

TECHNICAL MEMORANDUM FOR THE
IDENTIFICATION OF CANDIDATE
TECHNOLOGIES
LCP CHEMICALS, INC. SUPERFUND SITE
LINDEN, NEW JERSEY

Prepared for
ISP Environmental Services Inc., Wayne, NJ
April 2008
Revised November 2008

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April 2008

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TABLE OF CONTENTS

1. INTRODUCTION.....	1-1
2. SITE CHARACTERIZATION SUMMARY.....	2-1
2.1 Site Location and Description.....	2-1
2.2 Hydrogeologic Conditions.....	2-1
2.3 Chemical Constituents.....	2-2
3. IDENTIFICATION OF CANDIDATE TECHNOLOGIES AND PRELIMINARY SCREENING.....	3-1
3.1 Mercury Remediation Considerations.....	3-1
3.2 Identification of Candidate Remediation Technologies.....	3-2
3.3 Preliminary Screening.....	3-2
4. CONCLUSIONS.....	4-1
5. REFERENCES.....	5-1

APPENDIX

Appendix A Candidate Technology Descriptions

LIST OF TABLES

Table 1 Identification of Candidate Technologies and Preliminary Screening

1. INTRODUCTION

This Technical Memorandum for Identification of Candidate Technologies identifies candidate technologies that may be considered for the remediation of the LCP Chemicals, Inc. Superfund Site, located in Linden, New Jersey. This task has been performed as a part of the Remedial Investigation/Feasibility Study (RI/FS) that is currently being conducted by ISP Environmental Services Inc. (ISP-ESI) in accordance with Administrative Order No. II CERCLA-02-99-2015 (hereinafter referred to as the Order) issued by USEPA and as executed by ISP-ESI on May 13, 1999. A Technical Memorandum for the Identification of Candidate Technologies, dated August 6, 2002, was previously prepared by Brown and Caldwell and submitted to USEPA following the Phase I Remedial Investigation. Subsequently a Phase II Remedial Investigation was conducted, which was documented in the Phase II Site Characterization Summary Report (SCSR) prepared by Brown and Caldwell and dated September 2007. A second technical memorandum was then prepared by Brown and Caldwell, dated April 2008. Since the completion of the Phase II SCSR and April 2008 Technical Memorandum, the Remedial Investigation was completed and submitted in September 2008 and the Risk Assessment (RA) was completed and submitted in October 2008. This technical memorandum represents an update of the April 2008 Technical Memorandum for the Identification of Candidate Technologies following completion of the RI and RA and based on comments received from the USEPA via electronic mail dated November 18, 2008. This document is presented in accordance with the requirements of Section VII.25.D of the Order.

In addition to identification of candidate technologies, this memorandum presents the results of a preliminary screening of remedial technologies. The preliminary screening was conducted on the basis of technical implementability of remedial technologies to address the primary constituent of concern (COC): mercury. The screening also includes a preliminary evaluation of the potential applicability of remedial technologies to address other potential COCs. The preliminary screening task does not represent the CERCLA technology/process option screening, which will be conducted subsequently per Section VII.25.G of the Order. Also, the preliminary screening does not serve to eliminate any of the identified technologies from further consideration, as each technology will be evaluated in the subsequent CERCLA technology screening step as part of the Feasibility Study. Rather the preliminary screening serves to provide an initial evaluation of the status of various technologies with respect to mercury remediation.

2. SITE CHARACTERIZATION SUMMARY

2.1 Site Location and Description

The LCP Chemicals Inc. Superfund Site (LCP Site) is located in the Tremley Point section of the City of Linden, Union County, New Jersey along the western shore of the Arthur Kill. The site was an industrial complex with a variety of operations. A mercury-cell chlorine production (chlor-alkali) plant was operated at the site from 1955 until cessation of manufacturing operations in 1985 and included a mercury-cell chlorine process area, hydrogen gas processing plant, and sodium hypochlorite manufacturing area. The site was used as a terminal for products produced at other facilities and various other industrial operations. In addition, a variety of tenants operated on site until it was closed in August 1994.

The area surrounding the LCP Site had been historically developed for heavy industrial use, much of which is currently inactive. Primary active land use in the area is bulk storage and transport of petroleum products and aggregate.

Tidal wetlands are known to have existed in this area. The placement of anthropogenic fill to raise the grade for industrial development is known to have occurred starting in the 1880s along the margins of the Arthur Kill. South Branch Creek is a tidal water body that currently drains much of the site to the Arthur Kill.

2.2 Hydrogeologic Conditions

In accordance with the RI, the following observations have been made regarding the hydrogeologic conditions at the LCP site:

- The following stratigraphic units were encountered beneath the LCP site:
 - Anthropogenic fill that continuously overlies the site with a range of thickness of 0.7 to 17 feet, and an average thickness of approximately 9 feet.
 - Marine tidal marsh deposits ranging in thickness from 5 to 10.5 feet. The unit has been subdivided into two subunits, including a peat layer and an organic silt and clay layer.
 - Glacial till ranging in thickness from 18.5 to 20.5 feet.
 - Passaic formation bedrock consisting of red-brown shales and siltstones.
- Three distinct, laterally continuous hydrostratigraphic zones exist at the site, including:
 - The uppermost water-bearing zone contained within the Fill and the Peat subunit of the Tidal Marsh deposits, termed the “overburden water-bearing zone”.
 - The aquitard consisting of the Organic Silt & Clay subunit of the tidal marsh deposits (where present) and the Glacial Till.
 - The aquifer contained within the upper portion of the Passaic Formation bedrock, termed the “bedrock water-bearing zone”.

- The shallow groundwater flows toward and discharges to the surface water features including South Branch Creek and the tidal ditch located immediately south of the site. A water table mound is evident in the center of the site, located between the two ditches.
- A regionally extensive aquifer exists within the competent bedrock portion of the Passaic formation that flows regionally east towards the Arthur Kill, its ultimate point of discharge. This pattern of bedrock groundwater flow is confirmed by the measurements made in the bedrock monitoring wells on the LCP site.
- Pumping from the bedrock water-bearing zone as part of the groundwater remediation at the adjacent ISP Linden facility creates a reversal of groundwater flow and provides bedrock groundwater capture for nearly all but the most easterly portions of the LCP site.
- No community public water supply wells exist within a two-mile radius of the site. The nearest is approximately three miles upgradient from the site.
- Due to the proximity of the Arthur Kill and other tidal waters groundwater in this area is naturally saline. Groundwater quality meets the definition of Class III-B and is thus not suitable for conversion to potable uses. An application has been submitted to NJDEP to request concurrence that the Class III-B classification applies to the site.

2.3 Chemical Constituents

Chemical concentrations in various media were screened against available regulatory values for the purpose of identifying chemicals that may require further evaluation. Risk Assessment has been completed (October 2008) as part of the RI..

The primary constituent of interest at the LCP Site is mercury. Mercury has been detected in various media including soil, groundwater, sediment, surface water, and building materials. During remedial investigation activities visible, metallic mercury was observed in soil samples. The remedial investigation results indicate that mercury impacts in soil, as evidenced by observations of visible metallic mercury or concentrations exceeding the current New Jersey Non Residential Direct Contact Soil Cleanup Criteria (NRDCSCC) (270 mg/kg), are primarily located in the vicinity of the former production buildings. At depth, mercury concentrations tend to be lower. The results of selective sequential extraction conducted on site soil samples reveal that mercury in soil is primarily present in insoluble forms including elemental (metallic) mercury and mercury sulfide. The low solubility of mercury at the LCP site is supported by the observed low concentration and limited migration in groundwater, as discussed below.

