full scale commercial units. Key contributions have been in design of wet slurry feed system and electronic logic controls for operation of treatment system.

Galson Engineers and Architects, Rochester, NY

1987-1990

Engineering consultant responsible for research and design of batch making system with programmable logic controller-based controls, extruder temperature controls using Eurotherms EM-1 systems, and complete instrumentation for an experimental emulsion making lab. Designed water heating system to reduce start-up time on a paper-making machine. Completed research and development on a system that provides flexibility in making emulsions using a variety of techniques.

Eastman Kodak Company, Rochester, NY

1972-1977, 1979-1986

Responsible for researching, developing, designing, releasing, and debugging various control systems including batch processing system with programmable logic controller, extruder temperature controls, and complete instrumentation for an experimental emulsion making lab. Was also responsible for process instrumentation work with paper making equipment, system temperature and humidity controls for emulsion coating machines, and dye flow control on emulsion delivery systems.

Eastman Kodak Company, Rochester, NY

1972-1977

Responsible for research and design of batch processing system with programmable logic controller, extruder temperature controls, and complete instrumentation for an experimental emulsion making lab. Was also responsible for process instrumentation work with paper making equipment, system temperature and humidity controls for emulsion coating machines, and dye flow control on emulsion delivery systems.

Note ✓ items

EPA/540/2-91/001

FIRST ISSUE

Please return
Bob Eisenberger

INNOVATIVE TREATMENT TECHNOLOGIES: SEMI-ANNUAL STATUS REPORT

January, 1991



U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office

FIRST ISSUE

**INNOVATIVE TREATMENT TECHNOLOGIES:
SEMI-ANNUAL STATUS REPORT**

January, 1991



U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office

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FOREWORD

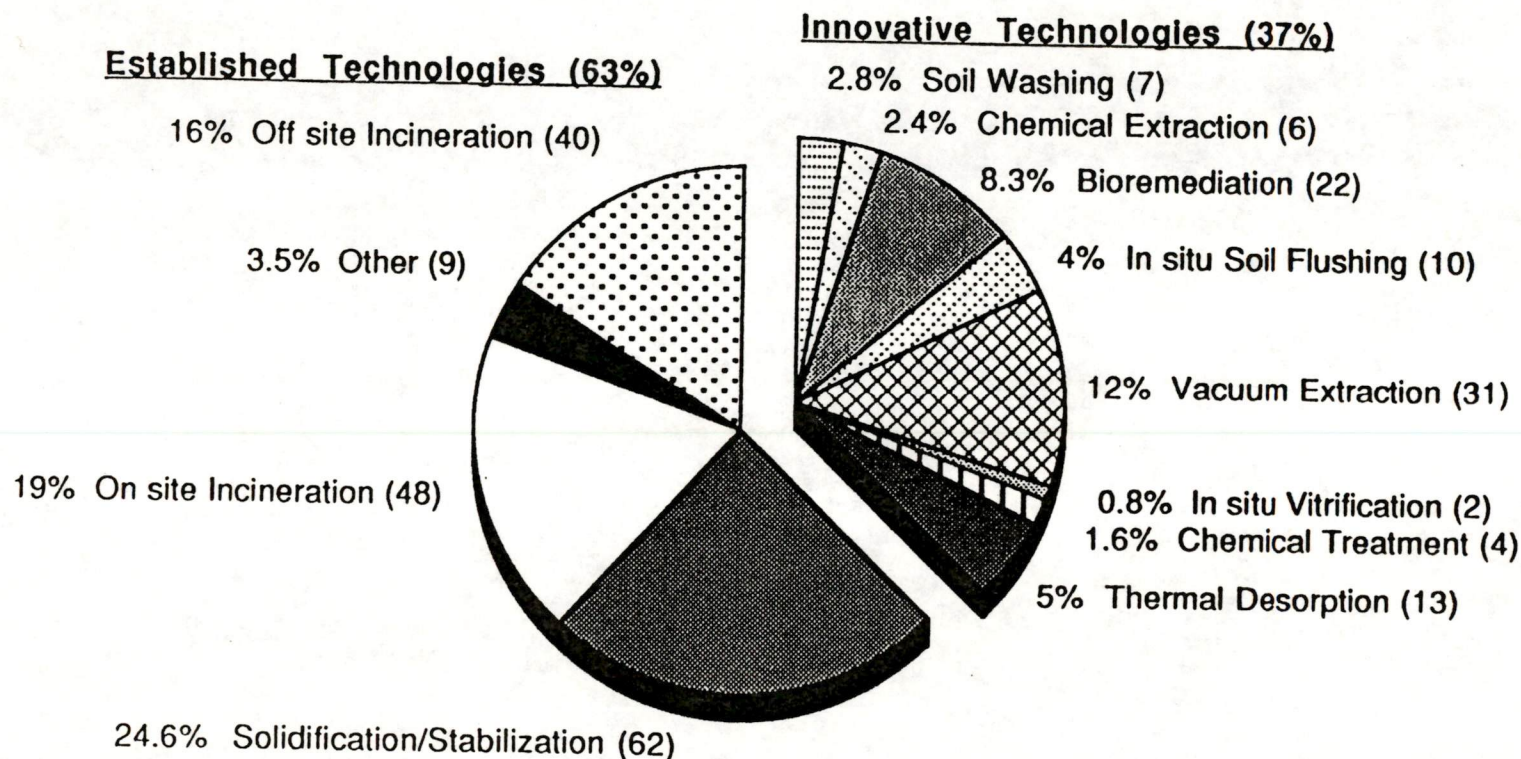
The Technology Innovation Office (TIO) was established in April 1990 by the U.S. EPA's Office of Solid Waste and Emergency Response to promote the use of innovative treatment technologies for contaminated site cleanup. TIO believes that an important part of this mission is to inform technology vendors and EPA Superfund site managers of sites at which innovative technologies are being successfully used. Accordingly, TIO has developed this document, "Innovative Treatment Technologies: Semi-Annual Status Report," to provide information on specific sites that have selected or used innovative treatment technologies. The information serves several purposes: (1) to track the progress of innovative technology use; (2) to provide market information to technology vendors; and (3) to facilitate communication among innovative technology users.

This report will be updated and distributed biannually. This first issue of the report addresses National Priorities List (NPL) sites where innovative technologies are planned for use or are being used. Data initially derived from Records of Decision (RODs) signed through Fiscal Year 1989 (FY89) have been updated with design and implementation information through telephone interviews with remedial project managers (RPMs). The data pertaining to project status does not duplicate data in CERCLIS, EPA's Superfund tracking system. This report provides more detailed information pertaining specifically to the implementation of various innovative technologies. The next biannual report (planned for July 1991) will contain information on innovative technologies selected in FY90 RODs, ongoing and completed removal actions utilizing innovative technologies, and project updates. Future reports may be expanded to include innovative treatment technologies used outside of Superfund.

This report is comprised of three sections. Section 1 provides a summary of innovative technology use by EPA Regions; Section 2 provides a project status summary of innovative technologies; and Section 3 provides more detailed site specific information for each technology. Figure 1 on the following page contrasts Superfund selection and use of innovative versus established treatment technologies for source control. This status report focuses on the innovative treatment technologies identified in this figure. Figure 2 provides a tabular summary of project status information contained in Section 2 of the report.

