# APPENDIX A

# SELECTED REMEDIATION TECHNOLOGIES AND ASSOCIATED POTENTIAL RELEASES

This appendix contains two exhibits designed to assist during the FS in identifying some of the potential releases that are associated with commonly used remediation technologies. Exhibit A-1 briefly describes each of the process options of each technology in Exhibit A-2. Exhibit A-2 summarizes several potential releases to air or water of common remedial technologies. Process variations for which potential releases are similar are combined under the technology category. Potential releases to surface water or ground water are included in the "water" column. "Other" releases include treatment residuals that need further treatment or proper disposal. In most cases, this column refers to sludge or solid residues that may also be hazardous.

Risk Reduction Engineering Laboratory (RREL; Cincinnati, Ohio) plans and conducts engineering, research, and development related to treatment of solid and hazardous wastes. RREL personnel provide site-specific technical services involving specific treatment technologies and CERCLA response processes including:

- analysis of treatment alternatives,
- treatability studies,
- remedial design review,
- construction QA/QC methods, and
- contaminant source control and geotechnical test methods.

Regional EPA CERCLA staff should direct questions regarding evaluations of remediation technologies, previous experience with remediation technologies, and releases associated with remediation technologies to the Engineering and Treatment Technical Support Center, RREL at FTS 684-7406 or 513-569-7406.

# EXHIBIT A-1

## REMEDIATION TECHNOLOGY DESCRIPTIONS

| Technologies | Description of Process |
|---|---|
| **SOIL AND SLUDGE** | |
| **Soil Handling** | |
| Soil Excavation, Transport, Dumping, and Grading | These processes use mechanized equipment to move contaminated soil. For some treatment techniques, soil must be removed from a contaminated site and be transported for treatment. Soil is then returned and replaced at either the original excavation or another disposal site. Grading is a technique which can reduce infiltration into contaminated soils and can also control runoff. |
| **Thermal Destruction** | These are destruction processes which control temperature and oxygen availability, and convert hazardous materials to carbon dioxide, water, and other products of combustion. |
| Circulating Bed Incineration | Wastes and auxiliary fuel are introduced into the combustion chamber. Air is forced up through the chamber from the bottom to promote mixing and complete combustion. Particulate and gaseous products of combustion exit from the top of the combustion chamber for treatment and disposal. |
| Rotary Kiln Incineration | The combustion chamber is a rotating, inclined cylinder which mixes combusting materials as it rotates. Wastes are fed into the chamber at the high end, along with air and auxiliary fuel. Exhaust gases are treated and released, and ash residue is collected on the low end of the kiln. |
| Fluidized Bed Incineration | A bed of inert particles (e.g., sand) lies at the bottom of the cylindrical combustion chamber. Air is forced up through the bed and the particles are fluidized (i.e., the particles "float" in the airstream). Wastes and fuel are injected at the top of the chamber, into the fluidized mass, where the mixture combusts. The turbulent atmosphere in the chamber provides good mixing of wastes to ensure complete combustion and efficient heat transfer. |
| Infrared Incineration | Waste materials are fed into the furnace on a conveyor belt, and pass through on a wire mesh belt. Heating elements provide infrared energy, oxidizing the materials. Waste gases are passed through a secondary combustion chamber; ash exits on the conveyor. |
| Pyrolysis | Organics are slowly volatilized at lower temperatures than incineration processes. Waste is fed into the primary combustion chamber and thermally treated without sufficient oxygen to completely combust. Volatilized organics pass to a secondary chamber and are incinerated. Solid residues from the primary chamber receive other treatment. |

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## EXHIBIT A-1 (Continued)