In groundwater, exceedances of the New Jersey Groundwater Quality Standard (NJGWQS) for mercury (2 µg/L) are primarily located within the overburden deposits in the vicinity of the former mercury cell buildings. In overburden groundwater mercury concentrations range from non-detect to 233 µg/L for non-filtered samples and 164 µg/L for filtered samples. To the east of the production area, total mercury concentrations decrease to below the NJGWQS. Mercury concentrations in bedrock groundwater are substantially lower than in the overburden (i.e., ranging from non-detect to 11 µg/L for both non-filtered and filtered samples).

Mercury has been detected in low marsh soil and sediment associated with South Branch Creek, a man-made, tidal channel located on the eastern portion of the LCP Site, which extends to the Arthur Kill. Mercury concentrations in sediment exceed Effects Range – Low (ER-L) and Effects Range – Median

(ER-M) screening values in both on-site samples and samples collected from the Arthur Kill and a nearby Reference Channel.

Other metals including arsenic, beryllium, chromium, copper, lead, and zinc have also been detected in site media. The RI data suggest that the occurrence of most other metals is not linked with site operations; rather it is most likely associated with the presence of anthropogenic fill materials.

Organic constituents have been identified at the LCP Site, including polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-furans (PCDFs) and polychlorinated dibenzo-p-dioxins (PCDDs), polycyclic aromatic hydrocarbons (PAHs), and various other organic compounds, including benzene, chlorobenzenes, methylene chloride, and hexachlorobutadiene. In site soil and groundwater, the PCBs, PCDDs, and PAHs appear to be associated with anthropogenic fill and urban background. Other organics, the most prevalent of which are benzene and chlorobenzenes, infrequently exceed applicable criteria and generally decrease in concentration with increasing depth.

3. IDENTIFICATION OF CANDIDATE TECHNOLOGIES AND PRELIMINARY SCREENING

Based on the results from the RI activities completed to date, candidate remediation technologies have been identified for the LCP Site to address the various constituents (COC) and media of concern that have been reported for the LCP Site. The identification of candidate technologies and preliminary screening has been focused on the primary COC at the LCP Site: mercury. In addition, the potential applicability of remedial technologies to address other potential COCs has also been preliminarily evaluated. Management of the risks associated with mercury is anticipated to manage and address the risks associated with other COCs.

3.1 Mercury Remediation Considerations

Remediation technologies for mercury-impacted media must consider the unique physical and chemical properties of mercury as well as regulatory factors.

Mercury can be present in the environment in various forms. The properties, (i.e., water solubility and volatility) and chemical behavior of mercury vary widely among the different species. Mercury in the environment is most frequently encountered as elemental mercury, organic mercury compounds (e.g., methyl mercury), mercury salts [mercury (I) (mercurous) salts or mercury (II) (or mercuric) salts], and mercury oxides. Some of the various species can be inter-converted through biological and other processes occurring within the various media.

Elemental mercury is a silver white, heavy liquid at ambient temperatures. Due to its high surface tension, it forms small compact spherical droplets. The vapor pressure of elemental mercury is high relative to other metals and, as such, mercury can volatilize and represent an air hazard. The solubility of mercury compounds varies greatly ranging from negligible (Hg_2Cl_2 , HgS) to very soluble (HgCl_2 , $\text{Hg}(\text{NO}_3)_2$). Ionized forms of mercury are strongly adsorbed by soils and sediments and are desorbed slowly. In acid soils, most mercury is adsorbed by organic matter. Therefore, the environmental mobility and the risk of exposure to mercury depend on the mercury species present and other environmental conditions (i.e., soil type, geochemistry).

The following results from the RI sampling indicate that mercury at the Site is primarily present in low mobility forms:

- Results from selective sequential extraction conducted on site soil samples reveal that mercury in soil is primarily present in insoluble forms including elemental (metallic) mercury and mercury sulfide.
- Numerous sediment samples were tested for the presence of methyl mercury and revealed that methyl forms constitute a low percentage of the total mercury concentration (0.0015 to 0.059%). The primary forms of mercury that are methylated are soluble forms of divalent ($\text{Hg}+2$) mercury, which have a relatively high solubility compared to other species. Therefore, the low levels of methyl mercury found at the site are an indicator that mercury is in low solubility forms.
- Dissolved mercury in groundwater is either non-detectable or is present at low concentrations, even in areas with relatively high total mercury concentrations in soils.

In addition to chemical and physical considerations for mercury, remediation options must also factor in regulatory considerations. The RCRA Land Disposal Restrictions (LDRs) (40 C.F.R. 268) require treatment of hazardous wastes to Universal Treatment Standards (UTSs) prior to land disposal unless exemptions apply or variances are obtained. The LDRs for mercury impacted hazardous waste (including listed or characteristic) prohibit land disposal of hazardous waste in the high mercury subcategory (i.e., mercury concentration greater than 260 mg/kg) unless an LDR exemption or variance is sought [e.g., Equivalent Method Variance (40 CFR 268.42(b)), Treatability Variance (40 CFR 268.44), and No-Migration Petition (40 CFR 268.60)]. The regulations stipulate that hazardous waste in the high mercury subcategory must be retorted or roasted. The capacity of these treatment technologies is limited and not specifically designed to treat the volumes generated from large-scale site remediation, thus, off-site management of remediation hazardous waste in the high mercury subcategory is impractical. Based on the available information, no listed hazardous wastes are known to be present at the site with the potential exception of sludge contained in the RCRA-closed lagoon, which may be considered a K071 waste (i.e., brine purification muds from mercury cell process in chlorine production, where separately prepurified brine is not used). At this time, no data has been generated to evaluate whether waste is present that exhibits the toxicity characteristic for mercury (i.e., TCLP >0.2 mg/L mercury). The RCRA regulations impact the potential applicability and feasibility of remedial technologies discussed herein, in particular those that include removal, ex situ treatment, and/or off-site disposal.

3.2 Identification of Candidate Remediation Technologies

The list of candidate remediation technologies is presented in Table 1 and a description of each technology is presented in Appendix A. The list was generated based on a review of the available literature, published databases, vendor contacts and prior experience (a list of technical references utilized herein is attached). The list of candidate technologies includes both conventional and innovative remedial technologies. Technologies have been identified for each medium of concern (i.e., soil/sediment, groundwater, surface water, and building debris) and are categorized under the following general response actions:

- Containment
- Disposal
- Ex Situ Treatment
- In Situ Treatment
- Institutional Controls
- Removal

3.3 Preliminary Screening

A preliminary screening of remedial technologies has been performed and the results are presented in Table 1. The preliminary screening was conducted on the basis of technical implementability of remedial technologies to address the primary COC: mercury. The screening also includes a preliminary evaluation of the potential applicability of remedial technologies to address other potential COCs, as presented in Table 1. This task does not represent the CERCLA technology/process option screening, which will be conducted subsequently per Section VII.25.G of the Order. Also, the preliminary screening does not serve to eliminate any of the identified technologies from further consideration, as each technology will be evaluated in the subsequent CERCLA technology screening step as part of the Feasibility Study.

Rather the preliminary screening serves to provide an initial evaluation of the status of various technologies with respect to mercury remediation.