Questions pertaining to individual sites may be directed to the contacts listed in the table. Changes and updates to the report contents may be made to Mr. David Pepson, PRC Environmental Management, Inc., (PRC) at (703) 883-8802 or faxed to (703) 556-1130. General comments on the usefulness and scope of this report may be provided in writing to Ms. Linda Fiedler, USEPA, OS-110, 401 M Street, SW, Washington, DC 20460, or faxed to (202) 382-7863. To get on the mailing list for this document, complete and mail the form at the end of this document or call Ms. Deborah Lyne, PRC, at (703) 883-8408. To receive additional copies of this report, call EPA/ORD Publications at (513) 569-7562.

Figure 1
Summary of Innovative vs. Established Treatment Technologies For Source Control at Superfund Sites*



* Data are derived from 1982 - 1989 Records of Decision (RODs) and anticipated design and construction activities.
 The 254 technologies are associated with approximately 211 sites; the difference reflects the use of more than one technology per site.
 () Number of times this technology was selected or used.

January 1991

Figure 2

Project Status of Innovative Treatment Technologies For Source Control at Superfund Sites*

Technology	Predesign / In Design	Being Installed/ Operational	Project Completed	Total
Vacuum Extraction	25	5	1	31
Bioremediation	16	5	1	22
In Situ Soil Flushing	8	2	0	10
Thermal Desorption	10	0	3	13
Soil Washing	7	0	0	7
Chemical Extraction	5	1	0	6
Chemical Treatment	2	1	1	4
In Situ Vitrification	2	0	0	2

* Data derived from 1982 - 1989 Records of Decision (RODs) and anticipated design and construction activities.

Abbreviations

BTEX	benzene, toluene, ethylbenzene, and xylene
BTX	benzene, toluene, and xylene
cy	cubic yards
DCA	dichloroethane
DCE	dichloroethylene
FY	fiscal year
gw	ground water
PAHs	polynuclear aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PCE	perchloroethylene or tetrachloroethylene
PCP	pentachlorophenol
PRP	potentially responsible party
RODs	Records of Decision
RSKERL	Robert S. Kerr Environmental Research Laboratory, Ada, OK (U.S. EPA)
SVOCs	semivolatile organic compounds
TCA	trichloroethane
TCE	trichloroethylene
VOCs	volatile organic compounds

January, 1991

SECTION 1.0

EPA REGIONAL SUMMARY FOR INNOVATIVE TECHNOLOGIES

This section contains a table summarizing the innovative treatment technologies used at NPL sites in each EPA region. As shown in this table, regional use of innovative technologies ranges from 2 to 19 sites. Five of the regions are using innovative technologies at 10 or more sites.

TABLE 1
EPA REGIONAL SUMMARY FOR INNOVATIVE TECHNOLOGIES

TECHNOLOGY	SITE NAME	STATE	TECHNOLOGY	SITE NAME	STATE	TECHNOLOGY	SITE NAME	STATE
<u>Region 1</u>			<u>Region 2 (continued)</u>			<u>Region 4</u>		
Vacuum Extraction	Kellogg-Deering Well Field	CT	Thermal Desorption	Metaltec/Aerosystems	NJ	Bioremediation	American Creosote Works (Pensacola)	FL
Bioremediation	Iron Horse Park	MA	Thermal Desorption	Reich Farms	NJ	Bioremediation	Brown Wood Preserving	FL
Chemical Extraction	Norwood PCBs	MA	Thermal Desorption	Waldick Aerospace Devices	NJ	Soil Washing	Cape Fear Wood Preserving	NC
Chemical Treatment	Re-Solve	MA	Vacuum Extraction	FAA Technical Center	NJ	Chemical Treatment	Palmetto Wood Preserving	SC
Thermal Desorption	Cannon Engineering/Plymouth	MA	Chemical Treatment	Wide Beach Development	NY	Thermal Desorption	Wamchem	SC
Thermal Desorption	Re-Solve	MA	In situ Soil Flushing	Byron Barrel & Drum	NY	<u>Region 5</u>		
Vacuum Extraction	Groveland Wells	MA	Thermal Desorption	Fulton Terminals	NY	Bioremediation	Galesburg/Koppers	IL
Vacuum Extraction	Wells G&H	MA	Thermal Desorption	Marathon Battery	NY	Thermal Desorption	Outboard Marine/Waukegan Harbor	IL
Chemical Extraction	O'Connor	ME	Thermal Desorption	SMS Instruments (Deer Park)	NY	Bioremediation	Seymour Recycling	IN
Chemical Extraction	Pinette's Salvage Yard	ME	Chemical Extraction	GE Wiring Devices	PR	In situ Soil Flushing	Ninth Avenue Dump	IN
Thermal Desorption	McKin	ME	Vacuum Extraction	Upjohn Manufacturing Co.	PR	Vacuum Extraction	MIDCO I	IN
Thermal Desorption	Ottati & Goss	NH	<u>Region 3</u>			Vacuum Extraction	Seymour Recycling	IN
Vacuum Extraction	South Municipal Water Supply Well	NH	In situ Soil Flushing	Harvey-Knott Drum	DE	Bioremediation	Cliff/Dow Dump	MI
Vacuum Extraction	Tinkham Garage	NH	Vacuum Extraction	Bendix	PA	In situ Soil Flushing	U.S. Aviex	MI
<u>Region 2</u>			Vacuum Extraction	Henderson Road	PA	In situ Vittrification	Ionia City Landfill	MI
Bioremediation	FAA Technical Center	NJ	Vacuum Extraction	Tyson's Dump	PA	Vacuum Extraction	Kysor Industrial	MI
Chemical Extraction	Ewan Property	NJ	Bioremediation	L.A. Clarke & Sons	VA	Vacuum Extraction	Verona Well Field	MI
In situ Soil Flushing	Goose Farm	NJ	In situ Soil Flushing	L.A. Clarke & Sons	VA	Bioremediation	Burlington Northern (Railroad Tie Treating Plant)	MN
In situ Soil Flushing	Lipari Landfill	NJ	Bioremediation	Leetown Pesticide	WV	Bioremediation	Joslyn Manufacturing & Supply Co.	MN
In situ Soil Flushing	Vineland Chemical	NJ	Bioremediation	Ordnance Works Disposal	WV	Vacuum Extraction	Long Prairie	MN
Soil Washing	Ewan Property	NJ				Soil Washing	United Scrap Lead/SIA	OH
Soil Washing	Vineland Chemical	NJ						
Thermal Desorption	Caldwell Trucking	NJ						

TABLE 1 (Continued)
EPA REGIONAL SUMMARY FOR INNOVATIVE TECHNOLOGIES

<u>TECHNOLOGY</u>	<u>SITE NAME</u>	<u>STATE</u>	<u>TECHNOLOGY</u>	<u>SITE NAME</u>	<u>STATE</u>
<u>Region 5 (continued)</u>			<u>Region 8</u>		
Vacuum Extraction	Miami County Incinerator	OH	Vacuum Extraction	Sand Creek Industrial	CO
Vacuum Extraction	Pristine	OH	Bioremediation	Burlington Northern (Somers Plant)	MT
Vacuum Extraction	Wausau Groundwater Contamination	WI	Bioremediation	Libby Ground Water Contamination	MT
<u>Region 6</u>			<u>Region 9</u>		
Bioremediation	Old Inger Oil Refinery	LA	Vacuum Extraction	Motorola 52nd Street	AZ
Bioremediation	AT&SF/Clovis	NM	Vacuum Extraction	Phoenix-Goodyear Airport Area	AZ
Vacuum Extraction	South Valley/Edmunds	NM	Bioremediation	Koppers (Oroville Plant)	CA
Bioremediation	French Limited	TX	Soil Washing	Koppers (Oroville Plant)	CA
Bioremediation	North Cavalcade Street	TX	Vacuum Extraction	Fairchild/Intel FY89	CA
Bioremediation	Sheridan Disposal Services	TX	Vacuum Extraction	Fairchild/Raytheon	CA
Chemical Extraction	United Creosoting	TX	Vacuum Extraction	Fairchild Semiconductor/MTV-I	CA
Chemical Treatment	Sol Lynn/Industrial Transformers	TX	Vacuum Extraction	Fairchild Semiconductor/MTV-II	CA
In situ Soil Flushing	South Cavalcade Street	TX	Vacuum Extraction	Fairchild Semiconductor (San Jose)	CA
Soil Washing	Koppers/Texarkana	TX	Vacuum Extraction	IBM (San Jose)	CA
Soil Washing	South Cavalcade Street	TX			
<u>Region 7</u>			<u>Region 10</u>		
Bioremediation	Vogel Paint & Wax	IA	In situ Soil Flushing	United Chrome Products	OR
Vacuum Extraction	Hastings Groundwater* Contamination	NE	In situ Vittrification	Northwest Transformer (Mission Pole)	WA
Vacuum Extraction	Hastings Groundwater* Contamination	NE			
Vacuum Extraction	Hastings Groundwater* Contamination	NE			

* Different operable units at the same site.

