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**NUS CORPORATION, 1987, EVALUATION OF SOURCE CONTROL
TECHNOLOGIES, DOUGLASSVILLE DISPOSAL SITE, BERKS
COUNTY, PENNSYLVANIA, - NUS, PITTSBURGH, PA - (USED AS
A REFERENCE IN OU5 FS REPORT)**

05/00/87

**225
REPORT**

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MAY 1987

DRAFT EVALUATION OF
SOURCE CONTROL TECHNOLOGIES

DOUGLASSVILLE DISPOSAL SITE
BERKS COUNTY, PENNSYLVANIA

EPA WORK ASSIGNMENT NUMBER 122-3L51
UNDER
CONTRACT NUMBER 68-01-7250

PREPARED BY:
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PITTSBURGH, PENNSYLVANIA

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000001

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7267
EBASCO

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May 26, 1987
RM/3/87-113
Response Required

Mr. Victor Janosik
U.S. Environmental Protection Agency
Region III
841 Chestnut Street
Philadelphia, Pennsylvania 19107

SUBJECT: REM III PROGRAM - EPA CONTRACT NO. 68-01-7250
EPA WORK ASSIGNMENT NO. 122-3L31
DOUGLASSVILLE DISPOSAL SITE, BERKS COUNTY, PA
DRAFT EVALUATION OF SOURCE CONTROL
TECHNOLOGIES REPORT

Dear Mr. Janosik:

The REM III Team is pleased to submit this Draft Evaluation of Source Control Technologies Report, which summarizes information gathered during a literature review and provides recommendations regarding data requirements and bench and pilot scale studies. This report has been prepared in accordance with Work Assignment Number 122-3L31, and is intended to provide guidance for the conduct of Phases I and II of the Remedial Investigation for the Douglassville Disposal Site.

If you have any questions regarding this submittal, please feel free to call me or our Task Manager, Mr. Robert J. Hubbard at (412) 788-1080.

Very truly yours,



Richard C. Evans, P.E.
Regional Manager, Region III

RCE/RJH/lmd
Attachment

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1.0 INTRODUCTION

This evaluation of onsite source control technologies for the Douglassville Disposal Site has been prepared at the request of the United States Environmental Protection Agency (USEPA), Region III, under Work Assignment Number 122-3L51, Contract Number 68-01-7250. The primary objective of the evaluation is to provide a compilation of data requirements that should be satisfied so that a feasibility study of alternatives (FS) may be conducted in accordance with the provisions of the National Contingency Plan For Oil and Hazardous Substances (NCP); the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); the Superfund Amendments and Reauthorization Act (SARA); and EPA Interim Guidance on the Selection of Remedy.

SARA and EPA Interim Guidance on the Selection of Remedy require that emphasis be placed on permanent solutions to hazardous-waste-related problems in feasibility studies and CERCLA response actions. Although the developmental status of remedial technologies has previously been considered during the screening of remedial technologies, recent guidance requires that all potential remedial technologies appropriate for site conditions be considered, regardless of the technical development state.

Bench- and pilot-scale studies are almost invariably required to adequately assess the feasibility of innovative or emerging technologies. Recent guidance requires that such studies be conducted during the remedial investigation (RI) so that all necessary information is available prior to the preparation of the FS. Promising remedial technologies must be identified early in the RI/FS process to accomplish this objective. In addition, the necessary data for the evaluation of the effectiveness of the technologies must be identified early so that such information can be collected during the RI.

The Douglassville Disposal Site has been tentatively selected for study under the Superfund Innovative Technology Evaluation (SITE) Program. Hazcon, Inc. is scheduled to perform a solidification/fixation study at the site in conjunction with this program.

Since it is anticipated that bench- and pilot-scale studies will be required to provide the necessary information for the development of remedial alternatives, this report has been geared to identify data requirements and to focus preliminary bench- and pilot-scale studies. Available literature regarding source control technologies has been reviewed to identify data requirements. The source control technologies discussed in this report are primarily limited to those that include onsite treatment of contaminated material. Particular technologies such as incineration may also be utilized at offsite facilities. While encapsulation and other containment technologies are

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source control measures, such technologies have not been considered in this document, since a permanent solution with minimal operation and maintenance and no replacement costs is sought.

An overview of issues discussed in the balance of this document follows:

Section 1 (Introduction):

The history of the site and the nature and extent of the problem are discussed in the remainder of this section.

Section 2 (Source Description and Characterization):

Ten distinct sources are identified and discussed in this section. Sources are identified based on site history, available analytical data, and site reconnaissance visits. The sources are grouped into three separate remedial response units, based on the foreseeable response actions for each.

Section 3 (Description of Source Control Technologies):

Five general categories of source control technologies are discussed in this section, including: thermal treatment; extraction-based treatment; biological treatment; solidification/fixation, and; physical treatment. Descriptions of various methods are provided. The waste treatment capabilities of each, as well as associated logistical requirements, public health and environmental concerns, and data requirements are discussed. Case histories and a description of the technical development status of the technologies are also provided. Vendors are identified who provide services using each of the technologies discussed. Bench and pilot scale recommendations are provided in the form of preliminary specifications to be issued to vendors. Unit costs are summarized for each technology (where available).

Section 4 (Evaluation of Source Control Technologies):

The evaluation of source control technologies generally follows guidance for the preparation of feasibility studies. Qualitative evaluations of compatibility with site conditions, waste treatment capabilities, the degree of public health and environmental protection afforded, implementability, developmental status, effectiveness, and reliability are considered. This qualitative evaluation may result in the conclusion that the treatment technologies are acceptable, unacceptable, or questionable for each of the criteria identified above. In the event that a technology is considered unacceptable for one reason or another, it can be deleted from further consideration, and bench and pilot scale studies need not be conducted. Questionable ratings indicate the need for

the collection of additional data and/or performance of bench and pilot-scale studies.

Various advantages and disadvantages of each of the technologies are also highlighted in this section. A summary table of representative costs is also included.

Section 5 (Recommendations for Bench and Pilot Scale Studies):

Bench- and pilot-scale study requirements for each of the technologies are identified in Section 3. Section 5 is intended to focus Phases I and II of the remedial investigation so that adequate data for identification of feasible alternatives can be obtained. A general outline for the conduct of bench and pilot scale studies in the overall RI/FS process is provided.

Section 6 (Conclusions and Recommendations):

This section provides a summary of those technologies that are considered most promising and require further investigation at least at the bench-scale. The major conclusions reached in the report are summarized.

1.1 SITE BACKGROUND AND HISTORY

The Douglassville Disposal Site is located along the southern bank of the Schuylkill River, in southeastern Berks County, Pennsylvania. The site lies approximately 11 miles downstream of Reading and 2.5 miles upstream of Pottstown, Pennsylvania (Figure 1). Berks Associates, Inc., conducted waste oil recycling operations at the site from 1941 through 1986. Several large lagoons were used for disposal of waste material from the recycling operation until approximately 1972. Commencing in 1979, a portion of the site property was used for the land application (landfarming) of waste products. Another area immediately north of the process facility itself was used for disposal of filter cake. The process facility and disposal areas presently encompass approximately 50 acres (Figure 2).

The site has flooded on at least three occasions. In 1970, heavy rains caused the lagoons to breach their containing berms and overflow. It is estimated that 1 to 3 million gallons of oil sludge were released to the Schuylkill River as a result of this incident. Federal and state actions were initiated to remove the remaining waste oil, but Tropical Storm Agnes caused the river to flood, and the lagoons were inundated before these actions could be completed. It is estimated that 6 to 8 millions gallons of oil sludge were released during this flood in June 1972. After this release the lagoons were drained of standing liquid and backfilled with soil borrowed from the strip of land lying between the river and the lagoons. The site apparently flooded again in 1979. However, the backfill material apparently prevented the release of additional sludges during this event.

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The site has been investigated by the EPA Region III Field Investigation Team and by the NUS Corporation Remedial Planning Office as of this date. As a result of these investigations, it was determined that extensive residual contamination exists in environmental matrices at the site.

1.2 NATURE AND EXTENT OF THE PROBLEM

Because of the nature of the recycling operations, oil and grease contamination is profuse at the site. Although the recycling operations were allegedly oriented toward recovery of lubricating and fuel oils, analytical data suggest that transformer, capacitor, and hydraulic fluids, or lubrication/fuel oils containing these fluids, were also processed at the facility. This is evident since polychlorinated biphenyls were detected at high concentrations in waste disposal areas. In addition to standard constituents of oily wastes (i.e., polynuclear aromatic hydrocarbons, monocyclic aromatics, and alkanes) various organic solvents were also detected at the site. It is apparent that either solvent recovery operations, solvent storage and use, or treatment of oils containing degreasing agents was also conducted on the site, since numerous halogenated aliphatic hydrocarbons were detected in soil and groundwater samples. Table 1-1 summarizes the substances and concentration ranges detected in various site media.

Under present site conditions, human health impacts could occur as a result of direct dermal contact with wastes or contaminated soil/sediment or through inhalation of fugitive dust particles. In addition, although residential wells in the vicinity of the site lie upgradient of contaminant sources, it is believed that contaminated groundwater is discharging to the Schuylkill River. A number of downstream communities use the Schuylkill as a potable water source. The closest downstream intake is approximately 4 miles from the site and may draw up to 8 million gallons of water per day from the river. Hence both aquatic organisms and human consumers (of both fish and water) are potential receptors of site contaminants.

While no conclusively site-related contamination has been detected in the river, the Pennsylvania Department of Environmental Resources has indicated that discharge of contaminated groundwater from the site would not meet the requirements of the National Pollutant Discharge Elimination System (NPDES) if it were considered a point source. The NPDES requirements may be considered appropriate requirements for the site, and it is evident that some degree of aquifer restoration is required. Other appropriate requirements include the Ambient Water Quality Criteria for the protection of freshwater organisms and of human health through ingestion of aquatic organisms and water. In addition, cleanup to MCLs or background levels may be dictated, since the aquifer at the site is categorized as a Class 1 aquifer under the EPA's groundwater protection strategy.

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TABLE 1-1
 CONCENTRATION RANGES OF HSL CONTAMINANTS FOUND ABOVE DETECTION LIMITS
 DOUGLASSVILLE DISPOSAL SITE
 BERKS COUNTY, PENNSYLVANIA

PP. No.	CAS No.	Contaminant	Air ($\mu\text{g}/\text{m}^3$)	Surface Soils ($\mu\text{g}/\text{kg}$)	Subsurface Soils ($\mu\text{g}/\text{kg}$)	Surface Water ($\mu\text{g}/\text{l}$)
<u>Volatile Organics</u>						
	67-64-1	acetone	8.8 - 26.6	190	92 - 980	102 - 660
	79-93-3	2-butanone	-	-	150 - 210	55 - 63
	519-78-6	2-hexanone	-	-	150 - 230	12
4V	108-10-1	4-methyl-2-pentanone	2.6	-	95 - 540	14
86V	71-43-2	benzene	2.6 - 3.3	-	6.6 - 9,200	7.4 - 11.0
38V	107-88-3	toluene	2.6 - 28	33 - 257	17 - 79,000	34 - 70
	100-41-4	ethylbenzene	2.6 - 3.4	-	7.4 - 36,000	6.5 - 8
7V	103-90-7	xylene	2.6 - 16	42 - 120	6.6 - 85,000	20
15V	79-34-5	chlorobenzene	-	-	-	-
11V	71-55-6	1,1,2,2-tetrachloroethane	-	-	-	-
13V	75-54-3	1,1,1-trichloroethane	2.7	-	7.7 - 34	40 - 47
10V	107-06-2	1,1-dichloroethane	-	-	9.2	-
16V	75-00-3	1,2-dichloroethane	-	-	5.2 - 45	-
85V	127-18-4	chloroethane	-	-	16 - 37	-
87V	79-01-6	tetrachloroethene	2.6 - 8.0	18	6.4 - 17,000	13
30V	156-60-5	trichloroethene	2.6	-	14 - 59,000	19 - 367
29V	75-35-4	1,2-dichloroethene	-	-	-	10 - 33
88V	75-01-4	1,1-dichloroethene	-	-	-	-
6V	50-23-5	vinyl chloride	-	-	-	-
25V	67-63-3	carbon tetrachloride	-	-	6.6 - 7.6	-
44V	75-89-2	chloroform	-	-	8.2	-
32V	78-87-5	methylene chloride	-	-	16 - 15,000	26 - 69
47V	75-25-2	1,2-dichloropropane	-	-	17	-
49V	75-69-4	bromoform	-	-	-	-
	10061-01-5	fluorotrichloromethane	-	-	-	-
	108-05-4	cis-1,3-dichloropropene	-	-	5.8 - 7.0	5.5 - 6.0
	75-15-0	vinyl acetate	-	-	-	-
		carbon disulfide	-	-	5.2	-