As indicated in Table 1, based on the preliminary technology screening, the remedial technologies that can be categorized under the general response actions of institutional controls, containment, removal, and landfill disposal, are likely to be retained for each medium of concern. Since these technologies have been proven to be effective at other sites and are technically implementable, it is anticipated that they will be retained for further evaluation in the Feasibility Study.

There are a number of potentially applicable in situ and ex situ technologies for mercury remediation of soil, sediment, and groundwater. These technologies include soil washing, chemical leaching, electrokinetics, solidification/stabilization (S/S), and thermal treatment approaches (including retorting, thermal desorption and vitrification). At this point, many of these technologies have not been substantively demonstrated as there are few documented full-scale applications. Based on available case studies, the in situ and ex situ technologies, which appear to have the most potential applicability for the LCP Site, include soil washing and/or chemical leaching, solidification/stabilization, and thermal treatment via retorting.

Based on the preliminary technology screening, the remedial technologies anticipated to be retained for detailed evaluation in the FS are listed below along with the basis for retaining each:

All Media

- **Institutional Controls (ICs):** ICs, including Deed Notices and Classification Exception Areas (CEAs) are likely remedial components of any remedial alternative considered technically practicable for the LCP Site.
- **Monitored Natural Attenuation (MNA):** MNA employs naturally occurring physical, chemical, and biological processes to reduce constituent concentrations and limit constituent migration. Natural attenuation is potentially effective for all constituents and occurs to some extent at every site, although mechanisms vary by constituent and medium (e.g., ionized mercury adsorption, chlorobenzene biodegradation).

Soil/Sediment

- **Caps/Covers:** effective for a wide-range of constituents and can effectively control direct contact risks associated with impacted soil/sediment and limit inter-media transfer of constituents (i.e., soil to groundwater and/or sediment to surface water). Capping alternatives may include measures to mitigate potential vapor migration concerns.
- **Vertical Cutoff Walls:** effective for a wide-range of constituents and can effectively control lateral migration of constituents.
- **Excavation/Dredging:** removal technologies can effectively remove source material from soil and sediment and are effective for all constituent types. The practicality of removal technologies is contingent on the availability of feasible disposal/ex situ treatment options, which must contemplate regulatory considerations and the limited documented effectiveness of ex situ treatment technologies for mercury. In addition, costs and impacts to the community including increased emissions and safety concerns from increased trucking must be considered.
- **Landfill Disposal:** on-site or off-site landfill disposal could effectively contain excavated/dredged materials. The management of waste material is governed by RCRA regulations. The RCRA LDRs

require treatment of hazardous waste to Universal Treatment Standards (UTSs) prior to land disposal. The LDRs prohibit land disposal of hazardous waste in the high mercury subcategory (i.e., mercury concentration greater than 260 mg/kg) unless an LDR exemption or variance is obtained (Note: LDRs require retorting for this material).

- **Ex Situ Soil Washing and/or Chemical Leaching:** effectiveness is primarily dependent on soil characteristics (soil type, grain size distribution, total organic carbon), chemical amendments, and remedial objectives. Available case studies indicate that the technology may be able to reduce leachability, however, achieving a total concentration goal is likely not feasible. Anticipated to be retained for evaluation in the FS as an option to be considered for ex situ treatment prior to off-site or on-site disposal.
- **Solidification/Stabilization:** effectiveness of S/S is primarily dependent on the type of S/S agent, characteristics of the media to be treated, degree of mixing, mercury species present, and remedial objectives. Given the nature of the technology, S/S could only be expected to reduce leachability and would not be effective in achieving a total concentration goal. Available data indicates that mercury mobility is low under existing site conditions and there may be little benefit in applying an S/S technology. S/S is anticipated to be retained for evaluation in the FS as an option to be considered for in situ or ex situ treatment prior to off-site or on-site disposal.
- **Thermal Retorting:** retorting is a commonly used thermal technology for mercury recovery and is considered the EPA Best Demonstrated Available Technology (BDAT) for hazardous waste containing mercury in the high mercury subcategory (i.e., mercury concentration greater than 260 mg/kg). Treatment of mercury via thermal desorption presents off gas treatment concerns as thermal desorption systems are typically designed for treatment of organics, not mercury. Commercial thermal retort capacity is limited and not designed for volumes contemplated for large-scale site remediation. In addition, commercial retort facilities can not accept waste streams with multiple contaminants in addition to the mercury such as PCBs. However, retorting is anticipated to be retained for evaluation in the FS as an option for concentrated waste streams (e.g., following soil washing). ISP would not support shipment of waste material to retorting facilities which distribute recovered mercury into the world market.

Groundwater

- **Caps/Covers:** effective for a wide-range of constituents and can effectively limit inter-media transfer of constituents from soil to groundwater by restricting infiltration. Capping alternatives may include measures to mitigate potential vapor migration concerns.
- **Vertical Cutoff Walls:** effective for a wide-range of constituents and can effectively control lateral migration of constituents and can improve efficiency of groundwater extraction and treatment systems in achieving hydraulic control.
- **Groundwater Extraction:** can effectively and reliably control constituent migration through establishing hydraulic control of site groundwater.
- **Ex Situ Groundwater Treatment:** Treatment of mercury-impacted groundwater is currently being conducted on the adjacent ISP Linden Site¹. Dissolved phase mercury concentrations in the treatment

¹ The treatment system on the adjacent ISP Linden Site is being operated as part of the remedial activities for that Site. Dissolved phase mercury concentrations in the treatment system influent are comparable to those observed at the LCP Site and the system is effective in treating mercury to below the permit limits. Treated effluent is

system influent are comparable to those observed at the LCP Site and the system is effective in treating mercury to within the permit limits. Based on the effective mercury removal observed at ISP Linden Site, if groundwater treatment is a component of the remedy for the LCP Site, then the remedy could consist of discharge to surface water following treatment via metals precipitation, biological treatment, sand filtration, and carbon adsorption. An engineering evaluation would be conducted to assess the capacity of the existing system to accept the increased hydraulic and mass loading from the LCP Site. In addition, an evaluation would be conducted to assess the ability of the system to achieve current and potential future permit limits.

Building Debris

- **Caps/Covers:** effective for a wide-range of constituents and can effectively control direct contact risks associated with impacted building material and limit transfer of constituents from building material to soil and/or groundwater. Capping alternatives may include measures to mitigate potential vapor migration concerns.
- **Vertical Cutoff Walls:** effective for a wide-range of constituents and can effectively control lateral migration of constituents.
- **Landfill Disposal:** on-site or off-site landfill disposal could effectively contain impacted building debris. The management of hazardous waste material is governed by RCRA regulations. The RCRA LDRs include separate treatment standards for hazardous debris (40 C.F.R. 268.45).
- **Debris Washing and/or Chemical Leaching:** effectiveness is primarily dependent on debris characteristics (size, porous vs. non-porous), chemical amendments, and remedial objectives. Anticipated to be retained for evaluation in the FS as an ex situ treatment option to reduce constituent mass prior to off-site or on-site disposal. The RCRA LDRs include treatment standards for hazardous debris (40 C.F.R. 268.45), which include physical extraction (blasting, scarification, and high pressure steam or water sprays) and chemical extraction (acid extraction).
- **Thermal Retorting:** retorting is a commonly used thermal technology for mercury recovery. Treatment of mercury via thermal desorption presents off gas treatment concerns as thermal desorption systems are typically designed for treatment of organics, not mercury. Commercial thermal retort capacity is limited and not designed for the volumes contemplated for large-scale site remediation. However, retorting is anticipated to be retained for evaluation in the FS as an option for heavily impacted building debris. ISP would not support shipment of waste material to retorting facilities which distribute recovered mercury into the world market.

discharged to the Arthur Kill under New Jersey Pollutant Discharge Elimination System – Discharge to Surface Water (NJPDES-DSW) Permit No. NJ0000019.