## REMEDIATION TECHNOLOGY DESCRIPTIONS

| Technologies | Description of Process |
|---|---|
| Wet Air Oxidation | The high temperature and high pressure properties of water are utilized in destroying wastes. Contaminated solutions are treated at high temperatures (>600° C) and pressures (3400 psi to 3700 psi). Contaminants are oxidized to simple organic compounds as large amounts of oxygen are dissolved in solution. |
| Aqueous Thermal Decomposition | Aqueous thermal decomposition works on the same principles as wet air oxidation, without the addition of excess oxygen. |
| **Dechlorination** | |
| Glycolate Dechlorination | Using a specific solvent, chlorine atom(s) are removed from chlorinated hazardous materials, and toxic compounds are converted to less toxic, more water-soluble compounds. Reaction products are more easily removed from soil and more easily treated. |
| **Biological Treatment** | |
| Composting | Contaminated material is mixed with bulking agents (e.g., sawdust, wood chips) and placed in reactor vessels or piles. Aeration, temperature, and nutrient levels are controlled to encourage microbial growth. Microorganisms then metabolize contaminants, breaking them down into less-harmful materials. |
| In-situ Biodegradation | Microorganisms are encouraged to decompose contaminants in soil without excavating the soil and placing it in a controlled reactor. Nutrients, oxygen, and other necessary materials can be injected into the contaminated area. |
| Slurry-phase Biodegradation | The wastes are mixed with water to achieve an aqueous mixture. The mixture is then treated in a bioreactor, where it is mixed continuously to contact microorganisms and contaminants. The bioreactor serves as a controlled environment for contaminant degradation. |
| Solid-phase Biodegradation | Soils are excavated and treated above ground so that treatment conditions can be closely monitored and adjusted to conditions that are ideal for biodegradation. Materials are treated in a prepared area which can include volatile emissions collection and leachate collection. |

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## EXHIBIT A-1 (Continued)

## REMEDIATION TECHNOLOGY DESCRIPTIONS

| Technologies | Description of Process |
|---|---|
| **Vacuum/Vapor Extraction, Thermal Desorption** | |
| Low Temperature Thermal Stripping | Air, pressure, heat, and/or mechanical agitation provides a driving force for volatilizing and removing contaminants from soil into an airstream for further treatment. Separating contaminants from soil simplifies the final treatment of contaminants. |
| In-situ Vacuum/Steam Extraction | VOCs are removed from soil by applying a vacuum to wells that are placed in the contaminated soil. VOC vapors are collected and treated above ground. Some systems also inject hot air or steam into contaminated zones, raising temperatures and volatilizing organic chemicals. |
| **Chemical Extraction & Soil Washing** | |
| In-situ Chemical Treatment | Treatment chemicals are applied directly to contaminated soil. A variety of compounds can be applied, including neutralizing agents, oxidants, solidification/stabilization agents, and nutrients for biological treatment. |
| Chemical Extraction & Soil Washing | Contaminants are washed from the excavated soil into a chemical solvent. The liquid is treated to remove and destroy contaminants, and the solvent is reused. |
| In-situ Soil Flushing | Inorganic or organic contaminants are extracted from soil by washing the soil with solvents. Solvents are recovered, contaminants are extracted, and the solvents are recirculated through the soils. |
| **Immobilization** | |
| Capping | Contaminated soil is covered with low-permeability layers of synthetic textiles or clay. The cap is designed to limit infiltration of precipitation and thus prevent migration of contaminants away from the site and into ground water. |
| Solidification/Stabilization | Wastes are converted to chemically stable forms or are bound in a stable matrix. Chemical reactions are utilized to transform hazardous materials into new, non-hazardous materials. The goal is to prevent migration of contaminants. |
| In-situ Vitrification | Electrodes are placed vertically into the contaminated soil region, and an electrical current is applied. The soil is melted by the resulting high temperatures. When the melt cools and solidifies, the resulting material is stable and glass-like, with contaminants bound in the solid. |

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## EXHIBIT A-1 (Continued)

## REMEDIATION TECHNOLOGY DESCRIPTIONS

| Technologies | Description of Process |
|---|---|
| **GROUND AND SURFACE WATER** | |
| **Natural Attenuation** | Contaminants in an aquifer disperse and dilute through natural ground-water transport. Some natural degradation may occur. |
| **Aeration/Air Stripping** | Contaminants, usually volatile organic compounds, are transferred from liquid phase to gaseous phase. By contacting contaminated water with clean air, dissolved VOCs are transferred to the airstream to create equilibrium between the phases. The process takes place in a cylindrical tower packed with inert material which allows sufficient air/water contact to remove volatiles from water. Contaminants are then removed from the airstream. |
| **Filtration** | Filtration removes suspended solids from liquids by passing the mixture through a porous medium. |
| **Sedimentation** | Solids that are more dense than liquid settle by gravity and can be removed from the liquid. Chemicals to aid settling may be added. Settled solids result in a sludge which may be treated further. |
| **Granular Activated Carbon (GAC) Adsorption** | GAC is packed in vertical columns, and contaminated water flows through it by gravity. GAC has a high surface area to volume ratio, and many compounds readily bond to the carbon surfaces. Contaminants from water are thus adsorbed to the carbon, and effluent water has a lower contaminant concentration. Water may be passed through several of these columns to complete contaminant removal. Spent carbon (i.e., carbon that has reached its maximum adsorption capacity) is regenerated by incineration. |
| **Ion Exchange** | As contaminated water flows through the reactor vessel, ions of contaminants are adsorbed to a synthetic resin in the vessel. The resin attracts and adsorbs contaminant ions, while releasing non-harmful ions into the treated water. |
| **Chemical Treatment** | Chemicals can be added to contaminated waters to chemically change or to remove constituents. Precipitation can be accomplished through pH control; solutions can be neutralized; contaminants can be oxidized; and solids can be settled out of solution. |
| **Biological Treatment** | Microorganisms in controlled-environment reactors are utilized to decompose contaminants in water. Nutrients, pH, temperature, and oxygen availability are controlled. The organisms degrade contaminants into simpler, safer compounds. |