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TABLE 1-1
 CONCENTRATION RANGES OF HSL CONTAMINANTS FOUND ABOVE DETECTION LIMITS
 DOUGLASSVILLE DISPOSAL SITE
 PAGE TWO

PP. No.	CAS No.	Contaminant	Air (µg/m ³)	Surface Soils (µg/kg)	Subsurface Soils (µg/kg)	Surface Water (µg/l)
Semi-Volatile Organics						
Acid Extractables						
	108-95-2	phenol	-	-	2,500 - 67,000	8
	108-39-4	4-methylphenol	-	-	560 - 11,000	-
34A	105-67-9	2,4-dimethylphenol	-	-	4,200 - 4,400	-
59A	51-88-5	2,4-dinitrophenol	-	-	11,000	-
60A	534-52-1	4,6-dinitro-2-methylphenol	-	-	3,200	-
22A	59-50-7	p-chloro-m-cresol	-	-	-	-
21A	88-06-2	2,4,6-trichlorophenol	-	-	5,300	2
65A	65-85-0	benzoic acid	-	180	37,000	-
Base Neutral Extractables						
66B	117-81-7	bis(2-ethylhexyl)phthalate	-	182 - 9,100	2,800 - 20,000	26
68B	84-74-2	di-n-butyl phthalate	-	170 - 4,800	2,400 - 10,000	-
69B	117-84-0	di-n-octyl phthalate	-	1,400	1,700	-
70B	84-66-2	diethyl phthalate	-	-	-	-
72B	56-55-3	benzo(a)anthracene	-	120	-	-
74B	205-99-2	benzo(b)fluoranthene	-	260	-	-
75B	318-01-9	benzo(k)fluoranthene	-	260	40,000	-
78B	191-24-2	benzo(g,h,i)perylene	-	-	-	-
73B	50-33-8	benzo(a)pyrene	-	130	-	-
76B	191-24-2	chrysene	-	260	-	-
39B	206-44-0	fluoranthene	-	93 - 230	17,000	-
80B	86-73-7	fluorene	-	-	-	-
83B	183-39-5	indeno(1,2,3-cd)pyrene	-	-	-	-
	91-57-6	2-methylnaphthalene	-	-	-	-
55B	91-20-3	naphthalene	-	-	2,200 - 39,000	-
84B	129-00-0	pyrene	-	140 - 210	1,400 - 27,000	5
					3,000 - 39,000	-

TABLE 1-1
 CONCENTRATION RANGES OF HSL CONTAMINANTS FOUND ABOVE DETECTION LIMITS
 DOUGLASSVILLE DISPOSAL SITE
 PAGE THREE

PP. No.	CAS No.	Contaminant	Air ($\mu\text{g}/\text{m}^3$)	Surface Soils ($\mu\text{g}/\text{kg}$)	Subsurface Soils ($\mu\text{g}/\text{kg}$)	Surface Water ($\mu\text{g}/\text{l}$)
Base Neutral Extractables (Continued)						
81B	85-01-8	phenanthrene	-	150	6,800 - 26,000	-
8B	120-82-1	1,2,4-trichlorobenzene	-	-	12,000	-
25B	95-50-1	1,2-dichlorobenzene	-	-	-	-
26B	541-73-1	1,3-dichlorobenzene	-	-	-	-
27B	106-46-7	1,4-dichlorobenzene	-	-	-	-
18B	11-44-4	bis(2-chloroethyl) ether	-	-	-	-
54B	78-59-1	isophorone	-	-	-	-
62B	86-30-6	N-nitrosodiphenylamine	-	-	2,300	-
	62-53-3	aniline	-	-	-	-
	132-6409	dibenzofuran	-	-	-	-
Pesticide Fraction						
90P	57-1	dieldrin	-	7.7	-	-
92P	50-29-3	4,4-DDT	-	7.0	48	-
93P	72-55-9	4,4-DDE	-	-	76	-
94P	72-54-8	4,4-DDD	-	5.2	59	-
97P	1031-07-8	endosulfan sulfate	-	-	-	-
107P	11097-69-7	PCB-1254	-	38 - 2,100	290 - 12,000	-
110P	12672-29-6	PCB-1248	-	1,200	1,800 - 25,000	-
111P	11096-82-5	PCB-1260	-	70 - 24,000	57 - 500,000	-
	58-89-9	gamma-BHC	-	-	-	-

TABLE 1-1
 CONCENTRATION RANGES OF HSL CONTAMINANTS FOUND ABOVE DETECTION LIMITS
 DOUGLASSVILLE DISPOSAL SITE
 PAGE FOUR

PP. No.	CAS No.	Contaminant	Air ($\mu\text{g}/\text{m}^3$)	Surface Soils ($\mu\text{g}/\text{kg}$)	Subsurface Soils ($\mu\text{g}/\text{kg}$)	Surface Water ($\mu\text{g}/\text{l}$)
	7429-90-5	aluminum	-	736 - 23,500	720 - 16,000	150 - 9,500
	7440-36-0	antimony	-	2.1 - 4	0.089 - 290	-
	7440-38-2	arsenic	-	3 - 8.98	0.5 - 26	-
	513-77-9	barium	-	85.5 - 1,910	42 - 1,600	28 - 30
	100-44-7	beryllium	-	0.21 - 2.6	0.30 - 1.8	-
	7440-43-9	cadmium	-	0.076 - 3.2	0.06 - 12	-
	7440-70-2	calcium	-	688 - 2,720	-	13,400 - 34,200
	7440-47-3	chromium	-	9.7 - 227	2.1 - 47	11 - 21
	7440-48-4	cobalt	-	4.7 - 73.5	3.9 - 42	-
	7440-50-4	copper	-	12.5 - 117	5.6 - 240	6.9
	1309-37-1	iron	-	1,760 - 41,800	940 - 22,000	330 - 8,610
	7439-92-1	lead	-	1.3 - 7,140	52 - 23,400	5.2 - 973
	7439-95-4	magnesium	-	1,390 - 6,740	-	3,530 - 11,300
	7439-96-5	manganese	-	179 - 3,080	14 - 1,100	41 - 541
	7439-97-6	mercury	-	0.12 - 1.0	0.27 - 0.81	-
	7440-02-0	nickel	-	7.70 - 69.5	4.1 - 24	19
	7440-09-7	potassium	-	403 - 1,270	-	2,780 - 3,210
	7782-49-2	selenium	-	0.17 - 0.62	-	-
	7440-23-5	sodium	-	409	-	3,200 - 23,000
	7440-28-0	thallium	-	-	0.1 - 0.5	-
	7440-31-5	tin	-	3.80	-	-
	7440-62-2	vanadium	-	11.5 - 169	2.4 - 54	-
	7440-66-6	zinc	-	43.7 - 640	16 - 950	21 - 253

TABLE 1-1
 CONCENTRATION RANGES OF HSL CONTAMINANTS FOUND ABOVE DETECTION LIMITS
 DOUGLASSVILLE DISPOSAL SITE
 PAGE FIVE

PP. No.	CAS No.	Contaminant	Sediment (µg/kg)	Groundwater (Shallow Monitoring Wells) (µg/l)	Groundwater (Bedrock Monitoring Wells) (µg/l)	Groundwater (Residential Wells) (µg/l)
Volatile Organics						
	67-64-1	acetone	340 - 4,000	-	-	-
	79-93-3	2-butanone	390 - 590	17	10	-
	519-78-6	2-hexanone	7.4	-	8.2	-
	108-10-1	4-methyl-2-pentanone	-	29	7	-
4V	71-43-2	benzene	-	5 - 18	5.1 - 100	-
86V	107-88-3	toluene	43 - 36,000	3.6	2.6 - 91	-
38V	100-41-4	ethylbenzene	2,200 - 16,000	19	2.4 - 160	-
		xylenes	400 - 32,000	10 - 18	2.3 - 840	-
7V	103-90-7	chlorobenzene	-	5.5 - 12	2.9 - 17	-
15V	79-34-5	1,1,2,2-tetrachloroethane	-	-	2.4	-
11V	71-55-6	1,1,1-trichloroethane	34 - 120	4.8 - 8.4	2 - 30	-
13V	75-54-3	1,1-dichloroethane	110	2.2 - 55	2.7 - 470	-
10V	107-06-2	1,2-dichloroethane	-	45 - 75	10 - 330	-
16V	75-00-3	chloroethane	-	9.7 - 12	3.4 - 9	-
85V	127-18-4	tetrachloroethene	820	2.1 - 7.5	2.6 - 29	-
87V	79-01-6	trichloroethene	30 - 460	3.3 - 29	2.9 - 68	-
30V	156-60-5	1,2-trans-dichloroethene	620	2.2 - 290	4.1 - 990	-
29V	75-35-4	1,1-dichloroethene	-	2.2	-	-
88V	75-01-4	vinyl chloride	-	5.1 - 29	2.7 - 160	-
6V	50-23-5	carbon tetrachloride	-	-	-	-
25V	67-63-3	chloroform	-	-	8	-
44V	75-89-2	methylene chloride	9.1 - 170	-	320	66
32V	78-87-5	1,2-dichloropropane	-	-	16	-
47V	75-25-2	bromoform	160	-	-	-
49V	75-69-4	fluorotrichloromethane	10	-	-	-
	10061-01-5	cis-1,3-dichloropropene	-	-	5.7	-
	108-05-4	vinyl acetate	-	-	2.2	-
	75-15-0	carbon disulfide	4 - 38	-	-	-

TABLE 1-1
 CONCENTRATION RANGES OF HSL CONTAMINANTS FOUND ABOVE DETECTION LIMITS
 DOUGLASSVILLE DISPOSAL SITE
 PAGE SIX

PP. No.	CAS No.	Contaminant	Sediment (µg/kg)	Groundwater (Shallow Monitoring Wells) (µg/l)	Groundwater (Bedrock Monitoring Wells) (µg/l)	Groundwater (Residential Wells) (µg/l)
Semi-Volatile Organics						
Acid Extractables						
	108-95-2	phenol	-	4.7 - 6.0	7.1	-
34A	108-39-4	4-methylphenol	2,800 - 3,200	-	-	-
59A	105-67-9	2,4-dimethylphenol	-	-	-	-
60A	51-88-5	2,4-dinitrophenol	-	-	-	-
22A	534-52-1	4,6-dinitro-2-methylphenol	-	-	-	-
21A	59-50-7	P-chloro-m-cresol	-	-	-	-
65A	88-06-2	2,4,6-trichlorophenol	-	-	-	-
	65-85-0	benzoic acid	970 - 5,000	-	-	-
Base Neutral Extractables						
66B	117-81-7	bis(2-ethylhexyl)phthalate	470 - 91,000	24	-	-
68B	84-74-2	di-n-butyl phthalate	-	-	4.3	-
69B	117-84-0	di-n-octyl phthalate	2,900	-	-	-
70B	84-66-2	diethyl phthalate	-	-	4.7	-
72B	56-55-3	benzo(a)anthracene	240	-	-	-
74B	205-99-2	benzo(b)fluoranthene	200	-	-	-
75B	318-01-9	benzo(k)fluoranthene	210	-	-	-
78B	191-24-2	benzo(g,h,i)perylene	170	-	-	-
73B	50-33-8	benzo(a)pyrene	260	-	-	-
76B	191-24-2	chrysene	290	-	-	-
39B	206-44-0	fluoranthene	440	-	-	-
80B	86-73-7	fluorene	-	-	-	-
83B	183-39-5	indeno(1,2,3-cd)pyrene	150	-	6.7	-
55B	91-57-6	2-methylnaphthalene	13,000 - 51,000	-	-	-
84B	91-20-3	naphthalene	7,900 - 31,000	2.1	215	-
	129-00-0	pyrene	430	-	12 - 277	-