4. CONCLUSIONS

Based on the foregoing, additional data collection is not deemed necessary at this time. The potential need for treatability studies is currently under evaluation as preliminary work toward preparation of the FS is underway and the RI and RA are under review by the agencies. It is recommended that the need for additional data and/or treatability testing be evaluated as a part of the ongoing RI, RA, and FS process and a final treatability determination be made prior to the development and screening of alternatives step within the FS.

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TABLES

APPENDIX A

Candidate Technology Descriptions

CANDIDATE TECHNOLOGY DESCRIPTIONS

Below is description of each candidate remediation technology identified in Table 1. The list was generated based on a review of the available literature, published databases, vendor contacts and prior experience (a list of technical references utilized herein is attached). The list of candidate technologies includes both conventional and innovative remedial technologies. Technologies have been identified for each medium of concern (i.e., soil/sediment, groundwater, surface water, and building debris) and are categorized under the following general response actions:

- Containment
- Disposal
- Ex Situ Treatment
- In Situ Treatment
- Institutional Controls
- Removal

A preliminary screening of remedial technologies has been performed and the results are presented in Table 1. The preliminary screening was conducted on the basis of technical implementability of remedial technologies to address the primary COC: mercury. The screening also includes a preliminary evaluation of the potential applicability of remedial technologies to address other potential COCs, as presented in Table 1. The preliminary screening serves to provide an initial evaluation of the status of various technologies with respect to mercury remediation. Table 1 indicates whether or not a technology is likely to be retained based on the preliminary screening.

General Response Action - Institutional Controls (Soil, Sediment, and Groundwater)

- **Deed Notices** are established at a site if soil is present above applicable standards following remedial action. If a property is sold, the deed notice will provide notice to subsequent owners and other prospective users (i.e., lessee's, etc.). The deed notice will provide information regarding the site, presence of contaminants and any compliance monitoring requirements. The requirements may include; but not limited to; cap maintenance, inspection requirements and notification requirements, etc. Deed Notices in New Jersey require biennial certification.
- **Classification Exception Areas (CEAs)** are established in order to provide notice that the constituent standards for a given aquifer classification are not or will not be met in a localized area due to natural water quality or anthropogenic influences, and that designated aquifer uses are suspended in the affected area for the term of the CEA. The intent of a CEA is to ensure that the uses of the aquifer are restricted until standards are achieved. CEAs require biennial certification in New Jersey.

General Response Action - Containment (Soil, Sediment, and Groundwater)

- **Covers/Caps** can be made of earthen and/or geosynthetic materials. Covers/ caps range in permeability from low permeability caps, such as clay and/or synthetic materials (e.g., geomembranes), to more permeable covers comprised of vegetation, soils, and/or permeable geosynthetics. They limit or control infiltration of rainwater, runoff, and volatilization. Caps/covers create a layer or layers above impacted soil or waste to control direct contact exposure, as well as migration via erosion or dust.

Sediment covers are comprised of sand or other materials and can be used to reduce exposure to and movement of impacted sediments. Pumping of slurry mixtures or depositing cover materials from a barge are among the methods used. The thickness of the cover may depend on a number of factors including tidal impacts, stream velocity, or potential disturbance from watercraft.

Capping alternatives may include vapor collection and treatment systems (as necessary) to mitigate potential vapor migration concerns.

- **Vertical Cutoff Walls** are used to impede lateral migration of groundwater. A wide variety of methods and materials are used to construct cutoff walls. Commonly used materials include soil-bentonite, cement-bentonite, geomembrane panels, and steel sheet piles. Barrier walls can be coupled with groundwater extraction and treatment to limit pumping required to achieve hydraulic control.
- **Groundwater Extraction and Treatment** involves groundwater extraction through vertical or horizontal wells or through interceptor trenches for above ground treatment. This process, frequently referred to as “pump and treat”, can serve as a hydraulic containment system. As concluded in numerous studies, groundwater recovery seldom has the potential to remediate sites that are not moderately to highly permeable and impacted with at least moderately soluble species.

The extracted water is typically treated above ground by several methods, which may include physical, chemical and biological processes. Methods for treating inorganic species may be different from those used to treat organic species. Inorganic species are removed in some form of pretreatment followed by treatment of the organic species. The treated water is then discharged by one of several methods. Typical methods include recharge to groundwater, discharge to surface waters, and discharge to a Publicly Owned Treatment Works (POTW). Permits (or permit equivalents) are required for the various forms of discharge.

Methods of water treatment for mercury-impacted water are described below (General Response Action – Ex Situ Treatment). Pretreatment to remove calcium, magnesium, iron, etc., may be required.

General Response Action - Removal (Soil/Sediment)

- **Excavation** (complete or partial) of soils can be accomplished by a variety of methods using readily available equipment such as backhoes and front-end loaders. Complete excavation of contaminated soils is the removal of all impacted soils that exceed cleanup goals. Partial excavation is the removal of targeted “hot spots” or “principal threat wastes” when these areas can be isolated and delineated. Excavations can reach significant depths. Shoring may be required where adequate slopes cannot be attained. The soil disturbance associated with excavation may cause elemental mercury to migrate. Also, for mercury impacted soils it is necessary to consider potential for elemental and organic mercury to volatilize and create an air hazard in addition to the usual concerns due to dust.

- **Dredging** of sediments is the counterpart to excavation of soils. Dredging is more complex often due to concerns regarding mobilization of fines into the water body. Methods of dredging include a variety of mechanical, hydraulic and pneumatic equipment. Dewatering of the dredged sediments is frequently required. Sediments may also be treated on-site or off-site by a variety of methods.

Disposal options for removed soil/sediment are dependent upon the waste characteristics and other considerations such as distance to the facilities. Waste classification and characterization analyses determine whether treatment is required prior to landfill disposal or reuse. Ex situ treatment methods of mercury impacted soil/sediment are presented below (General Response Action – Ex Situ Treatment). The disposal and reuse options are more limited for soil/sediment that are classified as listed or characteristic hazardous waste as they are subject to land disposal restrictions and treatment standards.

General Response Action - Disposal

- **Landfill Disposal** Following soil/sediment removal, material may be disposed at a landfill disposal facility. Landfill disposal may include disposal at an approved off-site facility or at an approved facility constructed on-site. Landfill disposal is essentially a containment approach coupled with collection and treatment of impacted water that comes in contact with the constituents (i.e., leachate collection and treatment).

The management of generated mercury-impacted waste is governed by RCRA regulations (40 CFR Parts 260-299). RCRA identifies several types of wastes that contain mercury as “listed hazardous wastes”, including those resulting from the mercury cell process employed at chlor-alkali facilities (Waste Codes K071 and K106). Non-listed mercury wastes may be considered hazardous if the concentration of mercury in an extract from the waste exceeds 0.2 mg/L using the Toxicity Leaching Characteristic Procedure (TCLP). A characteristic mercury hazardous waste receives the waste code D009.