SECTION 2.0

PROJECT STATUS SUMMARY BY INNOVATIVE TECHNOLOGY

This section contains a table summarizing the implementation status of innovative technologies selected or used at NPL sites. At six sites cleanup work using innovative technologies has been completed, and at an additional nine sites the technologies are operational. For two technologies (chemical extraction and soil washing), work has only progressed to the design stage.

TABLE 2
PROJECT STATUS SUMMARY BY INNOVATIVE TECHNOLOGY*

<u>BIOREMEDIATION</u>		<u>CHEMICAL EXTRACTION</u>		<u>IN SITU VITRIFICATION</u>	
	<u>STATUS</u>		<u>STATUS</u>		<u>STATUS</u>
Iron Horse Park, 01, MA	D	Norwood PCBs, 01, MA	D	Ionia City Landfill, 05, MI	D
FAA Technical Center, 02, NJ	D	O'Connor, 01, ME	D	Northwest Transformer, 10, WA (Mission Pole)	D
L.A. Clarke & Sons, 03, VA	D	Pinette's Salvage Yard, 01, ME	D		
Leetown Pesticide, 03, WV	D	Ewan Property, 02, NJ	PD	<u>SOIL WASHING</u>	
Ordnance Works Disposal, 03, WV	D	GE Wiring Devices, 02, PR	PD	Ewan Property, 02, NJ	PD
American Creosote Works, 04, FL (Pensacola)	D	United Creosoting, 06, TX	D	Vineland Chemical, 02, NJ	PD
Brown Wood Preserving, 04, FL	O			Cape Fear Wood Preserving, 04, NC	D
Burlington Northern, 05, MN (Railroad Tie Treating Plant)	O	<u>CHEMICAL TREATMENT</u>		United Scrap Lead/SIA, 05, OH	D
Cliff/Dow Dump, 05, MI	PD	Re-Solve, 01, MA	D	Koppers/Texarkana, 06, TX	D
Galesburg/Koppers, 05, IL	PD	Wide Beach Development, 02, NY	O	South Cavalcade Street, 06, TX	D
Joslyn Manufacturing, 05, MN and Supply Company	O	Palmetto Wood Preserving, 04, SC	C	Koppers (Oroville Plant), 09, CA	D
Seymour Recycling, 05, IN	C	Sol Lynn/Industrial, 06, TX Transformers	D		
AT&SF/Clovis, 06, NM	I	<u>IN SITU SOIL FLUSHING</u>		<u>THERMAL DESORPTION</u>	
French Limited, 06, TX	D	Byron Barrel & Drum, 02, NY	D	Cannon, 01, MA Engineering/Plymouth	C
North Cavalcade Street, 06, TX	D	Goose Farm, 02, NJ	D	McKin, 01, ME	C
Old Inger Oil Refinery, 06, LA	I	Lipari Landfill, 02, NJ	O	Ottati & Goss, 01, NH	C
Sheridan Disposal, 06, TX Services	D	Vineland Chemical, 02, NJ	PD	Re-Solve, 01, MA	D
Vogel Paint & Wax, 07, IA	D	Harvey-Knott Drum, 03, DE	D	Caldwell Trucking, 02, NJ	D
Burlington Northern, 08, MT (Somers Plant)	D	L.A. Clarke & Sons, 03, VA	D	Fulton Terminals, 02, NY	PD
Libby Ground Water, 08, MT Contamination	D	Ninth Avenue Dump, 05, IN	D	Marathon Battery, 02, NY	PD
Koppers (Oroville Plant), 09, CA	D	U.S. Aviex, 05, MI	D	Metaltec/Aerosystems, 02, NJ	D
		South Cavalcade Street, 06, TX	D	Reich Farms, 02, NJ	D
		United Chrome Products, 10, OR	O	SMS Instruments, 02, NY (Deer Park)	D
				Waldick Aerospace Devices, 02, NJ	D

* Number following site name refers to the EPA Region.
C = Completed, D = In Design, I = Being Installed, O = Operational, PD = Pre-design

TABLE 2 (Continued)
PROJECT STATUS SUMMARY BY INNOVATIVE TECHNOLOGY*

January, 1991

<u>THERMAL DESORPTION (Continued)</u>	<u>STATUS</u>	<u>VACUUM EXTRACTION (Continued)</u>	<u>STATUS</u>
Wamchem, 04, SC	D	Wausau Groundwater, 05, WI Contamination	D
Outboard Marine/Waukegan, 05, IL Harbor	D	South Valley/Edmunds, 06, NM	D
		Hastings Groundwater, 07, NE Contamination	D
<u>VACUUM EXTRACTION</u>		Hastings Groundwater, 07, NE Contamination	D
Groveland Wells, 01, MA	D	Hastings Groundwater, 07, NE Contamination	D
Kellogg-Deering Well, 01, CT Field	D	Hastings Groundwater, 07, NE Contamination	D
South Municipal Water, 01, NH Supply Well	D	Sand Creek Industrial, 08, CO	D
Tinkham Garage, 01, NH	D	Fairchild Semiconductor, 09, CA (San Jose)	O
Wells G&H, 01, MA	D	Fairchild, 09, CA Semiconductor/MTV-I	PD
FAA Technical Center, 02, NJ	D	Fairchild, 09, CA Semiconductor/MTV-II	PD
Upjohn Manufacturing Co., 02, PR	C	Fairchild/Intel, 09, CA	PD
Bendix, 03, PA	D	Fairchild/Raytheon, 09, CA	PD
Henderson Road, 03, PA	PD	IBM (San Jose), 09, CA	I
Tyson's Dump, 03, PA	O	Motorola 52nd Street, 09, AZ	D
Kysor Industrial, 05, MI	D	Phoenix-Goodyear Airport, 09, AZ Area	D
Long Prairie, 05, MN	D		
MIDCO I, 05, IN	D		
Miami County Incinerator, 05, OH	PD		
Pristine, 05, OH	PD		
Seymour Recycling, 05, IN	I		
Verona Well Field, 05, MI	O		

* Number following site name refers to the EPA Region.

C = Completed, D = In Design, I = Being Installed, O = Operational, PD = Pre-design

SECTION 3.0

DETAILED SITE INFORMATION BY INNOVATIVE TECHNOLOGY

This section contains a table that provides detailed project information for each innovative treatment technology. The table includes information on the specific technology, site category, media, key contaminants, lead treatment contractor, and contact names and phone numbers. Also provided are dates for Records of Decision (RODs). The technologies and sites are listed in the same order as in Table 2.0.