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TABLE 1-1
 CONCENTRATION RANGES OF HSL CONTAMINANTS FOUND ABOVE DETECTION LIMITS
 DOUGLASSVILLE DISPOSAL SITE
 PAGE SEVEN

PP. No.	CAS No.	Contaminant	Sediment (µg/kg)	Groundwater (Shallow Monitoring Wells) (µg/l)	Groundwater (Bedrock Monitoring Wells) (µg/l)	Groundwater (Residential Wells) (µg/l)
Base Neutral Extractables (Continued)						
81B	85-01-8	phenanthrene	280	-	18	-
8B	120-82-1	1,2,4-trichlorobenzene	-	-	18 - 20	-
25B	95-50-1	1,2-dichlorobenzene	-	13 - 23	6.9 - 76	-
26B	541-73-1	1,3-dichlorobenzene	-	-	6.1	-
27B	106-46-7	1,4-dichlorobenzene	-	4.8 - 14	3.5 - 15	-
18B	11-44-4	bis(2-chloroethyl)ether	-	7.1	5.2 - 9.5	-
54B	78-59-1	isophorone	-	-	4.3	-
62B	86-30-6	N-nitrosodiphenylamine	-	-	-	-
	62-53-3	aniline	-	-	-	-
	132-6409	dibenzofuran	1,200	62	63	-
Pesticide Fraction						
90P	57-1	dieldrin	-	-	-	-
92P	50-29-3	4,4-DDT	-	0.25	-	-
93P	72-55-9	4,4-DDE	-	-	-	-
94P	72-54-8	4,4-DDD	-	-	-	-
97P	1031-07-8	endosulfan sulfate	-	-	-	-
107P	11097-69-7	PCB-1254	86 - 130	-	0.65 - 2	-
110P	12672-29-6	PCB-1248	7,800 - 30,000	-	1.7	-
111P	11096-82-5	PCB-1260	62 - 48,000	-	-	-
	58-89-9	gamma-BHC	-	-	0.049	-

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TABLE 1-1
 CONCENTRATION RANGES OF HSL CONTAMINANTS FOUND ABOVE DETECTION LIMITS
 DOUGLASSVILLE DISPOSAL SITE
 PAGE EIGHT

PP. No.	CAS No.	Contaminant	Sediment (µg/kg)	Groundwater (Shallow Monitoring Wells) (µg/l)	Groundwater (Bedrock Monitoring Wells) (µg/l)	Groundwater (Residential Wells) (µg/l)
	7429-90-5	aluminum	880 - 12,700	20 - 122,000	22 - 32,300	-
	7440-36-0	antimony	-	43 - 89	29 - 228	-
	7440-38-2	arsenic	3.1 - 84.2	188	31	-
	513-77-9	barium	50.5 - 585	29 - 378	22 - 637	105 - 150
	100-44-7	beryllium	0.36 - 3.4	5	28	-
	7440-43-9	cadmium	0.31 - 11	-	11	-
	7440-70-2	calcium	-	13,400 - 130,000	10,200 - 367,000	18,800
	7440-47-3	chromium	9.3 - 176	3.3 - 138	-	130
	7440-48-4	cobalt	3.65 - 52.5	13 - 341	5.1 - 512	-
	7440-50-4	copper	10 - 427	171 - 339	46	17 - 1,330
	1309-37-1	iron	1,300 - 26,600	75 - 325,000	134 - 323,000	7.6 - 273
	7439-92-1	lead	22.2 - 56,300	5.1 - 5.8	5.3 - 9.3	5.1 - 6.5
	7439-95-4	magnesium	1,720 - 9,920	4,000 - 70,500	7,390 - 161,000	8,100
	7439-96-5	manganese	44.3 - 1,460	26 - 101,000	30 - 162,000	11 - 893
	7439-97-6	mercury	0.15 - 2.3	0.67 - 2	0.67	-
	7440-02-0	nickel	7.55 - 79.5	10 - 342	11 - 672	-
	7440-09-7	potassium	569 - 1,160	559 - 8,020	816 - 15,000	2,560
	7782-49-2	selenium	0.14 - 0.47	-	-	8.8
	7440-23-5	sodium	657	8,940 - 147,000	10,200 - 288,000	1,260
	7440-28-0	thallium	12	-	-	-
	7440-31-5	tin	-	-	-	-
	7440-62-2	vanadium	8.35 - 44	4.2 - 13	3.7 - 30	-
	7440-66-6	zinc	37 - 4,260	6.3 - 5,910	3.8 - 1,030	55 - 367

Source: Remedial Investigation Report/Feasibility Study of Alternatives (Volume 1). MUS Corporation, June 1986.

Because the source areas at the site continue to affect the groundwater, and possibly the river, it is apparent that source control measures are also warranted. Treatment levels for contaminated soils and waste at the site are to be established through a risk assessment based on surface-water receptors. The Toxic Characteristic Leaching Procedure (TCLP) and groundwater modeling will be used to determine loading to the river during the course of the remedial investigation. The cleanup criteria may dictate the source control measures implemented at the site. At this point it is not possible to estimate what these cleanup criteria will be. No defensible argument can be offered regarding achievable levels of cleanup using treatment technologies until site-specific bench- and pilot-scale studies are completed.

In addition to Applicable, or Relevant and Appropriate Requirements (ARARs) for the protection of human health and aquatic organisms under existing site conditions, several requirements governing the implementation of remedial alternatives have also been identified. These include the Floodplains and Wetlands Executive Orders, the Pennsylvania Scenic Rivers Act, Occupational Health and Safety Administration (OSHA) requirements, the Resource Conservation and Recovery Act (RCRA) Land Disposal Bans, and PCB requirements dictated under the Toxic Substances Control Act (TSCA). Applicable, or Relevant and Appropriate Requirements are discussed in more detail in the Work Plan for the Phase II Remedial Investigation and Feasibility Study for the Douglassville Disposal Site. ARARs will be carefully considered during development of pilot-scale studies to be conducted as a result of guidance provided by this document.

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2.0 SOURCE DESCRIPTION AND CHARACTERIZATION

Numerous sources or potential sources of environmental contamination exist at the Douglassville Disposal Site. Based on historical chemical-analytical data and site reconnaissance, the following sources have been identified (See Figure 2):

1. The processing facility area
2. The backfilled lagoon and filter cake disposal area
3. The landfarm area
4. The sludge disposal area
5. The backfilled sludge lagoon area
6. The possible landfarm area
7. The incinerator and surrounding area
8. The drum and tank area
9. The backfilled lagoon area
10. The drum, tank, and refuse area

These sources are described to the extent possible in the sections that follow.

2.1 PHYSICAL AND CHEMICAL CHARACTERISTICS OF SOURCES

Based on site reconnaissance and/or historical analytical data, the aforementioned sources may be characterized to some extent.

No. 1: Processing Facility - Numerous above-ground and several underground storage tanks are located on this portion of the site. Several tank samples were collected from the processing facility during the Phase I RI/FS. These samples contained high concentrations of volatile and base/neutral extractable organic chemicals. Groundwater samples and sediment samples from adjacent drainage channels indicate that surface water and groundwater have been affected by this source. No evidence is available to indicate that the tanks are leaking; however, many of the tanks are deteriorated and leakage is possible. Ground stains are evident throughout the processing facility. It is believed that this source consists primarily of surface and subsurface soil containing residual contamination as a result of leaks and spills. If above-ground or underground storage tanks are leaking, these would also constitute ongoing sources of contamination.

No. 2: Backfilled Lagoon and Filter Cake Disposal Area - EPIC aerial photos clearly indicate that sludge lagoons were operated in this area. It is apparent from the present condition of this source that the lagoons were filled in with filter cake from the processing facility. Under present conditions this source consists of filter cake containing a large amount of oily material. Oil and grease concentrations in test pit samples from this area ranged as high as 36 percent. Polychlorinated biphenyls were detected in samples from this source at concentrations ranging to 500 ppm. Volatile organics and lead were detected at concentrations ranging to 40.4 ppm and

2,200 ppm, respectively. This source appears to be distinctly different from other sources at the site, since it consists primarily of waste materials rather than a mixture of wastes and environmental media.

An area to the west of the filter cake area receives runoff from both the processing facility and the disposal location. This area has apparently been affected by runoff from either the processing facility property, the backfilled lagoon and filter cake area, or both. A sediment sample collected from this area during the Phase I RI/FS contained volatiles, PCBs, PAHs, and lead at concentrations of 2.0 ppm, 48 ppm, 91 ppm, and 56,300 ppm, respectively. No water was noted in this drainage channel during a recent site reconnaissance.

No. 3: Landfarm Area - This source supports virtually no vegetative growth at this time. Surface material in this area consists of very fine particulates and appears to be subject to wind erosion. Several test pits were excavated in this location during the Phase I RI/FS, but no samples were collected. (No visual evidence of contamination was identified in these pits, and air monitoring did not reveal the presence of any volatile constituents.) A surface soil sample was collected at one location and contained low concentrations of toluene (257 ppb), PCBs (264 ppb), and PAHs (420 ppb.) Although data is limited for this area, this one sample seems to indicate that either very limited waste loads were allocated to this plot or that the landfarming practice was successful to some extent. At this point no explanation for the phytotoxic nature of the landfarm can be offered. (A minimal amount of volunteer vegetation was noted in the area.)

No. 4: Sludge Disposal Area - Several subsurface soil samples were collected at depths ranging to 7 feet in the backfilled sludge disposal area. Substances detected in subsurface soil samples include volatile organics (284 ppm), PCBs (22 ppm), PAHs (82 ppm), oil and grease (38 percent), phenolics (82.4 ppm), and lead (23,400 ppm.) It is apparent from the available analytical results that contamination is pronounced in this area to depths of at least 7 feet. No downgradient monitoring well samples are available; however, it seems safe to assume that groundwater contamination exists as a result of leaching from this source.

No. 5: Backfilled Sludge Lagoon Area - It is apparent that oil and grease have migrated through the backfill material in this area through capillary action, since surface oil seeps are evident in this area. Although this source supports some vegetation, some vegetative stress is evident. Surface soil, subsurface soil, and downgradient monitoring wells samples have been collected in this area. Contamination in the backfilled sludge lagoons is similar to that observed in the backfilled sludge disposal area. Volatile organics and phenolics were not detected in surface soil samples, probably as a result of the combined effects of backfilling, leaching, and volatilization

(in the case of the volatile organics). Substances detected in surface soil samples include PCBs (8.8 ppm), PAHs (9.1 ppm), oil and grease (11 percent), and lead (7,140 ppm.) Subsurface soil samples collected at depths of up to 10 feet contained volatiles (79 ppm), PCBs (7.1 ppm), PAHs (112.8 ppm), oil and grease (6.7 percent), phenolics (19.5 ppm), and lead (20,000 ppm.) Groundwater samples collected from monitoring wells downgradient of the backfilled lagoons contained volatiles at concentrations ranging to 1.4 ppm. Base/neutral extractable compounds were detected in downgradient monitoring well samples as well, although at comparatively low concentrations. Based on the available analytical data, it is apparent that volatile organics and some sparingly soluble base/neutral extractable organics are being leached from the backfilled sludge lagoon area.

No. 6: Possible Landfarm Area - Ground stains and furrows are evident in EPIC aerial photographs of this area. It is speculated that landfarming activities may have been conducted here during the same time period as in the other land application portion of the site (Source No. 3). No samples have been collected in this area to date. This area supports more vegetation than the landfarm area itself. Land application activities may have been limited in this portion of the site. Some overlap of this area and the backfilled sludge lagoons is evident in aerial photographs.