Landfill disposal of wastes containing mercury in the United States is applicable only to non-hazardous waste and hazardous wastes with mercury concentrations less than 260 mg/kg (i.e., low mercury waste category). Prior to landfill disposal pretreatment may be required to stabilize waste that fails the 0.2 mg/L TCLP. Pre-treatment would be conducted to achieve the Universal Treatment Standard of 0.025 mg/L TCLP or the Alternate LDR Treatment Standard for soil, if appropriate (i.e., 90% reduction in mercury TCLP value or total concentration or 10 times the UTS, which ever is less stringent). RCRA LDRs prohibit land disposal of hazardous waste in the high mercury subcategory (i.e., mercury concentration greater than 260 mg/kg). High mercury subcategory hazardous waste must be treated by retorting or roasting unless an LDR exemption or variance is received. Potential LDR exemptions/variances include the Equivalent Method Variance (40 CFR 268.42(b)), Treatability Variance (40 CFR 268.44), and No-Migration Petition (40 CFR 268.60).

Disposal options outside the United States are available for mercury-impacted wastes, including high and low mercury subcategory wastes. Stablex Canada Inc. operates an industrial waste disposal facility in Blainville, Quebec, Canada, which accepts mercury-impacted wastes including soil, sediment, and debris. If waste is determined to be acceptable following waste acceptance screening (including no visible mercury), waste is pre-treated (chemical treatment and/or stabilization/solidification) and the stabilized waste (termed “stablex”) is disposed in the on-site Stablex landfill. Future availability of this disposal option is uncertain and would require pre-approvals by USEPA and Environment Canada per 40 CFR 262.50 to 262.58.

General Response Action – Ex Situ Treatment

Soil/Sediment

- **Soil Washing** is a process that removes contaminants from soil through either dissolving or suspending them in the wash solution or by concentrating them into a smaller volume through particle separation. The latter takes advantage of the behavior of some contaminants to preferentially adsorb onto the fines fraction. The impacted soils are suspended in a wash solution and the fines are separated from the suspension, thereby reducing the contaminant concentration in the remaining soil. The finer grained material containing most of the constituents of concern may be treated by other methods or disposed of (on-site or off-site) in a permitted landfill. Soil washing equipment is transportable and thus can be used on site. Pretreatment may include sifting to remove debris, large rocks, etc. Other particle size separation processes include centrifugation, flocculation, hydroclones, screening, and sedimentation. Addition of special additives and/or applying aeration as a separation method can facilitate separation of the impacted fines. Provisions for off-gas collection and treatment may be required.
- **Thermal Treatment: Thermal Desorption** involves the use of heat to increase the volatilization of the constituents. Wastes are heated to 320 to 700°C (600 to 1,300°F) to promote desorption of constituents from media. Thermal desorption is not designed to destroy constituents. Two common thermal desorption designs are the rotary dryer and thermal screw. Rotary dryers are horizontal cylinders that can be indirect- or direct-fired. The dryer is normally inclined and rotated. For the thermal screw units, screw conveyors or hollow augers are used to transport the medium through an enclosed trough. Hot oil or steam circulates through the auger to indirectly heat the medium. There is limited commercial capacity for thermal desorption of mercury-impacted media.

A vacuum is typically applied to collect the desorbed compounds for subsequent treatment. This latter step involves particulate filtration (wet scrubber or fabric filters) and vapor/gas treatment. Typical gas treatment train may include condensation (i.e., of elemental Hg), carbon adsorption (sulfur-impregnated), and catalyst oxidation to treat residual organics. Recovered elemental Hg may then be resold as product or require amalgamation (if radioactive material is present) prior to disposal. Equipment and methods are available largely because this technology and variations have been commonly used to treat a range of compounds from fuel contaminated soils and sediments to pesticide, PCB, etc. impacted soil and sediments.

Retorting is similar to thermal desorption except that it does not involve agitation of the treated media. The main components of a retort system include a retort oven, condensers, mercury trap, carbon adsorber, and vacuum pump. The retort ovens typically operate under a vacuum and at temperatures ranging from 425 to 540°C (800 to 1,000°F). Off-gas treatment typically includes condensation and carbon adsorption. There is limited commercial capacity for retorting. Typical application today is for instruments, batteries, thermometers and other objects which contain mercury. On-site retorting may be an option.

Most mercury compounds could be readily removed through thermal treatment. Considerations for safe handling due to the volatility of elemental mercury and organic mercury compounds presents safety considerations. The presence of organic compounds (e.g., PCBs), waste characteristics, and/or quantities may pose difficulties in obtaining acceptance at thermal treatment facilities. As discussed previously, RCRA LDRs require that high mercury subcategory hazardous waste be retorted or roasted unless an LDR exemption is obtained. ISP would not support shipment of waste material to retorting facilities which distribute recovered mercury into the world market.

- **Solidification/Stabilization (S/S)** methods typically involve mixing impacted media with reagents to reduce the mobility of the constituents, reduce permeability and limit leaching. Solidification is a physical process where constituents are bound or enclosed within a matrix. Stabilization is a chemical reaction between the stabilizing agent and constituents to reduce mobility. The most common S/S methods involve use of Pozzolanic materials. The method is widely used for metal or inorganic species impacted soils or sediments. The presence of high levels of organic compounds can interfere with the process and volatile compounds may escape during processing.

Examples of Pozzolanic-based S/S reagents include Portland cement, fly ash, lime, and furnace slag. Mixtures may be used. The hardened mass can be placed or formed in lined pits or transferred to a landfill. Chemical leaching tests such as TCLP can be used to determine the success of immobilization of the constituents of concern. S/S may be combined with other technologies, including soil washing, which can be used to reduce the volume of material that requires S/S.

Typically the process involves dry mixing the impacted media in a pug mill with the appropriate reagent or mixture of reagents. The reagent or mixture is typically determined through bench-scale laboratory testing.

More advanced methods can incorporate sulfur-based polymer cements that are mixed and heated with the mercury contaminated material to form mercuric sulfide. The treated material can be disposed of as non-hazardous. Capture of off-gases is typically necessary and may involve operation at a slight vacuum. This S/S method is not applicable to quantities encountered during remediation due to the relatively low processing rates.

S/S of mercury wastes is complicated due to the various forms of mercury, wide range of mobility, and complex behavior of mercury species. Some S/S methods may be appropriate for certain forms of mercury and not for others. Commonly used Pozzolanic-based S/S approaches may cause some forms of mercury to become more soluble due to elevated pH conditions.

Amalgamation can be used to immobilize elemental mercury by dissolving the mercury in another metal (copper, tin, nickel, zinc) to form a semisolid alloy known as an amalgam. The process is a physical immobilization and is often combined with encapsulation to prevent volatilization of mercury from amalgam. Amalgamation is classified as Best Demonstrated Available Technology (BDAT) by EPA for the treatment of elemental mercury containing radioactive materials.