TABLE 3
DETAILED SITE INFORMATION BY TECHNOLOGY

January, 1991

Bioremediation

Site Name, State, Region (ROD Date)	Specific Technology	Site Category	Media (Quantity)	Key Contaminants Treated	Status	Lead; Treatment Contractor	Contacts/ Phone
Iron Horse Park, MA, 01 (09/15/88)	Land Treatment	Industrial Complex & Railyard Wastes	Sludge, Soil (28,000 cy combined)	Petroleum Hydrocarbons, BTEX, and PAHs	In Design	PRP Lead; ENSR	Don McElroy 617-223-5518 FTS 883-1518
FAA Technical Center, NJ - Area D, 02 (09/26/89) Also see Vacuum Extraction	In situ gw Bioremediation	Jet Fuel Farm	gw	BTX, PAHs (Naphthalene), and Phenols	In Design	PRP Lead	Carla Struble 212-264-4595 FTS 264-4595 Keith Buch (FAA) 609-484-6644
L.A. Clarke & Sons, VA, 03 (03/31/88) Also see In situ Soil Flushing	On-site Bioremediation - Type to be Determined	Wood Preserving	Soil (73,700 cy), Sediments (45,300 cy)	Creosote, PAHs, and Benzene	In Design	PRP Lead	Gene Wingert 215-597-1727 FTS 597-1727
Leetown Pesticide, WV, 03 (03/31/86)	On-site Bioremediation - Type to be Determined	Pesticide Storage and Disposal	Soil (3,600 cy)	DDT and Lindane	In Design; Treatability studies unsuccessful; reevaluating remedial action	Fund Lead	Andy Polestini 215-597-1286 FTS 597-1286
Ordnance Works Disposal, WV, 03 (09/29/89)	Land Treatment	Chemical Formulation	Soil (13,460 cy)	PAHs	In Design	PRP Lead	Bonnie Gross 215-597-9023 FTS 597-9023
American Creosote Works, Pensacola, FL, 04, (09/28/89)	Slurry Phase for fines from soil washing	Wood Preserving	Fines from 23,000 cy of soil	Creosote, PAHs, PCP, Dioxins	In Design; full-scale unit planned for FY92	Fund Lead	Natalie Ellington 404-347-2643 FTS 257-2643
Brown Wood Preserving, FL, 04 (04/08/88)	Land Treatment	Wood Preserving	Soil (7,500 cy)	Creosote and PAHs	Operational; field work almost completed	PRP Lead; Remediation Technology	Martha Berry 404-347-2643 FTS 257-2643
Galesburg/Koppers, IL, 05 (06/30/89)	Land Treatment	Wood Preserving	Soil (15,200 cy)	Creosote, PAH, Phenols, and PCP	Pre-design	PRP Lead/ State Enforcement	Brad Bradley 312-886-4742 FTS 886-4742

Note: Concentrations listed are maximums. Contacts listed are EPA regional staff unless otherwise indicated.

TABLE 3 (Continued)

January, 1991

Bioremediation

Site Name, State, Region (ROD Date)	Specific Technology	Site Category	Media (Quantity)	Key Contaminants Treated	Status	Lead; Treatment Contractor	Contacts/ Phone
Seymour Recycling, IN, 05 (09/30/87) Also see Vacuum Extraction	In situ Soil Bioremediation	Chemical Waste Management and Incineration	Soil (154,000 cy)	Petroleum Hydrocarbons, BTEX, and Various SVOCs	One-month application of nutrients completed Summer 1990	PRP Lead; ABB (Boston)	Jeff Gore 312-886-4747 FTS 886-4747
Cliff/Dow Dump, MI, 05 (09/27/89)	Excavation/On-site Bioremediation - Type to be Determined In situ Soil and gw Bioremediation	Waste Disposal for Charcoal Manufacturing Plant	Soil (9,200 cy) gw	Tar, PAHs, BTX, PCE, and Phenol BTX, PAHs, and Phenols	Pre-design	PRP Lead	Lida Tan 312-886-1842 FTS 886-1842
Burlington Northern (Railroad Tie Treating Plant), MN, 05 (06/04/86)	Land Treatment	Wood Preserving	Soil (9,500 cy), Sludge (9,600 cy)	Creosote, PAHs, Phenols	Remedial action underway; will be operational for 2-3 more years	PRP Lead; Retec	Amy Blumberg 312-353-9306 FTS 886-9306 Todd Goeks (MN) 612-296-7710 Rich Truax (Retec) 303-493-3700
Old Inger Oil Refinery, LA, 06 (09/25/84)	Land Treatment	Oil Refining & Waste Oil Reclamation	Soil (150,000 cy), Waste oil and sludge (800,000 gal combined)	Petroleum Hydrocarbons, Benzene, Ethylbenzene, and Metals	Installation underway; will be operational 4/91	Fund Lead; Westinghouse Haztech	Paul Sieminski 214-655-6710 FTS 255-6710
Sheridan Disposal Services, TX, 06 (12/29/88)	Slurry-Phase Bioremediation (Tank Bioremediation)	Commercial Waste Disposal	Soil (13,000 cy), Sludge (31,000 cy), Oil/emulsion (300 cy)	Benzene, Toluene (36,600 ppm sludge), PCBs, and Phenols	In Design	PRP Lead	Ruth Israeli 214-655-6735 FTS 255-6735
North Cavalcade Street, TX, 06 (06/28/88)	Excavation/On-site Bioremediation - Type to be Determined (Slurry phase or modified land treatment)	Wood Preserving	Soil (22,300 cy)	Creosote, PAHs, and BTX	In Design	State Lead/Fund Financed	Deborah Griswold 214-655-6715 FTS 255-6715 Lewis Rogers (TX) 512-463-8188
French Limited, TX, 06 (03/24/88)	In situ Lagoon Bioremediation	Petrochemical	Sludge, Sediments (70,100 cy)	BTEX, PAHs, Petroleum Hydrocarbons, and PCBs (616 mg/kg)	In Design	PRP Lead	Judith Black 214-655-6735 FTS 255-6735

Note: Concentrations listed are maximums. Contacts listed are EPA regional staff unless otherwise indicated.

TABLE 3 (Continued)

January, 1991

Bioremediation

Site Name, State, Region (ROD Date)	Specific Technology	Site Category	Media (Quantity)	Key Contaminants Treated	Status	Lead; Treatment Contractor	Contacts/ Phone
Joslyn Manufacturing and Supply Co., MN, 05 (ROD Planned)	Land Treatment	Wood Preserving	Soil (75,000 cy)	PAHs, PCP	Operational since 8/89; scheduled completion end of 1991	PRP Lead/State Enforcement; ECOVA	Cliff Twaroski (MN) 612-296-7827 Kevin Turner 312-886-4444 FTS 886-4444
Atchison/Santa Fe/ Clovis, NM, 06 (09/23/88)	In situ Soil Bioremediation	Railyard Wastes (Industrial Wastewater)	Soil, sludges (28,599 cy combined)	Phenols, Petroleum Hydrocarbons, Diesel, Arsenic, Chromium, and Lead	Construction underway; operational in June 1991	PRP Lead; Radian	Susan Webster 214-655-6730 FTS 255-6730
Vogel Paint & Wax, IA, 07 (09/25/89)	Land Treatment	Paint Manufacturing Wastes	Soil (3,000 cy)	BTEX and PAHs	In Design	PRP Lead/ State Enforcement	Steve Jones 913-551-7755 FTS 276-7755
Libby Ground Water Contamination, MT, 08 (12/30/88)	Land Treatment (soil, sediments)	Wood Preserving	Soil, Sediments, (30,000 cy combined)	Creosote, PCP, Benzene, PAHs, and Dioxin	Land treatment: in design, operating by summer 1991	PRP Lead	Julie Dalsoglio 406-449-5414 FTS 585-5414 Scott Huling (RSKRL) 405-332-2313 FTS 743-2313
	In situ Soil Bioremediation		gw	Creosote, Benzene, PAHs, PCP, and Oil	In situ gw and Soil: in design		
Burlington Northern (Somers Plant), MT, 08 (09/27/89)	Land Treatment	Wood Preserving	Soil, Sediments (11,700 cy combined)	Creosote, PAHs, Phenol, and Zinc	In Design; operational in 1992	PRP Lead	Jim Harris 406-449-5414 FTS 585-5414
	In situ gw Bioremediation		gw				
Koppers (Oroville Plant), CA, 09 (09/13/89) Also see Soil Washing	In situ Soil Bioremediation	Wood Preserving	Soil (110,000 cy)	PCP, Creosote, PAHs, BTX, Dioxin, Arsenic, and Chromium	In Design	PRP Lead	Fred Schaffler 415-744-2365 FTS 485-2365