No. 7: Incinerator and Surrounding Area - No historical information regarding the use of this incinerator has been identified. Drums were reportedly stored in this area and some of these drums are still present, although all of the remaining drums are apparently empty. Two surface soil samples were collected in the vicinity of the incinerator during the Phase I RI/FS. These samples contained volatiles (0.152 ppm), PCBs (3.1 ppm), PAHs (0.182 ppm), oil and grease (3.6 percent), and lead (6,070 ppm.) Vegetation is apparent in this area, although a surface oil seep approximately 6 feet in diameter was noted during site reconnaissance.

No. 8: Drum and Tank Area - This potential source was allegedly a drum storage area. At the present time, a number of tanker trailers remain in this portion of the site. Approximately 15 empty 55-gallon drums are present in the easternmost portion of the drum and tank area. Two surface soil samples were collected in the vicinity of the drums during the Phase I RI/FS. Substances detected in surface soil samples include volatiles (0.051 ppm), PCBs (1.7 ppm), PAHs (0.51 ppm), oil and grease (290 ppm), and lead (334 ppm.) With the exception of the access road that traverses this area, vegetative growth is well established.

No. 9: Backfilled Lagoon Area - This potential source can be identified in EPIC aerial photographs. Based on its appearance in the photos, it is surmised that the waste in this source area is similar to that in the backfilled sludge lagoon area (Source

No. 5). No analytical results for samples from this area were available at the time this document was prepared. The processing facility drainage channel is located in this source area.

Based on visual inspection, the drainage channel appears to be stressed. Blue-green algae (cyanophytes) were observed in the drainage channel. These microorganisms will proliferate in areas where no other microorganisms can survive. Oil stains were evident on the banks approximately 6 to 8 inches above the water line. This drainage channel does not appear to discharge to the river except under high flow (post-precipitation) conditions. Rather, it appears that water in the drainage channel recharges the groundwater. Several surface water and sediment samples were collected from this drainage channel during the Phase I RI/FS. Substances detected in sediment samples include volatiles (84 ppm), PCBs (65 ppm), PAHs (97 ppm), oil and grease (0.14 percent), phenolics (8.2 ppm), and lead (3,570 ppm.) Volatiles and oil and grease were detected in surface water samples from the drainage channel at concentrations ranging to 934.4 ppb and 33 ppm, respectively.

No. 10: Drum, Tank, and Refuse Area - Empty drums and debris were noted in this area during site reconnaissance. No samples of this potential source have been collected as of this date.

This area has apparently been affected by runoff from either the processing facility property, the backfilled lagoon and filter cake area, or both. A sediment sample collected from this area during the Phase I RI/FS contained volatiles, PCBs, PAHs, and lead at concentrations of 2.0 ppm, 48 ppm, 91 ppm, and 56,300 ppm, respectively. No water was noted in this drainage channel during a recent site reconnaissance.

2.2 DEFINITION OF REMEDIAL RESPONSE UNITS

Based on the descriptions presented above, it is apparent that some general similarities exist between the various sources identified at the Douglassville Disposal Site. While it is evident that sources cannot be categorized on the basis of the chemical nature of contamination, some distinctions can be made based on the spatial distribution of contamination. Some sources appear to include only surficial contamination, while others consist of waste materials ranging to depths of 10 feet or more. Based on visual inspection and analytical data, it is apparent that some sources contain a great deal of waste as a separate phase (e.g., the backfilled sludge lagoons), whereas others appear to contain comparatively low levels of residual adsorbed contaminants (e.g., the landfarm). Some areas are markedly more contaminated than others. Although the treatment methods ultimately selected may be identical for all source areas, it is worthwhile to consider the distinctions between the various sources and potential response actions for each. The primary objective in drawing these distinctions is to identify

any source-specific data requirements that must be satisfied during Phases I and II to the RI. Based on the similarities and/or differences, the sources have been grouped into three separate remedial response units. The distinctions between the various remedial response units are primarily based on foreseeable response actions or logistical requirements for each area. Any distinct data requirements for a given source should also be satisfied for any other sources included in the same remedial response unit. For the purpose of this evaluation it has been assumed that any process equipment at the processing facility has been removed. The various remedial response units are discussed briefly below.

Remedial Response Unit Number 1: Backfilled Lagoon and Filter Cake Disposal Area (No. 2) - As discussed in Section 2.1, this source is distinctly different than other site sources in that it consists primarily of waste materials rather than a mixture of soil and waste. This source may be particularly suited for incineration.

Remedial Response Unit Number 2: Processing Facility (No. 1); Sludge Disposal (No. 4); Backfilled Sludge Lagoon (No. 5); and Backfilled Lagoon (No. 9) Areas - One reason these sources have been grouped together as one operable unit is that contamination is (or is expected to be) most pronounced in these areas. In addition, all of these areas are expected to require either extensive excavation followed by treatment, or in-situ treatment capable of handling waste materials at depth (e.g., vitrification, solidification, in-situ biodegradation, etc.)

Remedial Response Unit Number 3: Landfarm (No. 3); Possible Landfarm (No. 6); Drum and Tank (No. 8); Drum, Tank, and Refuse (No. 10); and Incinerator (No. 7) Areas - These sources have been grouped together as an operable unit, since it may be possible to handle these areas via a limited excavation/treatment scenario, or through continued landfarming methods. Contamination is apparently much less pronounced in these areas, and no evidence is available to indicate that they have impacted groundwater or surface water.

3.0 DESCRIPTION OF SOURCE CONTROL TECHNOLOGIES

3.1 INTRODUCTION

Five general categories of treatment-oriented source control technologies are discussed in this section. Technologies discussed include the following:

- Thermal treatment methods
- Extraction-based treatment methods
- Biological treatment methods
- Solidification/fixation treatment methods
- Physical treatment methods.

Chemical treatment methods are not considered suitable for wastes present at the Douglassville Disposal Site and have not been considered. An effort has been made to review as much of the available information with regard to the aforementioned technologies, but some oversights may have been made as a result of the dynamic nature of remedial technology.

3.2 THERMAL TREATMENT

3.2.1 General Description

The May 19, 1980, Federal Register defines Thermal Treatment as "the treatment of hazardous waste in a device which uses elevated temperatures as the primary means to change the chemical, physical, or biological character or composition of the hazardous waste. Examples of thermal treatment processes include incineration, molten salt, pyrolysis, calcination, wet air oxidation, and microwave discharge" (5). Thermal treatment processes discussed in this document include incineration, pyrolysis, molten salt (discussed under pyrolysis), calcination, and wet-air oxidation.

Incineration is a thermal treatment process that uses controlled flame combustion in an enclosed reactor to decompose hazardous wastes (5). Incineration is essentially an oxidation process that converts organic wastes to inorganic substances (33). Common combustion products include carbon monoxide, carbon dioxide, water, and hydrochloric acid. Types of incinerators discussed in this section include multiple and fixed hearths, fluidized and circulating bed systems, rotary kilns, and infrared systems.

Pyrolysis differs from incineration in that combustion is performed under starved air conditions. Available air provides less than the stoichiometric oxygen requirements for complete combustion. The products of pyrolysis are generally combustible gases that can be used as fuel (33). Processes of this type are also discussed in this section and include plasma arc pyrolysis, molten salt combustion, and high-temperature, fluid wall reactions.

Cement kilns are used to treat liquid industrial wastes using the calcination process. Cement kilns operate at high temperatures and the waste is subjected to long residence times. They are viable liquid hazardous waste treatment systems (109). However, contaminated soils cannot be treated effectively in cement kilns, and these systems have not been considered for the Douglassville Disposal Site(78).

Wet-air oxidation is a process that oxidizes organic material in an aqueous waste stream by introducing atmospheric oxygen and subjecting the mixture to elevated temperatures and pressures (33). Supercritical water oxidation will be discussed along with wet-air oxidation.

A number of the thermal treatment systems are available as mobile units. Remedial actions with such systems are expected to be less expensive since offsite transport of waste materials or construction of onsite facilities would not be required.

3.2.1.1 Multiple Hearth/Fixed Hearth Incinerator

Multiple hearth incinerators are refractory-lined, vertical steel cylinders subdivided into horizontal stages (hearths). An air-cooled, rotating central shaft fitted with rabble arms conveys waste along the base of each stage to downcomers leading to the hearth below. Solid waste is introduced at the top of the incinerator. Liquid wastes can be introduced via burners located in the side of the incinerator. Auxiliary fuel burners and air inlets are located in the side of the incinerator. Air and combustion products flow upward, countercurrent to the waste. Exhaust gases are cooled and conveyed to air pollution control equipment. Ash is removed from the bottom of the incinerator, cooled, and transported for proper disposal. Multiple hearths are not available as mobile units.

3.2.1.2 Fluidized Bed Incinerators

Fluidized beds are vertical, refractory-lined chambers that contain an inert material, usually sand. Air is forced through a supporting distribution plate at the bottom of the bed at a rate sufficient to cause inert material to display fluid properties. Waste materials are introduced just above or directly into the fluidized bed. Waste materials with densities greater than the bed material cannot be treated in fluidized beds (62). The passage of air through the bed causes agitation and promotes rapid and uniform mixing of the waste material, air, and bed particles. Heat is transferred from the bed particles to the waste material, which burns rapidly and transfers heat back to the bed. The bed is preheated (to start-up temperatures) using other preheated air or an impinging burner located above the bed. Auxiliary fuel is usually added through nozzles within the bed. As the waste materials burn, the larger inert particles remain in the bed while the smaller

particles are separated from the exhaust gases in a freeboard area above the bed. The bed must be regenerated as the inert material within the bed increases. Renovation of the bed can be done as a batch process or continuously. As the bed material is removed from the incinerator, the inert particles are separated from the bed and the bed material can then be reused. Normal operating temperatures vary from 850° to 2,100°F and residence times vary with bed depth (78). Fluidized beds are available as mobile units.

3.2.1.3 Circulating Bed Incinerators

The circulating bed incinerator is similar to the fluidized bed incinerator, except that the system operates with higher combustion air velocities and finer bed material. The higher velocities create greater turbulence within the reactor, which allows efficient destruction of all types of halogenated hydrocarbons. The high turbulence entrains the solids and allows combustion to take place along the entire height of the unit. This allows uniform temperatures to be achieved in the unit. An integral cyclone is used to separate the fluidized solids from the off-gases. These solids are returned to the combustion zone. Secondary air is injected into the upper portion of the unit. Burning the waste material in the presence of dry limestone controls the formation of acidic gases. Normal operating temperatures are 850°F (78). Circulating beds are available as mobile units.

3.2.1.4 Rotary Kiln Incinerators

The rotary kiln incinerator is a slowly rotating, refractory-lined cylinder that has its axis at a slight incline from the horizontal. Solid waste material is added at the upper end of the incinerator. As the incinerator rotates, the waste material moves to the lower end as combustion takes place. This rotation also causes mixing of the waste with combustion air in order to provide sufficient turbulence and agitation for adequate destruction of the waste. Combustion air can enter the lower end of the incinerator and travel in the opposite direction of the waste. The heated combustion air dries the waste material as it moves across the material. A secondary high-temperature combustion chamber is sometimes necessary to complete the incineration of the vapor phase and particulate materials. Liquids and gaseous organic wastes can also be incinerated in the rotary kiln incinerator. Normal operating temperatures vary from 1,475° to 2,900°F, with residence times varying from a few seconds for gases to a few hours for solids.

Two types of rotary kilns are available. One is cocurrent, with the burner at the front end with the waste feed. The other is countercurrent, with the burner at the back end of the kiln. Rotary kilns are available as mobile units.

→ 1600°F Avg in 2 hours
2000°F Avg

CCCCC 7

3.2.1.5 Infrared Incineration Systems.

The primary chamber for an infrared incineration system consists of a carbon steel chamber lined with layers of lightweight ceramic fiber blanket. Silicon carbide resistance heating elements provide infrared energy. Waste material is placed on a woven wire belt and conveyed through the furnace, where it is exposed to the infrared energy. Gaseous products of waste combustion, solid residuals, and particulates are the residuals produced in these systems. Because of the quiescent combustion zone, particulate emissions are low. Gaseous emissions are reduced because auxiliary fuels are not required. A secondary combustion chamber can be added to further treat the off-gases. Mobile infrared incineration systems are available.