- **Chemical Leaching** is a process where chemical reagents are used to extract the constituents of concern, usually metals, from soil or sediments. Typically strong acids such as sulfuric or hydrochloric acid are used. The leachate is regenerated using activated carbon and an electrolytic system to recover the leached metals, e.g., mercury. The leachate can be recycled, but may require disposal after several uses. The processed soil will be acidic and requires water washing and, typically, drying. Lime can be added to neutralize residual acid. The wash water is passed through carbon or an electrolytic process and also recycled. In some cases reprocessing (multiple leaching cycles) may be required. As with the other processes, off-gas treatment may be required where organic mercury and/or elemental mercury is present.
- **Biological Treatment Methods** have been employed for centuries to recover metals, e.g., copper, from ores. Similar methods can be used to remove metals from soils using heap-leaching techniques. Soils are placed on an impermeable liner with a leachate collection system. Typically, dilute sulfuric acid is added at a pH of about 4 to the top of the leach pile. Addition of other sulfur compounds can also be used. Bacteria, *Thiobacillus*, utilize the sulfate ions to leach metals under aerobic conditions. Inorganic metal species can be solubilized, leached, collected, and purified. The process can also be

conducted in slurry reactors. The treated soil must be washed and, potentially, lime added to restore more neutral pH conditions.

Groundwater

- **Chemical precipitation/co-precipitation** can be used to remove mercury from groundwater by transforming dissolved target constituents into insoluble solids. Precipitation with sulfide is most commonly used for mercury removal. Co-precipitation is a process where target constituents do not precipitate but adsorb onto other species that are precipitated. Chemicals used in co-precipitation processes include alums, lignin derivatives, and ferric salts. Processes to remove mercury from impacted waters can include a combination of precipitation and co-precipitation. The resulting solids from precipitation/co-precipitation are then removed by clarification or filtration.
- **Ion exchange treatment** removes the dissolved cations or anions from the aqueous phase by exchange with the exchange medium. Ion exchanged for mercury, typically, involves the formation of a negatively charged mercuric chloride complex by the addition of chlorine or hypochlorite, to oxidize metallic mercury present as Hg (I) or mercury to Hg (II) chloride complex. The mercuric chloride complex is then removed on an anion exchange resin.
- **Adsorption** Constituents in the aqueous phase are adsorbed onto the surface of the adsorbents. Adsorbents are usually packed on columns and need to be periodically regenerated. Granular Activated Carbon (GAC) is the most commonly used adsorbent. Sulfur-impregnated GAC has been used to increase mercury removal. Proprietary sorption technologies are also available.
- **Membrane Filtration** separates constituents from water by passing it through a semi-permeable barrier or membrane. Types of membranes media processes include Microfiltration, Ultrafiltration, Nanofiltration, and Reverse Osmosis. Generally, the membrane allows some of the constituents to pass through while blocking others. The process results in two effluent solutions: The permeate (effluent stream) and the concentrate (reject stream). The permeate contains reduced levels of target constituents, which may require subsequent treatment (i.e., polishing) to achieve target concentrations. The concentrate, which can be passed again through the membrane to further reduce its water content, represents a smaller, concentrated waste volume to subsequently manage.
- **Biological Treatment** of mercury has been tested at pilot scale in a limited number of projects. Biological treatment may convert mercury to species that are retained in the biomass or are more easily removed from water by another technology, such adsorption or precipitation. Biological treatment can be aerobic or anaerobic. Aerobic processes can transform soluble mercury into elemental mercury by an enzyme called mercury reductase. A combination of aerobic and anaerobic treatment methods transforms mercury into insoluble mineral phases such as sulfides.

Is this paragraph missing a heading? Like “Innovative Technologies” or is this really supposed to part of “Biological Treatment”? Innovative technologies for ex situ water treatment include nano-technology and air stripping. These technologies have been applied in the pilot scale and proved to achieve the targeted removal for those applications. An example of nanotechnology is the thiol Self-Assembled Monolayers on Mesoporous Supports (thiol-SAMMS). Thiol-SAMMS is capable of selectively adsorbing mercury. The process in general involves a mixing step where the mercury-impacted water is mixed with thiol-SAMMS and a separation step in which the thiol-SAMMS carrying mercury is separated from the treated water. Air stripping is usually applied after a reducing agent, typically Stannous (i.e., Tin - Sn⁺²) Chloride, has been added to the water to be treated. Mercury is reduced into elemental mercury which has high volatility. The mix is then passed in air strippers and elemental mercury is collected in the vapor phase.

General Response Action – In Situ Treatment

- **In Situ Vitrification (ISV)** applies high temperature treatment aimed primarily at reducing the mobility of metals by incorporation into a chemically durable, leach resistant, vitreous mass. In situ application consists of applying an electric current through the soil. Resistance heating transfers heat to soils which begin to melt. The result is a monolithic mass of soils that is leach resistant. Temperatures reach 1600 to 2000°C. The heated mass is allowed to cool into a glass monolith. Volatiles are driven off as vapors and collected under a vacuum and treated by appropriate off-gas treatment methods such as cooling followed by activated carbon. Organic compounds are largely destroyed in place by pyrolysis. Inorganic constituents are typically incorporated into the glass. The method is applicable to a wide range of soil types. Treatment in the saturated zone would require considerable dewatering and/or fuel to achieve target temperatures.
- **In Situ Thermal Desorption (ISTD)** applies heat to increase the temperature of the treated media. Temperature can be raised to increase volatility of certain volatile organics or to reach the boiling point of certain high-boiling compounds such as PAHs and PCBs and increase their mobility. Soil permeability can also be increased due to water vaporization which causes soils to dry out and fracture. Heat generation can be accomplished through various methods, including Electrical Resistance Heating (ERH), Radio Frequency/Electromagnetic Heating (RFH), Hot Air/Steam Injection Heating or Conductive Heating. ERH applies electrical current to the subsurface through electrodes. The resulting resistance generates heat. Six-phase soil heating (SPSH) is a typical electrical resistance heating which uses low-frequency electricity delivered to six electrodes in a circular array to heat soils. RFH uses the electromagnetic energy to heat a discrete volume of soils. Hot Air/Steam Heating consists of injecting hot air and/or steam through injection wells to heat the soil matrix and act as carriers of the desorbed constituents. Conductive heating applies heat to the subsurface through heating elements installed in thermal wells, which transmit heat to the treatment area through thermal conduction.

Volatile compounds, including some forms of mercury, can be recovered by an SVE system. Collected mercury can then be condensed to liquid mercury, which can be further treated through amalgamation. Off-gases may require further treatment prior to discharge. Treatment in the saturated zone would require considerable dewatering and/or fuel to achieve target temperatures.

ISTD for mercury treatment is an emerging technology and there are no known pilot-scale or full-scale field applications.

- **Electrokinetic (EK) Separation** uses electrochemical and electrokinetic processes to desorb, and then remove, metals and polar organics from soil, sludge, and sediment. An electric field is imposed in the impacted soils through two arrays of ceramic electrodes: cathodes and anodes. Positively charged species including metal ions, ammonium, and positively charged organics move toward the cathode and negatively charged species including chloride, cyanide, fluoride, nitrate, and negatively charged organic compounds move toward the anode. The remediation of the mobilized constituents is performed by “Enhanced Removal” or by “Treatment without Removal.” Enhanced Removal involves electrokinetic transport of constituents to the electrodes where they become concentrated followed by removal for ex situ management. Removal at the electrodes includes: water pumping, electroplating and precipitation and coprecipitation. “Treatment without Removal” is achieved by electro-osmotic transport of contaminants through treatment zones placed between electrodes. The polarity of the electrodes is reversed periodically, which reverses the direction of the constituents back and forth through treatment zones. The rate at which species are moved through the groundwater is independent of the soil permeability and thus has its greatest advantage in low permeability formations. Extreme pHs created at each electrode need to be managed.