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## EXHIBIT A-1 (Continued)

## REMEDIATION TECHNOLOGY DESCRIPTIONS

| Technologies | Description of Process |
|---|---|
| **Membrane Separation** | |
| Reverse Osmosis | A semi-permeable membrane is used to separate dissolved contaminants from liquids. High pressure is applied to the contaminated solution, which drives only the liquid through the membrane. The result is a highly concentrated contaminated solution on the high pressure side of the membrane, and a purified liquid on the opposite side of the membrane. |
| Electrodialysis | This process concentrates ionic species that are in aqueous solution. The solution is passed through alternate cation-permeable and anion-permeable membranes that have an applied electric potential. This potential provides a driving force for ion migration. |

# EXHIBIT A-2

## REMEDIATION TECHNOLOGIES AND SOME POTENTIALLY SIGNIFICANT RELEASES

| Technologies | Air | Water[a] | Other[b] |
|---|---|---|---|
| **SOIL AND SLUDGE TECHNOLOGIES** | | | |
| **Soil Handling** | | | |
| Soil Excavation, Transport, Dumping, Screening and Grading | • Fugitive emissions of particulates and volatiles | • Runoff or leaching of contaminants to surface or ground water | • Seepage or runoff to nearby soil |
| **Thermal Destruction** | | | |
| Incineration: Rotary Kiln, Fluidized Bed, Circulating Bed, and Infrared | • Fugitive and stack emissions of metal fumes; particulates, including metals and salts; and products of incomplete combustion, including organic compounds, acid gases, CO, $NO_x$, and $SO_x$ | • Discharge of scrubber liquor and blowdown | • Disposal of ash and other solid residues |
| Pyrolysis | • Fugitive and stack emissions of metal fumes; particulates, including metals and salts; and products of incomplete combustion, including organic compounds, acid gases, CO, $NO_x$, and $SO_x$ | • Discharge of scrubber liquor and blowdown | • Disposal of ash and other solid residues |
| Wet Air Oxidation | • Fugitive emissions of volatile organic compounds | • Discharge of metals and unoxidized organics | • Disposal of sludge residues |
| Aqueous Thermal Decomposition | • Fugitive emissions of volatile organic compounds | • Discharge of metals and unoxidized organics | • Disposal of sludge residues |

(Continued)

## EXHIBIT A-2 (Continued)

## REMEDIATION TECHNOLOGIES AND SOME POTENTIALLY SIGNIFICANT RELEASES

| Technologies | Air | Water[a] | Other[b] |
|---|---|---|---|
| **Dechlorination** | | | |
| Glycolate Dechlorination | • Fugitive emissions of volatile organic compounds | • Discharge of spent solvents and degraded contaminants to surface water, or leaching to ground water | |
| **Biological Treatment** | | | |
| Composting | • Fugitive emissions of particulates and volatile organics | • Leaching of metals and/or organics | |
| In-situ Biodegradation | • Fugitive emissions of volatile organics | • Leaching of metals and/or organics<br>• Discharge of treated water | |
| Slurry-phase or Solid-phase Biodegradation | • Fugitive emissions of volatile organics | • Discharge of non-degraded byproducts in slurry liquor and treated effluent<br>• Runoff to surface water or to ground water (with solid-phase process) | • Disposal of residual biomass which may contain hazardous metals and refractory organics |
| **Vacuum/Vapor Extraction, Thermal Desorption** | | | |
| Low Temperature Thermal Stripping | • Stack emissions of volatile organics<br>• Fugitive emissions of volatile organics | • Discharge of scrubber blowdown<br>• Discharge of contaminant condensate | |
| In-situ Vacuum/Steam Extraction | • Fugitive emissions of volatile organics | • Discharge of contaminant or water condensate | • Disposal or regeneration of spent activated carbon |