3.2.1.6 Plasma Arc Pyrolysis

Plasma is a partially ionized gas composed of ions, electrons, and neutral species. The plasma arc pyrolysis units consist of a chamber where a low-pressure gas (argon, helium, hydrogen, etc.) is introduced in small quantities to create a swirling motion to keep the plasma flame in the center of the unit. An electrical discharge is established and is used to change minute quantities of the gas into the hottest sustainable flame known. This plasma flame supplies the heat needed for pyrolysis. Pyrolysis can take place because the plasma flame can be generated in the total absence of oxygen. The high temperatures cause reduction of compounds to atomic entities before they recombine into low-molecular-weight gases. The inorganic fraction of the wastes is removed as slag. The product gases are scrubbed to remove acid gases and then flared to oxidize combustibles.

3.2.1.7 Molten Salt Incinerators or Combustors/Molten Glass Combustors

The molten salt process was originally developed for coal gasification and involves the introduction of the waste material into a pool of molten sodium carbonate. As the waste material rises to the top of this pool, the hydrocarbons in the waste react with air that has been injected into the molten salt. The wastes are oxidized and carbon dioxide and water vapor are formed. Hot gases rise through the molten salt, pass through a secondary reaction zone, and then through an off-gas cleanup system. Acidic gases are removed by the sodium carbonate. Normal operating temperatures range from 1,500° to 2,000°F, with residence times of 0.75 seconds (78).

Molten glass combustors are similar to the molten salt combustors except that glass is used instead of salt. Molten salt and molten glass combustors are not available as mobile units.

3.2.1.8 High-Temperature Fluid Wall Reactor or Advanced Electric Reactor

High-temperature fluid wall reactors consist of a porous refractory carbon core, an array of electrodes used to heat a gaseous fluid, and a containment vessel. A gaseous fluid, such as nitrogen, is forced through the porous core to form a fluid wall, which prevents the waste material from coming in contact with the reactor. It also radiates high temperatures to the reactor core. These high temperatures rapidly raise the temperature of the wastes and thus cause pyrolysis of the waste material. Temperatures of the core can be as high as 4,000°F. Molten HTFW reactors are available.

3.2.1.9 Wet-Air Oxidation

In the wet-air oxidation process compressed air is added to an aqueous waste stream and the resultant mixture is preheated in a heat exchanger. The heated aqueous waste is then pumped into the reaction chamber. The elevated temperatures and pressures in the reaction chamber oxidize the organics in the waste stream. As the oxidation of the organics occurs, heat is generated. The heated effluent is then cooled in the heat exchanger and routed through a pressure-reducing valve. The process is self-regulating in many respects. The oxidation occurs in a large amount of water that serves as a heat sink and also keeps the reaction under control. Since contaminants tend to stay in the aqueous phase, air pollution is kept to a minimum. Operating temperatures and pressures vary from 350°F to 650°F and 13.6 to 204 atm, respectively. Wet-air oxidation systems are available as mobile units.

3.2.1.10 Supercritical Water Oxidation

Supercritical water oxidation involves dissolving organic material and oxygen in supercritical water (i.e., above a temperature of 705°F and a pressure of 218 atm.) and allowing oxidation to take place in the supercritical water medium. Oxygen and organic materials are completely soluble in water at these temperatures and pressures. Supercritical water is an excellent solvent for organic substances, whereas inorganic salts are only sparingly soluble. Low-molecular-weight products are formed when water above 662°F reacts with organic material. Under supercritical conditions, these products are gases such as carbon monoxide, hydrogen, methane, and carbon dioxide, and volatile organic liquids such as alcohols, aldehydes, and furans. These products are then oxidized to carbon dioxide and water. Chlorine atoms from chlorinated organics are liberated as chlorides. The influent is raised to operating temperatures by passing it through a heat exchanger with the effluent, which can reach temperatures of 930°F. Supercritical water systems are available as mobile units.

3.2.1.11 In-Situ Radio Frequency Heating

This process involves the placement of radio frequency electrodes along the ground surface. The soil material adsorbs the electromagnetic (EM) energy produced by these electrodes. As the EM energy is adsorbed, it is converted to heat as a result of dipole rotation and molecular vibration. The organics in the soil material are destroyed or mobilized by vaporization, thermal decomposition, or distillation. A containment and recovery barrier is placed above the heated area to collect the gases and vapors emitted. The gases and vapors require treatment prior to release to the atmosphere. This procedure works well with soil material contaminated with compounds having high vapor pressures. For chlorinated compounds with high boiling points and low vapor pressures, a reagent can be added to the soil material, in conjunction with the heating operation, to remove organically-bound chlorine. Operating temperatures range from 190°F to 280°F (91).

3.2.2 Waste Treatment Capabilities

The thermal treatment technologies basically have the same waste treatment capabilities. With modifications, most of these techniques can handle wastes in solid, liquid, or gaseous form. Wastes with a heating value greater than 1,000 Btu/lb. are preferred, since the thermal treatment process can become self-sustaining because heat is released from the waste material. Otherwise, an auxiliary fuel is needed to maintain a sufficient temperature. Inorganic salts in the waste material can create significant problems during thermal processing. Wastes with a high sulfur or halogen content, when heated, will normally release acid-forming compounds as off-gases. In general, organic compounds are destroyed, but heavy metals remain in the residual ash/solids. Specific waste treatment capabilities for each technology are provided below.

3.2.2.1 Multiple Hearth/Fixed Hearth

This process is most suited for materials that are difficult to burn or contain valuable metals that can be recovered (34). It has been used on sludge, tars, and solids, and can be used for gases or liquids. The multiple hearth incinerator is the most widely used method for sewage sludge incineration (78). Some researchers have recommended that it not be used for treating hazardous wastes (78). Low operating temperatures and short residence times make hearths ineffective for treatment of PCBs.

3.2.2.2 Fluidized Bed Incinerators/ Circulating Bed Incinerators

The fluidized bed incinerator is suitable for high-moisture-content wastes, sludges, and high-ash-content wastes (34), although the ash content of the bed must be kept below 20 percent or defluidization of the bed can occur (42). Liquids

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can be treated in a fluidized bed incinerator. A mixture of granular combustion catalyst and limestone can be mixed with the liquid before introduction into the reactor (109). Refractory wastes may not be destroyed in a fluidized bed incinerator (78), and certain organic wastes can cause the bed to agglomerate (76). Organic destruction efficiencies have been reported as greater than 99 percent (125).

The types of wastes that can be treated in a circulating bed incinerator are similar to those that can be treated in a fluidized bed incinerator. Solids, liquids, and sludges have been treated. PCB-contaminated soils have also been treated using this method (78). The waste feed to a circulating bed incinerator must be homogeneous to improve the operation of the reactor (78). A high salt content in the waste may affect refractories and operating conditions. Substances more dense than the bed material cannot be treated in fluidized/circulating beds. Metals and other inorganics are not treated by this technology. No throughput data could be found for mobile fluidized bed systems (76). An existing pilot-scale mobile circulating bed can treat 1 ton of contaminated soil/hr (9).

3.2.2.3 Rotary Kiln Incinerators

Rotary kilns are one of the most widely used incinerators for hazardous waste treatment. They have been used to treat solids, sludges, liquids, and gases. They have been tested on dioxin-contaminated soil, RCRA-listed substances such as dichlorobenzene, trichlorobenzene, tetrachlorobenzene, tetrachloromethane (131), solvent-contaminated soils, PCBs, acids, caustics, cyanides, oils, solvents/cleaners, various chlorinated organics, and pharmaceutical wastes (7). Wastes with low inorganic salt and low mercury content are preferred for treatment in a rotary kiln (7). Wastes that have a high salt content, a high heavy metals content, or that are explosive require special evaluation before they can be treated in a rotary kiln incinerator (78). Organic removal efficiencies have been reported as greater than 99 percent (125). Throughput for mobile rotary kilns is approximately 1.5 ton/hr (9).

3.2.2.4 Infrared Incineration Systems

Infrared incineration systems have been used to treat solids and sludges (78). Liquids and gases could be treated in one of these reactors, if modifications were made. Testing has been done on the infrared incineration systems using municipal and industrial sludges, simulated creosote pit wastes, and dioxin-contaminated soil (131). Organic removal efficiencies have been reported as greater than 99 percent (125). A demonstration scale mobile infrared incinerator is available with throughput of 100 lbs/hr.

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3.2.2.5 Plasma Arc Pyrolysis

Plasma arc pyrolysis has been used to treat liquid and solid wastes (7). Tests have been conducted on liquids contaminated with carbon tetrachloride, PCBs, and a methyl ethyl ketone/methanol mixture (133). Continuous operation of a plasma arc has not been demonstrated on liquids contaminated with organics, pesticides, PCBs, dioxins, or halogenated organics (78). Organic removal efficiencies have been reported as greater than 99 percent (125). No throughput data was identified for these fixed units.

3.2.2.6 Molten Salt/Molten Glass Combustor

Molten salt combustion is best suited for liquid or solid wastes with low ash and water contents. Inorganics such as phosphorus, sulfur, arsenic, and halogens are trapped in the salt bath and form either sodium halides or oxygenated sodium salts (34, 78). Molten salt combustion has been tested on PCBs, tetrachloroethene, chloroform, and trichloroethane. It may not be applicable to dilute acidic-type wastes (42). Chemical warfare agents and pesticides have been tested in a molten salt reactor with removal efficiencies of greater than 99.99 percent. Nitrogen-containing chemicals, organic arsenic compounds, and combustible wastes from nuclear power plants have also been tested. Municipal wastes and sludges and wastes with a high ash content are not suitable for treatment in a molten salt reactor (88).

Molten glass can be used on solids or liquids such as plastics, asphalt, PCBs, or pesticides. It is inappropriate for soils or high-ash-content wastes (78).

3.2.2.7 High-Temperature Fluid Wall Reactor

High-temperature fluid wall (HTFW) reactors are suited for organic hazardous waste treatment and vitrification of inorganic hazardous wastes and low-level nuclear wastes. Low-Btu-content material such as contaminated soils or pure PCBs can be treated using this technology (112). These reactors have been tested on carbon tetrachloride, PCB-contaminated soil, dioxin-contaminated soil, Agent Orange-contaminated soil, and nerve agents. Pretreatment of liquid and solid wastes may be required. Solids fed to the reactor must be finer than 35 U.S. Standard Sieve Size (approximately 0.6 mm) (78). Liquids may have to be mixed with solids (42). Organic removal efficiencies have been reported as greater than 99 percent (125). Mobile HTFW reactors are available that can handle 1.5 tons/hr (9).

3.2.2.8 Wet Air Oxidation

Wet air oxidation is suitable for aqueous wastes that are too dilute to incinerate, but too toxic for biological treatment (109). Wet air oxidation can be used to oxidize any

material, including inorganics with COD values. It has been used to recover chromium from glue sludge, silver from used photographic film, and reusable fillers from paper mill sludges (34). The destruction efficiencies for PCB-contaminated sediments appear to be too low to meet environmental goals. The process is basically applicable for preliminary treatment or for residuals from other treatment processes (59). Aliphatic compounds form other compounds that need further treatment. Although not recommended, aromatic hydrocarbons and halogenated aromatic compounds can be treated, provided there is one non-halogenated functional group in the compound (42, 78). Halogenated aromatic compounds and halogenated condensed-ring compounds require a copper catalyst for treatment (42). PCBs appear to be too stable for complete destruction without adding catalysts. Wet air oxidation is not appropriate for solids or viscous liquids (78). For liquids, organic removal efficiencies from 95 to 99 percent have been reported (125). Metals are not removed (76). Mobile wet air oxidation units with aqueous capacities of 800 gallons/hour are available.