Elemental mercury is non-polar and, therefore, is not amenable to EK remediation without first being oxidized to a cationic form. In addition, once oxidized, the mercury must form a water soluble complex for EK remediation to be effective. Amendments may be added to oxidize and/or increase the solubility of mercury species to enhance the effectiveness of EK remediation. However, the literature review indicated highly variable results with amendment addition during laboratory-scale testing.

EK remediation is an unproven technology, which does not have a successful performance history for mercury remediation. The literature review indicated that there have been only a limited number of laboratory (bench-scale) studies and fewer field applications that have evaluated EK remediation of media impacted with low solubility forms of mercury. No documentation of field-scale studies performed with mercury-contaminated soil was identified during the literature review.

- **Phytoremediation** uses plants to remove, transfer, stabilize, or destroy constituents in soils and groundwater. It is an innovative technique that is being evaluated for its effectiveness in removing mercury from sediments and other media. Phytoremediation applies to all the chemical, physical and biological processes that are influenced by plant activities and that aid in cleanup of the impacted media. In this regard, constituents may be treated through two routes: (1) water dissolved constituents are absorbed by the plant roots; and (2) constituents adsorbed to soils located in close vicinity to the roots are biodegraded by the root bacteria.

Plants can be genetically engineered to enhance their ability to detoxify mercury. In a bench –scale study rice plant embryos were injected with *MerA* enzyme. This enzyme reduces ionic mercury into elemental mercury in sediments. Elemental mercury is then volatilized and collected.

Phytoremediation can also involve the uptake of metals and inorganic species. The metals are concentrated in roots, stems, or leaves depending upon the plants and specific metals. The vegetative matter can be harvested, composted, or burned to reduce the volume of impacted material.

Concerns are the relatively shallow root zones of many plants, weather conditions, toxicity of metals to plants, and selectivity of some plants thus reducing effectiveness to treat mixtures of COCs.

- **In Situ Solidification/Stabilization (S/S)** technologies were previously described under ex situ treatment technologies. In situ S/S is similar to ex situ stabilization except that the soil and stabilizing agents are mixed in situ. In situ mixing can be achieved through several methods, including mixing using excavator bucket, vertical auger mixing, and injection grouting. The latter involves forcing a binder containing dissolved or suspended treatment agents into the subsurface, allowing it to permeate the soil.

Some S/S technologies that are applicable to ex situ applications do not lend themselves to treatment in situ (e.g., those involving multiple steps of mixing, heating, and curing). In addition to the complications of S/S for mercury waste identified under ex situ S/S, in situ S/S has additional difficulties associated with achieving adequate mixing (e.g., due to the nature of the fill material) and managing off-gassing.

- **In Situ Soil Flushing** involves the use of water, chemical solutions (e.g. surfactants), or organic extractants (e.g., ethanol) to recover constituents from soil. The constituents are mobilized by solubilization, formation of emulsions, or a chemical reaction with the flushing solutions. Flushing solutions or liquids are usually injected through injection wells and recovered through collection wells or drains. Recovered flushing fluids require treatment to separate the constituents from the solution (refer to technologies identified under General Response Action: Ex Situ Treatment of Groundwater). The various forms of mercury present a challenge in selecting the flushing solution.

- **Enhanced Bioremediation** is a method in which additives are provided to promote beneficial microbial processes such as degradation of organic compounds or conversion of inorganic species to less toxic or less mobile oxidation states. Typically an electron acceptor such as oxygen is added to promote oxidation reactions or an electron donor is added to create reducing conditions. Addition of nutrients, such as nitrogen and phosphorus sources, is sometimes necessary or beneficial. These processes are most common for petroleum hydrocarbons, chlorinated solvents, and metals such as chromium. Microbial enhanced reactions can change the form in which mercury is present. For example, reducing conditions can favor the formation of the relatively insoluble HgS, but can also result in formation of organic mercury compounds or elemental mercury. Treatment of mixtures of constituents might require sequential treatment or sequential reaction zones.
- **Permeable Reactive Barriers** are reactive zones that are implemented across the flow path of an impacted groundwater plume, which employ biological or chemical treatment processes to control the migration of contaminants while allowing groundwater to pass through the barrier. Permeable barriers may employ such agents as zero-valent metals, chelators (ligands selected for their specificity for a given metal), sorbents, microbes, and others. The contaminants are either degraded or retained in a concentrated form by the barrier material. Species of metals, such as uranium, selenium, arsenic, and mercury, have been treated at laboratory and field pilot scale. The University of Waterloo has field demonstrated removal of dissolved mercury to very low levels. Barriers require monitoring to evaluate treatment efficiency and identify if maintenance is required. It is not known how long the barriers will remain effective before they need some form of reactivation or replacement of the reactive media.
- **Monitored Natural Attenuation (MNA)** relies on natural processes to convert various species to less harmful or less toxic species and/or retard their movement through the formation. Implementation requires a strong understanding of site hydrogeology, historic groundwater quality data, speciation, presence of daughter products, as well as geochemical and biological conditions favoring the desired attenuation mechanisms. The process is well established for organic compounds, especially, petroleum hydrocarbons. Bioattenuation of PCBs for instance is very slow, however, these compounds have low solubilities and thus migrate slowly, especially in high organic content matrices. Application to metals has been less extensively studied and implemented. For metals, MNA usually consists of adsorption and precipitation. The principal mechanism in most cases is changes in oxidation states of the metal species from a more mobile and maybe more toxic oxidation state to a less mobile and less toxic oxidation state.

TABLE 1
IDENTIFICATION OF CANDIDATE TECHNOLOGIES AND PRELIMINARY SCREENING
LCP CHEMICALS, INC. SUPERFUND SITE
LINDEN, NEW JERSEY

Media	General Response Action	Candidate Technology	Constituent Type			Developmental Status With Respect to Hg Treatment	Likely to be Retained (Y or N)?	Preliminary Screening Comments
			Hg	M	O			
Soil/Sediment								
	Institutional Controls	Deed Notice/ Access Controls	A	A	A	X	Y	Likely component of any remedial alternative.
	Containment	Caps/Covers	A	A	A	X	Y	Options include: soil, geosynthetics, composites, concrete, asphalt.
		Vertical Cutoff Walls	A	A	A	X	Y	Options include: slurry, sheet pile, geomembrane, and others.
	Removal	Excavation	A	A	A	X	Y	Includes complete removal or partial ("hot spot") removal. Requires ex situ soil management. RCRA regulations including LDRs would apply.
		Dredging	A	A	A	X	Y	Includes complete removal or partial ("hot spot") removal. Requires ex situ soil management. RCRA regulations including LDRs would apply.
	Disposal	Off-Site Landfill Disposal	A	A	A	X	Y	Pre-treatment may be required. LDRs may preclude land disposal.
		On-Site Landfill Disposal	A	A	A	X	Y	Pre-treatment may be required. May require construction of a land disposal unit.
	Ex Situ Treatment	Soil Washing	A	A	A	Y	Y	Requires post-treatment management of concentrated material. May require off-gas controls.
		Thermal Desorption	A	A	A	Z	N	Requires gas collection/treatment and management of collected mercury. Limited experience with mercury.
		Retorting	A	A	A	X	Y	Requires gas collection/treatment and management of collected mercury. Limited commercial capacity.
		Solidification/ Stabilization	A	A	A	Y	Y	Includes micro or macro encapsulation and chemical stabilization. Requires management of solidified/stabilized material. S/S is not fully established for mercury treatment. May require off-gas controls.
		Amalgamation	A	n/a	n/a	X	N	LDRs require amalgamation of elemental Hg containing radioactive material. Site Hg is not radioactive.