Note: Concentrations listed are maximums. Contacts listed are EPA regional staff unless otherwise indicated.

TABLE 3 (Continued)

January, 1991

Chemical Extraction

Site Name, State, Region (ROD Date)	Specific Technology	Site Category	Media (Quantity)	Key Contaminants Treated	Status	Lead; Treatment Contractor	Contacts/ Phone
Norwood PCBs, MA, 01 (09/29/89)	Solvent Extraction	Industrial Waste Dumping	Soil (28,000 cy)	PCB and VOCs (TCE, Trichlorobenzene)	In Design	Fund Lead/Negotiation	Jane Downing 617-573-5730 FTS 833-1708
O'Connor, ME, 01 (09/27/89)	Solvent Extraction	Salvage & Electrical Transformer Recycling	Soil, Sediments (23,500 cy combined)	PCB and Lead	In Design	Fund Lead/Negotiation	Mike Jasinski 617-573-5786 FTS 833-1786
Pinette's Salvage Yard, ME, 01 (05/30/89)	Solvent Extraction	Salvage and Vehicle Repair	Soil (2,080 cy)	PCB, VOCs (Chlorobenzene, Dichlorobenzene, and Trichlorobenzene)	Contract awarded; mobilization scheduled to begin 4/91	Fund Lead; Sanivan Group	Ros Gilleland 617-573-5766 FTS 883-1766
Ewan Property, NJ, 02 (09/29/89) Also see Soil Washing	Solvent Extraction (followed by Soil Washing)	Industrial Waste Dumping	Soil (22,000 cy)	Chlorinated Aliphatic Organics, Aromatic Hydrocarbons, and Metals	Pre-design	PRP Lead	Craig DeBiase 212-264-5393 FTS 264-5393
GE Wiring Devices, PR, 02 (09/30/88)	Hydrometallurgical Treatment	Wiring Services Facility	Soil (5,500 cy)	Mercury	Pre-design	PRP Lead	Doug Tomchuk 212-264-7508 FTS 264-7508
United Creosoting, TX, 06 (09/29/89)	Critical Fluid Extraction	Wood Preserving	Soil (67,250 cy)	PAHs, PCP, and Dioxin	In Design	State Lead/ Fund Financed	Deborah Griswold 214-655-6715 FTS 255-6715 Paul Cravens (TX) 512-463-8182

Note: Concentrations listed are maximums. Contacts listed are EPA regional staff unless otherwise indicated.

TABLE 3 (Continued)

January, 1991

Chemical Treatment

Site Name, State, Region (ROD Date)	Specific Technology	Site Category	Media (Quantity)	Key Contaminants Treated	Status	Lead; Treatment Contractor	Contacts/ Phone
Re-Solve, MA, 01 (09/24/87) Also see Thermal Desorption	Dechlorination of Residuals from Thermal Desorption	Chemical Reclamation Facility	Residuals from Thermal Desorption of 22,500 cy of soil	PCBs	In Design	PRP Lead/ Mixed Funding: Chemical Waste Management, Inc.	Lorenzo Thanto 617-223-5500 FTS 883-1500
Wide Beach Development, NY, 02 (09/30/85)	APEG Dechlorination	Contaminated Road Dust, Driveways, and Ditches	Soil (20,000 cy)	PCBs	Operational; scheduled completion 6/91	Fund Lead/Negotiation; Soil Tech, Inc.	Herb King 212-264-1129 FTS 264-1129
Palmetto Wood Preserving, SC, 04 (09/30/87)	Reduction of Cr(VI) to Cr(III) (Followed by Solidification)	Wood Preserving	Soil (12,680 cy)	15,000 mg/kg Metals (Chromium, Arsenic, and Copper)	Project completed; was operational 09/28/88 - 02/04/89	Fund Lead/Negotiation; Roy F. Weston	Al Cherry 404-347-7791 FTS 257-7791
Sol Lynn/Industrial Transformers, TX, 06 (03/25/88)	APEG Dechlorination	Transformer and Solvent Recycler	Soil (2,400 cy)	PCBs	In Design	PRP Lead	John Meyer 214-655-6735 FTS 255-6735

Note: Concentrations listed are maximums. Contacts listed are EPA regional staff unless otherwise indicated.

TABLE 3 (Continued)

January, 1991

In situ Soil Flushing

Site Name, State, Region (ROD Date)	Specific Technology	Site Category	Media (Quantity)	Key Contaminants Treated	Status	Lead; Treatment Contractor	Contacts/ Phone
Byron Barrel & Drum, NY, 02 (09/29/89)	In situ Soil Flushing	Uncontrolled Dump Site and Landfill	Soil (5,200 cy)	VOCs (BTX, PCE, and TCE), PAHs, Phenol, and Dioxin	In Design	PRP Lead	Eduardo Gonzales 212-264-5714 FTS 264-5714
Goose Farm, NJ, 02 (09/27/85)	In situ Soil Flushing	Uncontrolled Dump Site	Soil (15,500 cy)	960 mg/kg VOCs (Toluene, Ethylbenzene, Dichloromethane, and TCE), SVOCs, PCBs, and PAHs	In Design	PRP Lead	Laura Lombardo 212-264-6787 FTS 264-6787
Lipari Landfill, NJ, 02 (09/30/85)	In situ Soil Flushing	Commercial Dump Site	Soil (650,000 cy)	257 mg/kg VOCs (Benzene, DCA, Dichloromethane, and Toluene), Phenol, and Metals (Chromium, Nickel, Lead, and Mercury)	Operational; scheduled completion 7/91	Fund Lead/Negotiation; COE/BECTEL	Fred Cataneo 212-264-9542 FTS 264-9542
Vineland Chemical, NJ, 02 (09/29/89) Also see Soil Washing	In situ Soil Flushing	Pesticide Manufacturing	Soil (126,000 cy)	1,921 mg/kg Arsenic, and 399 mg/kg VOCs (Dichloromethane)	Pre-design	Fund Lead	Matthew Westgate 212-264-3406 FTS 264-3406
Harvey-Knott Drum, DE, 03 (09/30/85)	In situ Soil Flushing	Uncontrolled Dump Site for Paint Solvent	Soil, Sediment (80,500 cy)	10,400 mg/kg VOCs (Benzene, Ethylbenzene, Methylene Chloride, and Dichloromethane), and SVOCs [Bis(2-Ethylhexyl) phthalate]	In Design: Reevaluating Alternative	PRP Lead	Paula Retzler 215-597-1113 FTS 597-1113
L.A. Clarke & Sons, VA, 03 (03/31/88) Also see Bioremediation	In situ Soil Flushing	Wood Preserving	Soil (6,000 cy)	Creosote, PAHs (5,000 mg/kg-Soil, 18 mg/kg-Sediments), and Benzene	In Design	PRP Lead	Eugene Wingert 215-597-1727 FTS 597-1727
Ninth Avenue Dump, IN, 05 (06/30/89)	In situ Soil Flushing	Commercial Dump Site	Soil (64,000 cy)	VOCs [BTX, TCE (1,500 mg/kg)], PAHs, Phenols, Lead, PCBs, and Total Metals (1.4 mg/kg)	In Design	PRP Lead	Alison Hiltner 312-353-6417 FTS 353-6417
U.S. Aviex, MI, 05 (09/07/88)	In situ Soil Flushing	Chemical Packaging Facility	Soil (11,500 cy)	37 mg/kg VOCs (Carbon Tetrachloride, DCA, Ethylbenzene, PCE, TCE, Toluene, TCA, Freon, Xylene, and Chloroform)	In Design	PRP Lead	Robert Whippo 312-886-4759 FTS 886-4759