3.2.2.9 Supercritical Water Oxidation

Supercritical water oxidation is suitable for large-volume, dilute aqueous waste streams having sufficient Btu content to sustain the process (78). Solid wastes can be diluted with water up to a 5 percent organic content (131), and 20 to 40 percent solids content (59). Organic chlorides can be destroyed by this method. Spent transformer oils, aromatic chlorides, and non-volatile chlorinated organics have been proposed for treatment by this method (111). Organic removal efficiencies of greater than 99 percent have been reported (125). Transportable supercritical water systems are available with capacities of 1.25 gallons/hour.

3.2.2.10 In-Situ Radio Frequency Heating

This method is especially suited for soils contaminated with volatile, low boiling point, or easily decomposed organic compounds (78, 134). Contaminants with high boiling points and low vapor pressures, such as high molecular weight PAHs, PCBs, and dioxin, may need a reagent to react with the contaminant before this method will work (91). Contamination in the soil can allegedly be treated to depths of 20 feet (134).

3.2.3 Logistical Requirements

The logistical requirements for the thermal treatment technologies are basically the same for all of the processes. Excavation of the material, storage areas for the material, and staging operations are needed for all of the technologies with the exception of in-situ radio frequency heating. Auxiliary fuel for startup or for sustaining the treatment process (if the waste material has insufficient heat value to sustain it) is needed for most of the technologies. An electrical power source

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is required for those processes that do not require an auxiliary fuel. In addition, electric power will be required for any auxiliary operations. Processes that require a secondary combustion chamber for burning combustible gases may also require an auxiliary fuel. Some form of waste preparation is required to ensure that the feed to the reactor does not cause clogging. Some sorting and sizing may be required for some units, particularly fluidized and circulating bed systems. Air pollution control equipment, such as scrubbers for removing acid gases and cyclones or baghouses for removing particulates, will be needed for most processes. A water supply for process needs or quenching will be required. A treatment system will then be needed for these wastewaters. Specific requirements for each technology are provided below.

3.2.3.1 Multiple-Hearth/Fixed-Hearth Incinerators

Waste feed preparation for multiple-hearth incinerators is needed to prevent damage to the rabble arms and to ensure that the waste material can fit through the drop holes as it passes from one hearth to the next.

3.2.3.2 Fluidized Bed/Circulating Bed Incinerators

A process step will be needed to separate ash from the bed material. This can be done as a batch process or continuously. Makeup bed material will be needed to replace spent-bed material. If limestone is added to a circulating bed incinerator, an off-gas scrubber will not be necessary (78).

3.2.3.3 Rotary Kiln Incinerators

Rotary kilns can handle most wastes without the need for significant preparation. Pelletizing may be required to prevent high dust loading in the off-gas (76).

3.2.3.4 Infrared Incineration Systems

Infrared incineration systems require an electric power source for the infrared heating units. Auxiliary fuel may be required for the secondary combustion chamber. Air pollution control equipment will probably be smaller than required for conventional incinerators because auxiliary fuels are not needed in the main reactor. This results in lower gaseous emissions. As a result of the quiescent operating conditions, particulate emissions are low (78).

3.2.3.5 Plasma Arc Pyrolysis

Auxiliary fuels are not required for the main reactor, but electric power is needed for the plasma torch. Gaseous emissions are low because fossil fuels are not burned. Air pollution control equipment will probably be smaller than that required for conventional incineration (42). Because of the

high temperatures, the durability of the plasma torch is a potential problem (42).

3.2.3.6 Molten Salt Combustor

The molten salt mixture acts as a scrubber, and thus reduces or eliminates acid gas emissions. Particulates are also controlled by the molten salt. Both of these aspects reduce the size of required air pollution control equipment. Because the molten salt is corrosive, special construction materials are required for the reactor. This factor raises the capital cost of the unit (88).

3.2.3.7 High-Temperature Fluid Wall Reactor

The waste feed preparation step involves grinding solid material into fine particulates (42). A source of nitrogen is needed for the gaseous envelope. Auxiliary fuel is not required for the main reactor, but electric power is needed for the heating electrodes. Intermediates are not formed in the reactor; therefore, the downstream air pollution control requirements are reduced (109).

3.2.3.8 Wet Air Oxidation

If the waste material is not a liquid, water will be required to produce a slurry that can be fed to the unit. The resulting waste stream from this process will require some form of treatment, such as carbon polishing, before discharge to surface or groundwater (76). High alloy materials may be required for the reactor, a factor which increases the cost of treatment (42).

3.2.3.9 Supercritical Water Oxidation

Again, water will be required to form a slurry if the waste material is not already a liquid (111). The resulting waste stream from this process will require some form of treatment before it can be discharged (59).

3.2.3.10 In-Situ Radio Frequency Heating

This treatment technique does not require excavating, staging, or storage of the waste material. Although auxiliary fuel is not required as part of the actual treatment process, supplemental fuel may be required to treat the off-gases produced. Electric power is required for this process. Some form of containment structure is required to collect the off-gases and vapors that are produced during the heating process.

3.2.4 Public and Environmental Health Concerns

All of the thermal treatment technologies will have at least one of the following waste streams: air, liquid, or solid. Air waste streams can include particulates, acid gases, oxides of nitrogen, carbon monoxide, carbon dioxide, water vapor, cyanides, uncombusted waste material, or hazardous decomposition products. The types of contaminants in the air stream will depend on the waste material and the treatment process used. Treatment of the air waste stream can include scrubbers to remove acid gases, cyclones or baghouses to remove particulates, secondary combustion chambers to incinerate uncombusted waste material or combustible gases produced in the main reactor, and activated carbon for removing uncombusted waste material or combustible gases produced in the reaction chamber.

Liquid residuals can consist of the treated waste stream itself (with remnants of the unreacted organic material) and inorganic material. Liquid residuals can also include scrubber water used to remove the acid gases from the air emissions and quench water from cooling the solid residuals.

Solid residuals will include inorganics and remnants of the contaminants present in the waste material.

Specific residues for each process are discussed below.

3.2.4.1 Multiple Hearth Incinerators

The composition of waste streams from multiple hearth incinerators is contingent upon the nature of the wastes treated. Gaseous emissions will occur, and adequate treatment of the off-gas is required.

3.2.4.2 Fluidized Bed/Circulating Bed Incinerators

Inorganics can be found in the air, liquid, and solid residues (125). Oxides of nitrogen in the air emissions are low because the operating temperatures are low (34, 76, 78). If the correct bed material is selected, acid gases can be trapped in the bed. This eliminates the need for a scrubber for the air emissions (78). The particulates in the air emissions are also low (78). Circulating beds can emit phosphorus, sulfur, and cyanide compounds (78). Metals and inorganic compounds, if present in the waste, can be found in the solid residuals. Such compounds may leach from the solid residuals.

3.2.4.3 Rotary Kiln Incinerators

Air, liquid, and solid residuals are generated by this process (125). Halogenated wastes will produce acid gases; a scrubber is required to remove them from the air effluent. The scrubber water will generally require treatment before it is discharged (62). If metals are present in the waste material,

the ash residue may present a disposal problem because the metals will remain in the ash (7). Ash residue may require solidification before it can be landfilled (78).

3.2.4.4 Infrared Incineration Systems

Air, liquid, and solid residuals are formed during this process. Inorganics will appear in these residuals if they are present in the waste material (125). Quiescent operating conditions result in low particulate emissions. Since no fossil fuels are burned, gaseous emissions are lower for this type of incinerator than for other types (78).

3.2.4.5 Plasma Arc Pyrolysis

Plasma arc pyrolysis results in the formation of slag. Because the slag may contain inorganics, it must be disposed of properly (7). Since no fossil fuels are burned, gaseous emissions are low (42). Acid gases are produced, and scrubbers will be required. The scrubber water must be treated before it is discharged (133).

3.2.4.6 Molten Salt Combustor

The low operating temperatures of a molten salt combustor reduce the formation of oxides of nitrogen (34). Tests on certain waste types (hexachlorobenzene and chlordanes) have shown that chlorine, phosgene, or NO_x are produced in the combustor (110). The molten salt acts as a scrubber and reduces or eliminates the production of acid gases and particulates (78). Inorganics are found in the solid residue. Tests have been conducted on spent salt to insolubilize the salt in glass and concrete (88).

3.2.4.7 High-Temperature Fluid Wall Reactor

The solid residue from this process is a glass-like particle that appears to be non-leachable (42). Inorganics from the waste material are found in the air, liquid, and solid residuals (125). Production of nitrogen oxides and particulates is low (112). Tests have shown that dioxins are not formed by this process. Treatment of the air emissions has included a cyclone, baghouse, caustic scrubber, and activated carbon bed (112).

3.2.4.8 Wet Air Oxidation

Solid residuals from this process must be separated from the liquid waste stream. The liquid waste stream can contain inorganics and organics not removed by the process (125). Further treatment of the liquid waste stream is almost always required. The off-gas has low concentrations of nitrogen oxides, sulfur oxides, and particulates (78).

3.2.4.9 Supercritical Water Oxidation

Inorganics can be found in the air, liquid, or solid residuals from this process (125). Inorganic salts will precipitate out of the liquid effluent, whereas some soluble organic acids and salts will remain in the liquid. Further treatment may be required (78). The gaseous effluent will include nitrogen and carbon dioxide (78).

3.2.4.10 In-Situ Radio Frequency Heating

Once collected, air emissions from this process will require separation of gases and liquids that have condensed from vapors. Both may be incinerated on site, or the gases can be sent through an activated carbon treatment unit, and the liquids can be sent off site for incineration (91). This process may not completely detoxify the contaminants, especially if the depth of contamination is too great. If contaminants remain, they may migrate.

3.2.5 Case Histories/Description of Developmental Status

3.2.5.1 Multiple Hearth Incinerators

Multiple hearth incinerators are commercially available (178) and have been widely used for sewage sludge incineration. Hazardous waste incineration by this method has not been extensively tested.

3.2.5.2 Fluidized Bed/Circulating Bed Incinerator

Fluidized bed incinerators are commercially available (108) and have been used for coal combustion and municipal sludge incineration (42). They have been tested at the pilot plant stage on dichlorobenzenes, tributyl phosphates, and liquids contaminated with carbon tetrachloride (109). They have also been tested on solids at the pilot plant stage (125).

Circulating bed incinerators have been tested at the pilot plant stage for PCBs. A PCB test burn has also been conducted (131).

3.2.5.3 Rotary Kiln Incinerators

Rotary kilns are the most highly developed hazardous waste incineration technology (108). Commercial mobile units and fixed units are available (125). Several commercial units have permits for incinerating PCBs (131). EPA has tested a mobile unit for incinerating dioxin-contaminated soil at the bench, pilot-plant, and field-test scales (132).

3.2.5.4 Infrared Incineration System

A mobile infrared incineration system has been tested on dioxin-contaminated soil at the pilot plant scale (131). Several

operational units are available. A pilot-plant test unit is available for use in evaluating its effectiveness for different types of wastes (78).

3.2.5.5 Plasma Arc Pyrolysis

A mobile, pilot-plant scale unit is available (78). EPA and the State of New York will test a unit currently being built at Love Canal (125).

3.2.5.6 Molten Salt Combustion

These commercially-available combustors have long been used in the metallurgical industry to recover metals (78). Current research is investigating their use in organic waste destruction, coal gasification, and flue gas desulfurization (42). Testing of these units on hazardous waste has been conducted at the bench- and pilot-plant scales. Rockwell has completed a conceptual design of a full-scale plant (110).

3.2.5.7 High-Temperature Fluid Wall Reactor

The Advanced Electric Reactor of J.M. Huber has been permitted under TSCA for the destruction of PCBs in Region IV (59). The high-temperature fluid wall reactor has been tested on solids and liquids at the pilot-plant scale (125). Commercial units are under construction by Thaggard, but none are in use at this time (78).

3.2.5.8 Wet-Air Oxidation

Wet-air oxidation has been used to treat industrial and municipal wastes for the past 40 years. This technology has been tested at the bench scale and pilot-plant scale for various hazardous organic wastes, with some units treating specific waste streams (42). Commercial units are available (78).