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LCP CHEMICALS, INC. SUPERFUND SITE
LINDEN, NEW JERSEY**

Media	General Response Action	Candidate Technology	Constituent Type			Developmental Status With Respect to Hg Treatment	Likely to be Retained (Y or N)?	Preliminary Screening Comments
			Hg	M	O			
		Chemical Leaching	A	A	n/a	Y	Y	Requires post-treatment management of aqueous stream and sludge generated from treatment. Can be coupled with Soil Washing. May require off-gas controls.
		Biological Treatment	A	A	A	Z	N	Biological treatment is not well established for mercury treatment.
	In Situ Treatment	Vitrification	A	A	A	Y	N	Off-gas collection and treatment required. High energy consumption.
		Thermal Desorption	A	n/a	A	Z	N	Off-gas collection and treatment required. ISTD is not established for Hg treatment.
		Electrokinetic Separation	A	A	n/a	Z	N	Limited experience with Hg. Effect on elemental Hg unclear.
		Phytoremediation	A	A	A	Y	N	Possible need for disposal of resulting biomass. Effect is limited to shallow zones.
		Solidification/ Stabilization	A	A	A	Y	Y	Refer to ex situ S/S comments. In-situ application dependent on characteristics of media (e.g., fill) and ability to achieve proper mixing.
		Soil Flushing (Chemical Leaching)	A	A	A	Y	Y	May include various chemicals (e.g., acids) to increase leaching. Requires extraction and treatment system.
		Monitored Natural Attenuation	A	A	A	X	Y	Relies on all naturally occurring processes and may be appropriate for all constituents – varies by constituent and media.
Groundwater								
	Institutional Controls	Classification Exception Area (CEA)	A	A	A	X	Y	Likely component of any remedial alternative.
	Containment	Caps/Covers	A	A	A	X	Y	Options include: soil, geosynthetics, composites, concrete, asphalt.
		Vertical Cutoff Walls	A	A	A	X	Y	Options include: slurry, sheet pile, geomembrane, and others.
		Groundwater Extraction and Treatment	A	A	A	X	Y	Effective for migration control of dissolved constituents. May include various extraction approaches (e.g., wells, trenches). Requires ex situ treatment.

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LCP CHEMICALS, INC. SUPERFUND SITE
LINDEN, NEW JERSEY**

Media	General Response Action	Candidate Technology	Constituent Type			Developmental Status With Respect to Hg Treatment	Likely to be Retained (Y or N)?	Preliminary Screening Comments
			Hg	M	O			
		Permeable Reactive Barrier (PRB)	A	A	A	Z	N	Options include zero-valent metals, chelators (ligands selected for their specificity for a given metal), sorbents, microbes. Not established for Hg.
	Ex Situ Treatment	Chemical Precipitation/Co-precipitation	A	A	n/a	X	Y	Fully developed for ionic Hg. Component of existing treatment system on adjacent ISP Site, which has demonstrated Hg removal.
		Ion exchange	A	A	n/a	X	N	Fully developed for ionic Hg. Effectiveness of existing system on adjacent ISP Site indicates technology is not required.
		Adsorption (Activated Carbon)	A	n/a	A	X	Y	Includes sulfur impregnated activated carbon. Component of existing treatment system on adjacent ISP Site, which has demonstrated Hg removal.
		Membrane Filtration	A	A	A	X	N	Fully developed for ionic Hg. Effectiveness of existing system on adjacent ISP Site indicates technology is not required.
		Biological Treatment	A	A	A	X	Y	Further treatment would be required. Component of existing treatment system on adjacent ISP Site, which has demonstrated Hg removal.
		Air Stripping	A	n/a	A	Z	N	Preceded by chemical or biological reduction can remove elemental mercury. Requires further treatment. Effectiveness of existing system on adjacent ISP Site indicates technology is not required.
	Treated Effluent Discharge	Injection to Groundwater	A	A	A	X	N	Likely not required due to availability of existing surface water discharge.
		POTW	A	A	A	X	N	Likely not required due to availability of existing surface water discharge.
		Surface Water	A	A	A	X	Y	Effluent discharge scenario for existing treatment system on adjacent ISP Site.

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			Hg	M	O			
	In Situ Treatment	Electrokinetic Separation	A	A	n/a	Z	N	Limited experience with Hg. Effect on elemental Hg unclear.
		Phytoremediation	A	A	A	Y	N	Possible need for disposal of resulting biomass.
		Enhanced Bioremediation	A	A	A	Z	N	Includes aerobic or anaerobic bioremediation. Limited experience with Hg.
		Monitored Natural Attenuation	A	A	A	X	Y	Relies on all naturally occurring processes and may be appropriate for all constituents – varies by constituent and media.
Surface Water								
	Soil, Sediment, and Groundwater Remediation	Various technologies (see above)	A	A	A		Y	Remedial actions to address impacted soil, sediment, and groundwater (i.e., via removal, treatment, containment) will benefit surface water quality.
Building Debris								
	Institutional Controls	Deed Notice/ Access Controls	A	A	A	X	Y	Likely component of any remedial alternative.
	Containment	Caps/Covers	A	A	A	X	Y	Options include: soil, geosynthetics, composites, concrete, asphalt.
		Vertical Cutoff Walls	A	A	A	X	Y	Options include: slurry, sheet pile, geomembrane, and others.
	Disposal	Off-Site Landfill Disposal	A	A	A	X	Y	Pre-treatment may be required. LDRs may preclude land disposal.
		On-Site Landfill Disposal	A	A	A	X	Y	Pre-treatment may be required. May require construction of a land disposal unit.
	Ex Situ Treatment	Retorting	A	n/a	n/a	X	Y	Requires gas collection/treatment and management of collected mercury. Limited commercial capacity.

**TABLE 1
IDENTIFICATION OF CANDIDATE TECHNOLOGIES AND PRELIMINARY SCREENING
LCP CHEMICALS, INC. SUPERFUND SITE
LINDEN, NEW JERSEY**

Media	General Response Action	Candidate Technology	Constituent Type			Developmental Status With Respect to Hg Treatment	Likely to be Retained (Y or N)?	Preliminary Screening Comments
			Hg	M	O			
		Solidification/ Stabilization	A	A	A	Y	N	Refer to ex situ S/S comments. For building debris S/S refers to macro encapsulation and/or chemical stabilization.
		Debris Washing	A	A	A	Y	Y	May include amendments to increase leaching. Requires post-treatment management of aqueous stream. For porous media (e.g., concrete) may require debris crushing to be effective.

Notes:

Constituent Type: Hg: Mercury; M: Other Metals (Arsenic, Beryllium, Cadmium, Chromium, Copper, Lead, Zinc); O: Organics (PCBs, PAHs, VOCs [benzene, chlorobenzenes, PCE]);

Applicability to Constituent Type: A = applies to some or all compounds in this class, n/a = not applicable

Development Status: X = Fully Developed: has been successfully implemented at full-scale; Y = Developing: has had some success in full-scale applications but needs improvement; Z = Not Established: technology is a pilot-scale technology (i.e., has not been implemented at full scale) and/or needs substantial improvement

Likely to Be Retained: Y : Yes; N: No (technology is shaded)