Note: Concentrations listed are maximums. Contacts listed are EPA regional staff unless otherwise indicated.

TABLE 3 (Continued)

January, 1991

In situ Soil Flushing

Site Name, State, Region (ROD Date)	Specific Technology	Site Category	Media (Quantity)	Key Contaminants Treated	Status	Lead; Treatment Contractor	Contacts/ Phone
South Cavalcade Street, TX, 06 (09/26/88) Also see Soil Washing	In situ Soil Flushing	Wood Preserving & Coal Tar Distillation	Soil (10,500 cy)	PAHs (8,567 mg/kg)	In Design	PRP Lead	Mark Fite 214-655-6715 FTS 255-6715
United Chrome Products, OR, 10 (09/12/86)	In situ Soil Flushing	Chrome Plating Facility	Soil (quantity not available)	162,580 mg/kg Chromium	Operational since 8/88	Fund Lead	Loren McPhillips 206-553-4903 FTS 399-4903

Note: Concentrations listed are maximums. Contacts listed are EPA regional staff unless otherwise indicated.

TABLE 3 (Continued)

January, 1991

In situ Vitrification

Site Name, State, Region (ROD Date)	Specific Technology	Site Category	Media (Quantity)	Key Contaminants Treated	Status	Lead; Treatment Contractor	Contacts/ Phone
Ionia City Landfill, MI, 05 (09/29/89)	In situ Vitrification	Municipal Landfill	Soil, Debris (5,000 cy combined)	VOCs (Methylene Chloride, Styrene, Toluene, 1-1-1 Trichloroethane), and Lead	In Design	PRP Lead	Michael Gifford 312-886-7257 FTS 886-7257
Northwest Transformer (Mission Pole), WA, 10 (09/15/89)	In situ Vitrification	PCB Storage and Recycling Operations	Soil (1,200 cy)	PCBs	In Design	PRP Lead	Christine Psyk 206-553-6519 FTS 399-6519

Note: Concentrations listed are maximums. Contacts listed are EPA regional staff unless otherwise indicated.

TABLE 3 (Continued)

January, 1991

Soil Washing

Site Name, State, Region (ROD Date)	Specific Technology	Site Category	Media (Quantity)	Key Contaminants Treated	Status	Lead; Treatment Contractor	Contacts/ Phone
Ewan Property, NJ, 02 (09/29/89) Also see Chemical Extraction	Soil Washing (preceded by Chemical Extraction)	Industrial Waste Dumping	Soil (22,000 cy)	Chlorinated Aliphatic Organics, Aromatic Hydrocarbons, and Metals	Pre-design	PRP Lead	Craig DeBiase 212-264-5393 FTS 264-5393
Vineland Chemical, NJ, 02 (09/29/89) Also see In situ Soil Flushing	Soil Washing	Pesticide Manufacturing	Sediments (62,600 cy)	Arsenic	Pre-design	Fund Lead	Matthew Westgate 212-264-3406 FTS 264-3406
Cape Fear Wood Preserving, NC, 04 (06/30/89)	Soil Washing	Wood Preserving	Soil (22,000 cy)	Creosote, PAHs, Copper, Chromium, and Arsenic	In Design	Fund Lead	John Bornholm 404-347-7791 FTS 257-7791
United Scrap Lead/SIA, OH, 05 (09/30/88)	Soil Washing	Lead Battery Recycling	Soil (45,000 cy), Sediments (45,550 cy)	Lead and Arsenic	In Design	Fund Lead/Negotiation; Corps of Engineers/Bureau of Mines	Anita Boseman 312-886-6941 FTS 886-6941
Koppers/Texarkana, TX, 06 (09/23/88)	Soil Washing	Wood Preserving	Soil (19,400 cy)	PAHs and PCP	In Design	PRP Lead	Ursula Lennox 214-655-6735 FTS 255-6735
South Cavalcade Street, TX, 06 (09/26/88) Also see In situ Soil Flushing	Soil Washing	Wood Preserving & Coal Tar Distillation	Soil (19,500 cy)	PAHs	In Design	PRP Lead	Mark Fite 214-655-6715 FTS 255-6715
Koppers (Oroville Plant), CA, 09 (09/13/89) Also see Bioremediation	Soil Washing	Wood Preserving	Soil, Sediments (200,000 cy combined)	PAHs, PCP, and Dioxin	In Design	PRP Lead	Fred Schaffler 415-744-2365 FTS 484-2365

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TABLE 3 (Continued)

January, 1991

Thermal Desorption

Site Name, State, Region (ROD Date)	Specific Technology	Site Category	Media (Quantity)	Key Contaminants Treated	Status	Lead; Treatment Contractor	Contacts/ Phone
Cannon Engineering/ Bridgewater, MA, 01 (03/31/88)	Thermal Aeration	Chemical Waste Handling, Storage, & Incineration Facility	Soil (11,330 cy)	VOCs (Benzene, TCE, and Vinyl Chloride)	Project completed; was operational 5/90 - 10/90	PRP Lead; Canonie Engineering	Dan Coughlin 617-573-1742 FTS 833-1742
McKin, ME, 01 (07/22/85)	Thermal Aeration	Waste Storage, Transfer, Disposal Facility	Soil (11,376 cy)	VOCs (TCE, BTX)	Project completed; was operational 7/86 - 2/87	PRP Lead; Canonie Engineering	Sheila Eckman 617-573-5784 FTS 833-1784
Ottati & Goss, NH, 01 (01/16/87)	Thermal Aeration	Drum Reconditioning Facility	Soil (16,000 cy)	VOCs (TCE, PCE, 1,2-DCA, and Benzene)	Project completed; was operational 6/89 - 9/89	PRP Lead; Canonie Engineering	Stephen Calder 617-573-9626 FTS 833-1626
Re-Solve, MA, 01 (09/24/87) Also see Chemical Treatment	Rotary Thermal Desorber	Chemical Reclamation Facility	Soil (22,500 cy)	PCBs	In Design	PRP Lead/ Mixed Funding	Lorenzo Thantu 617-223-5500 FTS 883-1500
Caldwell Trucking, NJ, 02 (09/25/86)	Low Temperature Vaporization	Unpermitted Septic Waste Facility	Soil (20,000 cy)	VOCs (TCE, PCE, and TCA)	In Design	Fund Lead	Ed Finnerty 212-264-3555 FTS 264-3555
Fulton Terminals, NY, 02 (09/29/89)	Low Temperature Thermal Treatment	Former Waste Tank Farm	Soil (4,000 cy)	VOCs (Xylene, Styrene, TCE, Ethylbenzene, Toluene) and PAHs (Pyrene, Naphthalene, Phenanthrene, and 2-Methylnaphthalene)	Pre-design	PRP Lead	Christos Islamis 212-264-5713 FTS 264-5713
Marathon Battery, NY, 02 (09/30/88)	Enhanced Volatilization	Former Battery Manufacturer	Soil (85,000 cy)	VOCs (PCE, Toluene, and TCE)	Pre-design	Fund Lead	Pam Tames 212-264-1036 FTS 264-1036
Metaltec/Aerosystems, NJ, 02 (06/30/86)	Low Temperature Thermal Treatment	Metal Manufacturing	Soil (8,000 cy)	TCE, other Chlorinated Organics, and Copper	In Design	Fund Lead	Ron Rusin 212-264-1873 FTS 264-1873