3.2.5.9 Supercritical Water Oxidation

Supercritical water oxidation has been tested at the bench-scale level (111) and at the pilot-plant scale on liquid waste and groundwater (125). Additional data needs include Destruction-Removal Efficiencies, residuals, bench-scale testing, pilot-plant testing, and field tests (59). A commercial unit is to be available in 1987 (78).

3.2.5.10 In-situ Radio Frequency Heating

Laboratory scale tests have been completed on tetrachloroethylene, PCBs, and PCB-contaminated soil treated with potassium polyethylene glycolate (KPEG) (134).

3.2.6 Vendor Summary

A listing of the vendors for the various technologies discussed in this section is provided in Table 3-1.

3.2.7 Data Requirements

A preliminary listing of the data requirements for the evaluation of the feasibility of thermal treatment at the Douglassville Disposal Site is presented in Table 3-2. The information presented in Table 3-2 is separated into two parts. The first part lists pre-bench/pilot-scale data needs. These data will be obtained during the Phase I Remedial Investigation (RI) to provide a basis for additional technology assessment. These data may also be provided to thermal treatment vendors in conjunction with the Phase II RI. Vendors may have specific data requirements not included in Table 3-2. Examples of such data are melting point, ignitability, corrosivity, explosivity, and reactivity. Vendors will generally satisfy these requirements during preliminary laboratory testing.

Table 3-2 also summarizes post-bench/pilot-scale requirements. Bench and pilot-scale studies will be designed to satisfy these data requirements to support the feasibility study.

Although an attempt has been made to make this listing of data requirements as complete as possible, additional data requirements may become apparent at a later date.

3.2.8 Bench/Pilot Scale Study Recommendations

Because of the heterogeneous nature of the wastes to be treated at the Douglassville Disposal Site, it is recommended that both bench- and pilot-scale studies (test burns) be conducted to determine the feasibility of thermal treatment.

Solicitations for bids will be issued to vendors of thermal treatment technologies who have field experience in its application (subject to EPA approval). These solicitations will include a summary of all relevant chemical-analytical and physical data for the site.

The vendors will be asked to provide the following background information and services:

- A technical description of a proposed thermal treatment method.
- Case histories and supporting data.
- Services for the destruction of oil and grease, polynuclear aromatic hydrocarbons, phthalate esters, phenols, polychlorinated biphenyls, non-halogenated aromatics, and halogenated aliphatics.

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TABLE 3-1

VENDOR SUMMARY - THERMAL TREATMENT TECHNOLOGIES

Technology	Vendor
Fluidized Bed Incinerators	Black-Clawson Fiberclaim, Inc. Energy Incorporated Battelle GA Technologies (mobile) Dorr-Oliver Waste-Tech Services (mobile)
Circulating Bed Incinerators	GA Technologies (mobile)
Rotary Kiln Incinerators	Environmental Elements Corp. S.D. Meyers, Inc. American Industrial Waste ENSCO, Inc. (mobile) Exceltech, Inc. International Waste Energy System Winston Technology, Inc. (mobile) Industronics Volund USA Universal Energy International, Inc.
Infrared Systems	Shirco Infrared Systems (mobile)
Plasma Arc Pyrolysis	Pyrolysis Systems, Inc. Applied Energetics, Inc. Westinghouse
Molten Salt Combustion	Rockwell International
Molten Glass Combustion	Penberthy Electromelt, Inc. Battelle Northwest
High Temperature Fluid Wall Reactor	Thaggard
Advanced Electric Arc Reactor	J.M. Huber (mobile)
Wet Air Oxidation	Zimpro, Inc. (mobile) IT Environscience MODAR Company (mobile) Methods Engineering Vertech Treatment Systems
Supercritical Water Oxidation	MODAR Company (mobile) Vertox Corporation
In-situ Radio Frequency Heating	Illinois Institute of Technology - Research

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TABLE 3-2

DATA REQUIREMENTS - THERMAL TREATMENT TECHNOLOGIES

Pre-Bench/Pilot-Scale Requirements

Chemical-analytical data (waste and soil/waste composition) <ul style="list-style-type: none"> • Organic composition • Metal content • Carbon, hydrogen, oxygen, halide, sulfur, nitrogen, and phosphorus content
Vertical and horizontal extent of contamination
Moisture and ash content
Heating value (BTu)
Density

Post-Bench/Pilot-Scale Requirements

Destruction and Removal Efficiencies
Effluent concentrations and evolution rates (all waste streams)
Auxillary fuel requirements
Electric power requirements
Water requirements

- An estimate of achievable levels of treatment.
- A conceptual model of a proposed thermal treatment alternative.
- Test studies designed to demonstrate that destruction can be effected.
- Initial unit cost estimates.
- An estimate of the time to complete the operation and capital/operation and maintenance costs (upon completion of test burns, etc.)
- A summary of all findings and conclusions in a report to be submitted upon completion of testing.
- Support with regard to compliance with state and Federal ARARs.
- Recommendations for the handling and treatment of waste from any process thermal treatment process.

3.2.9 Costs

Available unit-cost information for the various thermal technologies is summarized in Table 3-3.

3.3 EXTRACTION

3.3.1 General Description

Contaminants adsorbed on the solid particles of a soil matrix can conceivably be removed or separated from the soil through the use of extraction processes. The economic feasibility and success of such extraction technologies are dependent upon the properties of the contaminants, the characteristics of the solid matrix, the extraction method, and the site-specific environmental concerns.

For the Douglassville Disposal Site, one of the primary remedial objectives is the cleanup of contaminated soils or the prevention of continued release of contaminants to the water-table aquifer and the Schuylkill River. Therefore, the separation of contaminants from soil or sludge through the use of extraction technologies is considered a potential remedial method for the site.

Contaminants adsorbed on a soil or sludge matrix can be desorbed through the application of hydraulic forces and physiochemical reactions. The passage of water through the soil or sludge can scrub and/or dissolve the water-soluble contaminants and entrain these dissolved contaminants in the water. For those

TABLE 3-3

THERMAL TREATMENT TECHNOLOGY COSTS ¹

Method	Cost	Reference	Comments
Multiple Hearth Incinerator (2)	\$42-\$374/pound/hour - Installed Cost \$45-\$57/yard ³	138	Cost based on dry solids, sludges with 15% moisture
Fluidized Bed Incinerators	\$1500-\$2400/yard ³	9	For sludges/solids
Circulating Bed Incinerators	\$227-\$319/yard ³	9	
Rotary Kiln Incinerators	\$225-\$675/yard ³	9	
Infrared Incineration Systems	\$114-\$116/yard ³	9	
High Temperature Fluid Wall Reactor	\$1085-\$1233/yard ³ \$236-\$343/yard ³	59 9	For PCB-contaminated soil For advanced electric reactor
Supercritical Water Oxidation	\$327-\$959/yard ³	59	For PCB-contaminated sediments
In-Situ Radio Frequency Heating	\$44-\$86/yard ³	134	Based on laboratory tests

- Costs converted to consistent units: 1 ton = 2,000 pounds;
1 yard³ = 3,000 pounds; 1 m³ = 1.308 yard³.
- Multiple hearth incinerator installed cost - capital expenditure required to build unit on site.

contaminants that are hydrophobic in nature, solubility can be enhanced through the use of aqueous surfactants. A specific solvent can also be used in place of water. Processes such as ion-exchange, oxidation-reduction, complexation, and desorption can be involved, depending on the selected solvent. One mechanism that may be used to desorb contaminants from a solid matrix is through the modification of the surface tension of the interstitial aqueous solution. The consequential increase of the surface of contact between the contaminant and the solution can improve the separation of the contaminant from the solid particles. Surfactants are the additive used to strengthen this mechanism. Other mechanisms, such as the control of solvent properties through temperature changes and the application of gas stripping, etc., can also be used to remove contaminants from the soil matrix.

The contaminant entrained in the carrier fluid/gas (water, solvent, or air) should be removed from the interstitial pore area. The ease of removal of the carrier fluid from the soil/sludge or the clogging of pore spaces may significantly affect the application of extraction technologies. The removed carrier fluid containing the extracted contaminant can be treated for reuse.

Considering the volume of contaminated sludge and soil at the Douglasville Disposal Site, the nature of the contaminants at the site, and the availability of the extraction technologies, six methods are presented in this report. They are solvent extraction (including water), surfactant extraction, the Basic Extraction Sludge Treatment (B.E.S.T.) process, supercritical fluid extraction, the alkaline polyethylene glycol (APEG) process, and critical fluid extraction system. Although these methods are available and may be applicable at the site, treatability and pilot-scale studies are necessary to establish their effectiveness.

3.3.1.1 Solvent Extraction

Solvent extraction is a method for leaching of organic and inorganic pollutants from the soil (94). Soil at the site may be excavated prior to treatment or may be treated in situ. For post-excavation applications, the contaminated soil is mixed with an extracting agent (solvent) to transfer the contaminants from the solid to the liquid phase. The mixing step occurs in a stirred reactor. It is possible to remove not only the solvent-soluble contaminants but also insoluble contaminants that may form a stable colloidal suspension (6, 143). After extraction is complete, the treated soil particles are separated from the extracting agent via filtration or sedimentation. For in-situ applications, the site is flooded with an appropriate flushing solution (e.g., water, acidic solutions, basic solutions, etc.), and the elutriate can be collected in a series of shallow well points or subsurface drains. The elutriate is collected, treated, and recycled to the area to be treated.

Collection of the elutriate is required to prevent uncontrolled contaminant migration through uncontaminated soil or into groundwater or surface water (6, 7, 55).

Extraction processes may be effective for removing hazardous materials from a solid matrix, but additional treatment of liquid streams is necessary. Liquid waste streams (e.g., contaminated solvents) may be treated using conventional distillation columns, oil water separators, incinerators, or other treatment methods.

When large volumes of subsurface soils are contaminated, excavation of the soil may not be economically feasible. A mobile in-situ soil treatment system developed by EPA (146) can be used to flush the soil with water or other applicable solvents at reduced cost.

Specific solvents have been developed to extract certain classes of organic chemicals, such as halogenated compounds (39). Extraction of other types of contaminants, such as heavy metals, has been tested on the laboratory scale (145). Treatment of PCB-contaminated soil via solvent extraction has also been demonstrated. Reagents examined in the tests included an aliphatic solvent, insulating oil, and 1,1,1-trichloroethane. The laboratory tests indicated that PCBs can be readily extracted from contaminated sand, gravel, clay, or top soil.

3.3.1.2 Surfactant Extraction

Surfactants passing through a soil or sludge matrix can remove the adsorbed contaminants by substitution, emulsification, and/or solubilization. Laboratory studies have been conducted to determine if aqueous phase extraction efficiency can be enhanced through surfactant addition to the water (54). The bench- and pilot-scale results indicate that aqueous surfactant solutions may be applicable for in-situ washing of slightly hydrophilic and hydrophobic organics from soils. In-situ soil washing with surfactants can be applied when the soil has a hydraulic conductivity greater than 10^{-4} cm/sec (144). The liquid that contains the desorbed contaminants percolates to a perched or unconfined aquifer, where it can be removed through pumping. Collection of the liquid with an underground drainage system is also feasible, but this is also dependent on the hydraulic conductivity of the overburden.

Surfactant-assisted flushing or mobilization/solubilization of wastes can serve two purposes: to promote the recovery of contaminants from the subsurface for treatment, or to solubilize adsorbed compounds in order to enhance the rate of other in-situ treatment technologies such as biodegradation or hydrolysis (142). Although water may be sufficient for flushing or mobilizing relatively soluble compounds such as phenols or volatile organics, the use of surfactants is required for solubilization of hydrophobic compounds.

Based on applications used in the oil industry, the use of surfactant extraction at the Douglassville Disposal Site may be feasible.