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## EXHIBIT A-2 (Continued)

## REMEDIATION TECHNOLOGIES AND SOME POTENTIALLY SIGNIFICANT RELEASES

| Technologies | Air | Water[a] | Other[b] |
|---|---|---|---|
| **Chemical Extraction & Soil Washing** | | | |
| In-situ Chemical Treatment | • Fugitive emissions of volatile organic compounds | • Runoff of uncontained treatment chemicals | • Possible solvent residuals in treated soil |
| Chemical or Solvent Extraction | • Fugitive emissions of volatile organic compounds | • Post-extraction discharge of wastewater with extracted contaminants | • Possible solvent residuals in treated soil |
| Soil Washing | • Fugitive emissions of volatile organic compounds | • Post-washing discharge of wastewater with extracted contaminants | • Discharge of foam with metals and organics<br>• Deposition of sedimentation sludge residuals<br>• Deposition of untreated, contaminated fines |
| In-situ Soil Flushing | • Fugitive emissions of volatile organic compounds | • Leaching of contaminated flush water, acids, bases, chelating agents, or surfactants | |
| **Immobilization** | | | |
| Capping | • Fugitive emissions of particulates and volatiles during cap construction | • Leaching of contaminants to ground water | • Lateral movement of volatile organic compounds after capping |
| Solidification/Stabilization | • Fugitive emissions of particulates and volatiles | • None likely | • Potential leaching to soils and ground water of contaminants from deposited material over time |

(Continued)

## EXHIBIT A-2 (Continued)

## REMEDIATION TECHNOLOGIES AND SOME POTENTIALLY SIGNIFICANT RELEASES

| Technologies | Air | Water[a] | Other[b] |
|---|---|---|---|
| In-situ Vitrification | • Surface fugitive emissions of volatile organics and volatile metals during the process | • Discharge of scrubber solution<br>• Possible contamination of ground water under the treatment area | • Potential lateral migration of vaporized or leached contaminants into the soil that surrounds the vitrified monolith |
| **GROUNDWATER AND SURFACE WATER TECHNOLOGIES** | | | |
| **Non-Treatment Actions** | | | |
| Natural Attenuation | • Emissions of volatile organic compounds | • Aquifer discharge to surface water<br>• Continued aquifer transport of contaminants | |
| Pump without Treatment | • Emissions of volatile organic compounds | • Discharge of untreated water to surface water or Publicly Owned Treatment Works (POTW)<br>• Seepage of untreated water | • Disposal of sludge residuals from POTW |
| **Air Stripping** | • Stack and fugitive emissions of volatile organics | • Discharge to surface water of effluent treated water with residual metals, particulates, or nonvolatile organics | • Disposal of backwash or cleaning residues |
| **Filtration/Settling** | • Fugitive emissions of volatile organic compounds from settling basin | • Discharge of effluent water containing dissolved solids or unremoved particles | • Disposal of filter cake or sludge containing organics, metals, or other inorganics |
| **Granular Activated Carbon Adsorption** | • None likely | • Discharge of effluent with non-adsorbable, low molecular weight compounds | • Disposal and/or regeneration of spent carbon |

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## EXHIBIT A-2 (Continued)

## REMEDIATION TECHNOLOGIES AND SOME POTENTIALLY SIGNIFICANT RELEASES

| Technologies | Air | Water[a] | Other[b] |
|---|---|---|---|
| **Ion Exchange** | • None likely | • Discharge of backwash water | • Disposal and/or regeneration of spent resins |
| **Chemical Treatment** | • Fugitive emissions of volatile organic compounds from treatment tanks | • Discharge of effluent with treatment residues | • Disposal of treatment sludges |
| **Biological Treatment** | • Emissions of volatile organics in aerobic treatment or due to aeration | • Discharge of effluent with unremoved solids | • Disposal of treatment sludges |
| **Membrane Separation** | | | |
| Reverse Osmosis | • None likely | • Discharge of effluent containing unfiltered organics (depends on filter membrane used) | • Discharge of concentrate stream with contaminants removed from treated water |
| Electrodialysis | • None likely | • Discharge of treated effluent | • Discharge of concentrate stream with contaminants removed from treated water |

Notes:

[a] In general, seepage and leaching are more likely to affect ground water, but could also contaminate surface water. Runoff and discharge are releases that will most likely contaminate surface water, but could also contaminate ground water.

[b] Other releases include treatment residuals that need further treatment or proper disposal. In most cases, this column refers to sludge or solid residues that may also be hazardous.

# REFERENCES FOR APPENDIX A


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