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Thermal Desorption

Site Name, State, Region (ROD Date)	Specific Technology	Site Category	Media (Quantity)	Key Contaminants Treated	Status	Lead; Treatment Contractor	Contacts/ Phone
Reich Farms, NJ, 02 (09/30/88)	Enhanced Volatilization	Uncontrolled Waste Disposal	Soil (1,120 cy)	VOCs and Semivolatiles	In Design	PRP Lead	Gary Adamkiewicz 212-264-7592 FTS 264-7592
SMS Instruments (Deer Park), NY, 02 (09/29/89)	In situ Steam Stripping	Military Aircraft Component Overhauler	Soil (1,250 cy)	Solvents (TCE, Xylene, Ethylbenzene, and Chlorobenzene)	In Design	Fund Lead	Abram Fayon 212-264-4706 FTS 264-4706
Waldick Aerospace Devices, NJ, 02 (09/29/87)	In situ Hot Air Stripping	Manufacturing and Electroplating of Plane Parts	Soil (2,500 cy)	TCE, PCE, Cyanide, and Metals	In Design; estimated design completion 12/92	Fund Lead	Larry Granite 212-264-7668 FTS 264-7668
Wamchem, SC, 04 (06/30/88)	Low Temperature Thermal Treatment	Former Dye Production & Solvent Recovery/ Recycling Facility	Soil (2,000 cy)	BTX and SVOCs (Naphthalene)	In Design	PRP Lead	George Reedy 404-347-7791 FTS 247-7791
Outboard Marine/Waukegan Harbor, IL, 05 (03/31/89)	Low Temperature Thermal Extraction (Iaciuk Process)	Marine Products Manufacturing	Soil, Sediments (16,000 cy combined)	PCBs	In Design	PRP Lead; Canonic Engineering	Cindy Nolan 312-886-0400 FTS 886-0400

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Vacuum Extraction

Site Name, State, Region (ROD Date)	Specific Technology	Site Category	Media (Quantity)	Key Contaminants Treated	Status	Lead; Treatment Contractor	Contacts/ Phone
Groveland Wells, MA, 01 (09/30/88)	Vapor Extraction	Manufacturing	Soil (19,000 cy)	VOCs (TCE and methylene chloride)	In Design	PRP Lead	Bob Leger 617-573-5734 FTS 833-1734
Kellogg-Deering Well Field, CT, 01 (09/29/89)	Vacuum Extraction	Municipal Landfill	Soil (quantity not available)	VOCs (TCE, PCE, and BTX)	In Design	Fund Lead/Negotiation	Leslie McVicker 617-573-9689 FTS 833-1689
South Municipal Water Supply Well, NH, 01 (09/27/89)	Vacuum Extraction	Commercial Manufacturing	Soil (7,500 cy)	VOCs (PCE, TCA, and TCE)	In Design	PRP Lead	Roger Duwart 617-573-9620 FTS 833-1620
Tinkham Garage, NH, 01 (09/30/86)	Vacuum Extraction	Uncontrolled Dump Site	Soil (9,000 cy)	VOCs (Benzene, Chloroform, DCE, PCE, TCE, and Vinyl Chloride)	In Design	PRP Lead; Terra Vac	Diana King 617-573-9676 FTS 883-1676
Wells G&H, MA, 01 (09/14/89)	In situ Volatilization	Uncontrolled Dump Site	Soil (7,400 cy)	VOCs (PCE and TCE)	In Design	PRP Lead	Barbara Newman 617-573-5736 FTS 883-1736
FAA Technical Center, NJ, 02 (09/26/89) Also see Bioremediation	Vacuum Extraction	Jet Fuel (JP4) Spill	Soil (33,000 cy)	BTEX, PAH, Chlorophenol, Phenol, Lead, and Chromium	In Design	PRP Lead	Carla Struble 212-264-4595 FTS 264-4595 Keith Buch (FAA) 609-484-6644
Upjohn Manufacturing Co., PR, 02 (09/30/88 for gw; treatment completed prior to ROD)	Vacuum Extraction	Industrial Facility, Chemical Leak	Soil (quantity not available)	VOCs (carbon tetrachloride and acetonitrile)	Project completed; was operational, late 1984 - to 3/88	PRP Lead; Terra Vac	Alison Hess 212-264-6040 FTS 264-6040
Bendix, PA, 03 (09/30/88)	Vacuum Extraction	Aircraft Manufacturing	Soil (quantity not available)	VOCs (TCE, Toluene, Vinyl Chloride, DCE, and Carbon Tetrachloride), and SVOCs	In Design	PRP Lead	Humane Zia 215-597-7713 FTS 597-7713
Henderson Road, PA, 03 (06/30/88)	In situ Volatilization (Tentative)	Injection Well	Soil (quantity not available)	VOCs (BTEX, Chlorobenzenes, DCA, and 1,1,1-TCA)	Pre-design	PRP Lead	Gerallyn Valls, Ruth Rzepski 215-597-8186 FTS 597-8186
Tyson's Dump, PA, 03 (03/31/88)	Vacuum Extraction	Commercial Surface Impoundment	Soil (30,000 cy)	VOCs (Benzene, Toluene, TCE, PCE, and Trichloropropane)	Operational since 11/88	PRP Lead; Terra Vac	Eugene Dennis 215-597-8555 FTS 597-8555

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Vacuum Extraction

Site Name, State, Region (ROD Date)	Specific Technology	Site Category	Media (Quantity)	Key Contaminants Treated	Status	Lead; Treatment Contractor	Contacts/ Phone
Kysor Industrial, MI, 05 (09/29/89)	Vacuum Extraction	Truck Parts Manufacturing	Soil (13,200 cy)	VOCs (Xylene, Toluene, Ethylbenzene, and TCE)	In Design	Fund Lead/Negotiation Fishbeck, Thompson, and Carr Huber	Mary L. Gustafson 312-886-6144 FTS 886-6144
Long Prairie, MN, 05 (06/27/88)	Vacuum Extraction	Dry Cleaning Facility	Soil (3,600 cy)	VOCs (DCE, PCE, TCE, and Vinyl Chloride)	In Design	State Lead/Fund Financed	Kevin Turner 312-886-4444 FTS 886-4444
MIDCO I, IN, 05 (06/30/89)	Vapor Extraction	Commercial Dump Site	Soil (12,400 cy)	VOCs (BTX, TCE, Phenol, Dichloromethane, 2-Butanone, and Chlorobenzene), PAHs, and SVOCs	In Design	PRP Lead	Richard Boice 312-886-4740 FTS 886-4740
Miami County Incinerator, OH, 05 (06/30/89)	Vapor Extraction	Municipal Landfill and Surface Impoundment	Soil (98,000 cy)	VOCs (TCE, PCE, and Toluene)	Pre-design	PRP Lead	Anthony Rutter 312-886-8961 FTS 886-8961
Pristine, OH, 05 (12/31/87)	Vapor Extraction	Commercial Dump Site	Soil (38,720 cy)	VOCs (Benzene, Chloroform, 1-2 DCA, 1-2 DCE, Trichloroethene)	Pre-design	PRP Lead	Thomas Alcamo 312-886-7278 FTS 886-7278
Seymour Recycling, IN, 05 (09/30/87) Also see Bioremediation	Vacuum Extraction	Chemical Waste Management & Incineration	Soil (154,000 cy)	VOCs (TCA, Carbon Tetrachloride, PCE, Benzene, Vinyl Chloride, Chloroethane, and TCE)	Installation underway; will be operational Spring 1991	PRP Lead; Canonie Environment	Jeff Gore 312-886-4747 FTS 886-4747
Verona Well Field, MI, 05 (08/12/85)	Vacuum Extraction	Railroad Paint Shop, Solvent Reclaiming/ Distribution	Soil (35,000 cy)	VOCs (Dichloromethane, Chloroform, Carbon Tetrachloride, DCA, TCA, Vinyl Chloride, BTEX) and Naphthalene	Operational since 3/88	Fund Lead/Negotiation; Terra Vac	Margaret Guerriero 312-886-0399 FTS 886-0399
Wausau Groundwater Contamination, WI, 05 (09/29/89)	Vapor Extraction	Bulk Chemical Distribution, Machine Shop	Soil (1,300 cy)	TCE, PCE, and DCE	In Design	PRP Lead; Terra Vac	Margaret Guerriero 312-886-0399 FTS 886-0399
South Valley/Edmunds, NM, 06 (09/30/88)	Vapor Extraction	Aircraft Engine Manufacturing	Soil (36,000 cy)	VOCs (TCE)	In Design	PRP Lead	Tim Underwood 214-655-6730 FTS 255-6730

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TABLE 3 (Continued)

January, 1991

Vacuum Extraction

Site Name, State, Region (ROD Date)	Specific Technology	Site Category	Media (Quantity)	Key Contaminants Treated	Status	Lead; Treatment Contractor	Contacts/ Phone
Hastings Groundwater Contamination, NE, 07 (09/26/89)	Vapor Extraction	Former Grain Storage Area (Fumigants)	Soil (quantity not available)	VOCs (Carbon Tetrachloride, Ethylene Dibromide, PCE, TCA, and Chloroform)	In Design	PRP Lead	Darrel Sommerhauser 913-551-7052 FTS 276-7052
Hastings Groundwater Contamination, Colorado Ave., NE, 07 (09/28/88)	Vapor Extraction	Industrial Metal Finishing	Soil (42,700 cy)	VOCs (PCE, TCE, and TCA)	In Design	PRP Lead	Darrel Sommerhauser 913-551-7052 FTS 276-7052
Hastings Groundwater Contamination, Far-Mar-Co, NE, 07 (09/30/88)	Vapor Extraction	Former Grain Storage Area (Fumigants)	Soil (400 cy)	VOCs (Carbon Tetrachloride, Ethylene Dibromide, PCE, and TCA)	In Design	PRP Lead	Darrel Sommerhauser 913-551-7052 FTS 276-7052
Sand Creek Industrial, CO, 08 (09/29/89)	Vacuum Extraction	Refinery and Pesticides Manufacturing	Soil (>100,000 cy)	VOCs (TCE, PCE, methylene chloride, and Chloroform)	Design completed; will install after Non-Aqueous Phase Liquid addressed	Fund Lead; URS	Brian Pinkowski 303-293-1512 FTS 330-1512
Fairchild Semiconductor (San Jose), CA, 09 (03/20/89)	Vapor Extraction	Semiconductor Manufacturing Facility	Soil (3,400 cy)	VOCs (TCA, Xylenes, Acetone, Freon, DCE, and PCE)	Operational since 1988	PRP Lead/ State Enforcement; Canonie Environment	Helen McKinley 415-744-2236 FTS 484-2236 Will Bruhns (CA) 415-464-0838
Fairchild Semiconductor/ MTV-I, CA, 09 (06/09/89)	Vapor Extraction	Semiconductor Manufacturing Facility, Metal Finisher	Soil (quantity not available)	VOCs (TCE, PCE, Vinyl Chlorides, DCA, DCE, and Freon) and Phenol	Pre-design	PRP Lead	Pattie Collins 415-744-2229 FTS 484-2229
Fairchild Semiconductor/MTV-II, CA, 09 (06/30/89)	Vapor Extraction	Semiconductor Manufacturing Facility, Metal Finisher	Soil (quantity not available)	VOCs (TCE, PCE, Vinyl Chlorides, DCA, DCE, and Freon) and Phenol	Pre-design	PRP Lead	Pattie Collins 415-744-2229 FTS 484-2229

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TABLE 3 (Continued)

January, 1991

Vacuum Extraction

Site Name, State, Region (ROD Date)	Specific Technology	Site Category	Media (Quantity)	Key Contaminants Treated	Status	Lead; Treatment Contractor	Contacts/ Phone
Fairchild/Intel, CA, 09 (06/09/89)	Vapor Extraction	Semiconductor Manufacturing Facility, Metal Finisher, Aircraft Maintenance	Soil (quantity not available)	VOCs (TCE, PCE, Vinyl Chlorides, DCA, DCE, and Freon) and Phenol	Pre-design	PRP Lead	Pattie Collins 415-744-2229 FTS 484-2229
Fairchild/Raytheon, CA, 09 (06/09/89)	Vapor Extraction	Semiconductor Manufacturing Facility, Metal Finisher, Aircraft Maintenance	Soil (quantity not available)	VOCs (TCE, PCE, Vinyl Chlorides, DCA, DCE, and Freon) and Phenol	Pre-design	PRP Lead	Pattie Collins 415-744-2229 FTS 484-2229
IBM (San Jose), CA, 09 (12/15/88) (site delisted 10/04/89)	Vapor Extraction	Computer Manufacturer	Soil (24,000 cy)	VOCs (Xylenes, Acetone, Freon, isopropyl alcohol, petroleum naphtha, and TCA)	Installation underway; will be operational in 1991	PRP Lead/ State Enforcement; Terra Vac	Helen McKinley 415-744-2236 FTS 484-2236 Will Bruhns (CA) 415-464-0838
Motorola 52nd Street, AZ, 09 (09/30/88)	Vapor Extraction	Manufacturing Facility	Soil (quantity not available)	VOCs (TCA, TCE, Carbon Tetrachloride, and Ethylbenzene)	In Design	PRP Lead/ State Enforcement	Mike Montgomery 415-744-2394 FTS 484-2360 Don Atkinson (CA) 602-257-6899
Phoenix-Goodyear Airport Area, AZ, 09 (09/26/89)	Vapor Extraction	Defense-related Manufacturing Facility	Soil (4,390 cy)	VOCs (TCE, PCE, and Acetone) and Methyl ethyl ketone	In Design	PRP Lead	Craig Cooper 415-744-2360 FTS 484-2360

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APPENDIX A
DOCUMENT REQUEST FORM

The "Innovative Treatment Technologies: Semi-Annual Status Report" (EPA/540/2-91/001) is distributed twice a year to Superfund management in U.S. EPA Headquarters and regional offices, pertinent EPA laboratories, states, EPA libraries, and representatives of other federal agencies. All project contacts listed in the report also receive a copy. If you did not already receive this report directly, and would like to get on the mailing list, please complete the following form, and send to:

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