3.3.1.3 Basic Extraction Sludge Treatment Process (B.E.S.T.)

The Basic Extraction Sludge Treatment (B.E.S.T.) approach is a patented process developed in the 1970s by the Resources Conservation Company as a means of dewatering municipal wastewater treatment sludges. The process successfully recovered solids high enough in nutrients to be sold as animal feed or fertilizer. The low price of these products, along with the availability of inexpensive disposal alternatives, made this method economically infeasible at that time. The process was not developed further until the Resource Conservation and Recovery Act (RCRA) was promulgated. As a result, investigation of B.E.S.T. as a method for the treatment of oily sludges was initiated. This method handles difficult-to-treat, emulsified, oily sludge by breaking the emulsion and chemically separating the sludge into components of oil, water, and solids. (139)

The B.E.S.T. process uses one or more of a family of aliphatic amines as solvents to break oil/water emulsions. The aliphatic amines have a unique property: when cooled below 68°F, they become completely miscible with water, but when heated they become immiscible. The B.E.S.T. process involves mixing refrigerated amine solvents with the oily sludges. The solvent immediately liquifies the sludge and converts the mixture to a homogeneous solution. Since the temperature is kept below the solubility line, solids are no longer bound in the oil/water emulsion (that was part of the original sludge) and separate from the solution. Once the solids are removed, the temperature of the liquid fraction, which contains the oil, water, and solvent, is heated above the solubility line, and the water separates from the oil and solvent. The oil is then separated from the solvent via distillation.

3.3.1.4 Supercritical Fluid Extraction

Supercritical fluid (SCF) extraction is a promising new technology for the removal of organic chemicals from contaminated matrices at hazardous waste sites. The ability of SCF extraction to remove PCBs, DDT, and toxaphene from contaminated topsoils and subsoils has been demonstrated by Brady et al. (141).

Typically, a simple solvent gas, such as carbon dioxide, is brought into contact with a solid or liquid waste at high pressure and moderate temperature. Slight changes in the temperature or pressure can cause large changes in the density of the gaseous solvent and, consequently, in its ability to

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solubilize heavy non-volatile compounds from the waste. Following a pressure reduction, generally to below the system's critical conditions, the non-volatile material can be completely precipitated from the solvent.

Supercritical fluids exhibit density, viscosity, and diffusivity characteristics that are intermediate to those for liquids and gases; that is, SCF has the solvent power of liquids with better mass transfer characteristics than typical liquids. Consequently, separation efficiencies for extraction via SCF can be much higher than for typical liquid solvent extraction systems.

An attractive feature of this process is that the carbon dioxide is virtually inert and leaves no solvent residue in the treated soil. Furthermore, the ease of separation of the extracted solute from supercritical carbon dioxide results in a smaller waste volume of the concentrated organics, a factor which improves the efficiency of subsequent treatment processes, such as combustion.

3.3.1.5 APEG Process

The APEG Process has been developed by Galson Research Corporation and is particularly applicable for treatment of PCB-containing wastes. Contaminated soil may be excavated and mixed with an alkaline reagent consisting of potassium hydroxide and a solution of mixed polyethylene glycol (PEG) and dimethyl sulfoxide. The reagent dechlorinates the aryl halide to form a PEG ether, which may further degrade to a totally dechlorinated species. The soil and reagent are heated to a temperature of 86 to 302°F and mixed until the reaction is complete. Some of the metals present in the soil will be converted to metal hydroxides by the action of the alkali. At the end of the reaction, the reagent is recovered by decantation and washing the soil with several volumes of water. The water will also remove some of the metal hydroxides. The decontaminated soil is then discharged, and the reagent is recycled for reuse (12).

3.3.1.6 Critical Fluid System

The general principles of critical fluid (CF) extraction are similar to those of supercritical fluid extraction.

Contaminated soil is excavated and slurried so that a pumpable material is obtained. In the CF extraction unit, no chemical reagents are added. The recirculating solvent gas flows through the solids and extracts the contaminants. The process operates continuously at room temperature, and no chemical reaction takes place between the solvent gas and the waste stream (70).

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3.3.2 Waste Treatment Capabilities

The capabilities and effectiveness of extraction technologies are dependent on numerous site-specific factors, including the following:

- Properties of the contaminants, such as solubility, vapor pressure, etc.
- Soil characteristics, such as particle size, hydraulic conductivity, percentage of clay and silt, etc.
- Environmental factors, such as temperature, pH, content of organic matter, cation exchange capacity, etc., of soil/sludge.
- Volume of contaminated soil/sludge.
- Concentration level of the contaminants.
- Suitability of the site to flushing and recovery or excavation.
- Depth to groundwater and flow direction

Additional details with regard to the various extraction techniques are summarized in the sections that follow.

3.3.2.1 Solvent Extraction

Specific contaminant removal depends on the selection of an appropriate solvent. Results from various studies (6, 94, 143) indicate that the following contaminants can be removed via solvent extraction:

- Heavy metals, such as cadmium, zinc, copper, nickel, chromium, arsenic, lead and antimony, and metal-organic compounds.
- Hydrocarbons and halogenated hydrocarbons (e.g., trichloroethene).
- Cyanides or cyanide complexes.
- Aromatics (e.g., benzene, toluene, cresol, phenol).
- Gasoline and fuel oils.
- PCBs and chlorinated phenols.
- Water-soluble constituents.
- Basic organic constituents, such as amines, ~~esters~~ and anilines.

Mobile surface-mounted soil washing systems and mobile in-situ soil treatment systems have been developed and tested (146). Soil washing systems have been developed to remove hazardous materials from contaminated soil following excavation. A prototype system capable of processing 3 ~ 14 m³ soil per hour (depending on the soil particle size and the nature of the contaminant) has been devised. The in-situ system was designed to flush the soil in place with water or other solvents.

Ellis et al. (145) reported that solvent extraction can be a viable method for treating soils contaminated with heavy metals. Their tests indicated that sequential treatments of soils with ethylene diamine tetraacetic acid (EDTA), hydroxylamine hydrochloride, and citrate buffer were effective in removing metals from soils. The best removal efficiencies observed were as follows: cadmium (98 percent), lead (96 percent), copper (73 percent), chromium (52 percent), nickel (23 percent).

A patented method developed by Peterson also showed that soils contaminated with the following contaminants can be detoxified with an alkaline reagent (39).

- Halogenated organic compounds (e.g., chlorinated benzenes, phenols, PCBs, dioxins).
- Highly chlorinated aromatics (e.g., hexachlorobenzene, polychlorinated phenols, polybrominated biphenyls).
- Polyhalogenated aliphatics (e.g., carbon tetrachloride and trichloroethylene).

Although laboratory and pilot test results from various studies indicate that solvent extraction can be applicable for removal of contaminants present at the Douglassville Disposal Site, its use is dependent on site-specific waste and soil properties, as well as hydrogeologic conditions (if in-situ approaches are considered). Treatability studies using the soil/sludge materials at the site will be required.

3.3.2.2 Surfactant Extraction

Hazardous waste sites with large volumes of moderately to highly contaminated soils, such as the Douglassville Disposal Site, may be amenable to soil flushing using recirculating systems. A recent evaluation conducted by CDM (7) on the use of water-flushing techniques for the extraction of hydrophobic and slightly hydrophilic organics revealed that the addition of selected water soluble surfactants greatly enhanced the removal of such organic compounds. The contaminants amenable to this process include heavy metals (such as copper, lead, and zinc), halogenated aliphatics (such as trichloroethylene, trichloroethanes, and chloroform), aromatics (such as benzene, toluene, creosol, and phenols), oil, and gasoline.

In general, the use of surfactants can increase the mobilization of the following contaminants: aliphatic hydrocarbons, benzene and substituted benzene, halogenated aromatic compounds, fused polycyclic hydrocarbons, fused non-aromatic polycyclics, ethers, heterocyclic nitrogen compounds, heterocyclic oxygen compounds, heterocyclic sulfur compounds.

It is recognized that an in-situ application to the Douglassville Disposal Site may be limited by the vertical distribution of wastes in relation to the water table and by the ability to fully recover the flushed contaminants. (Secondary permeability dictates bedrock groundwater flow and subsurface control may be difficult.)

3.3.2.2 B.E.S.T. Process

B.E.S.T. can be used to treat soil contaminated with the following materials:

- Creosote
- Oil emulsion solids
- Heat-exchanger-bundle cleaning sludges
- API-separator sludge
- Tank bottoms
- Primary oil/solids/water separation sludges
- Secondary soil/solids/water separation sludges
- Biological sludges
- Cooling tower sludges
- HF alkylation sludges
- Waste FCC catalysts
- Spent catalysts
- Stretford Unit solution
- Treated clays

A number of these types of materials are believed to be present at the Douglassville Disposal Site. An existing B.E.S.T. full-scale unit has a capacity of 100 tons of sludge per day. It can handle sludges containing up to 30 percent oil and 40 percent solids without modifications.

3.3.2.4 Supercritical Fluid Extraction

Supercritical fluid (SCF) has the capability to solubilize heavy molecular weight organic chemicals such as those present at the Douglassville Disposal Site. In general, SCF can be used to extract a wide range of soluble organic compounds. The treatability of soils contaminated with relatively insoluble chemicals such as PCBs, DDT, and toxaphene has been demonstrated in the laboratory (141).

3.3.2.5 APEG Process

The APEG process is commercially available for transformer fluids. The waste treatment capability of the process has been demonstrated at the pilot-scale for the following contaminants:

- Aromatic halides, including PCBs
- Chlorinated dioxins
- Dibenzofurans

3.3.2.6 Critical Fluid System

This method is also commercially available. Waste treatment capability is reported to include the following substances that are present or presumed present at the Douglassville Disposal Site:

- Gasoline (aromatic and straight-chain constituents)
- Alkanes
- Halogenated aliphatics
- Oils and greases
- Organic acids
- Phenol and chlorinated phenols
- Polynuclear aromatic hydrocarbons

3.3.3 Logistical Requirements

Required onsite facilities include access roads, safety facilities, decontamination areas, chemical storage facilities, and possibly an onsite or nearby offsite laboratory for quality control tests. Utilities required include electricity and water. Extraction processes can be performed in-situ or after the waste has been excavated.

For in-situ techniques, extraction agent injection wells (or infiltration galleries) and recovery wells must be installed. An onsite area would be designated as a processing area for the extraction agent. This includes equipment required to separate the contaminants that are extracted from the soil from the extraction agent. The extraction agent can then be recycled for reuse. Any waste streams or residuals generated by the separation process must be further treated and/or properly disposed. These waste streams/residuals will contain the contaminants removed from the waste.

For extraction following excavation, a staging area may be required to prepare the waste prior to treatment. Waste preparation may include sizing, mixing, and/or grinding. As with in-situ techniques, a processing area is needed where the waste will be treated and the contaminated extraction agent can be cleaned and recycled for reuse. Any waste streams which will contain the contaminants extracted from the waste, must be further treated and/or disposed properly. The treated (decontaminated) waste can be used to backfill the excavation.

The Douglassville Disposal Site is located in the 100-year floodplain of the Schuylkill River. This is an important consideration in evaluation of onsite treatment/disposal actions. In addition, there may be some residual contamination that may remain in the waste following treatment. The scheduled land disposal bans of certain RCRA hazardous wastes by EPA should also be evaluated.

3.3.4 Public Health and Environmental Concerns

Extraction of excavated contaminated soils in a closed contactor will not normally pose any significant environmental problems, except that any residual wastes must be further treated or disposed. Methods like B.E.S.T., supercritical fluid, APEG, and critical fluid fall into this category. In-situ soil washing using a solvent or surfactant may complicate site problems. For example, when specific contaminants and extracting agents are combined, other hazardous compounds may form, especially in the form of gases. The release of hazardous gases into the atmosphere should be prevented. The release of volatile organics, chelating agents, reducing agents, and organic acids into the environment is possible. An in-situ approach should not be conducted unless a great deal of control can be exerted using pumping wells. Backup systems would be necessary.

The flushing solutions may be potential pollutants themselves. They may have toxic and other environmental impacts on the hydrologic domain. Following treatment, the soil is altered from its original state. The physical, chemical, and biological properties may be adversely altered. The soil properties may need to be restored to assure that other treatment processes (e.g., biodegradation) can proceed. Additionally, the future land use should also be considered.

3.3.5 Case Histories/Description of Developmental Status

Extraction technology testing at the laboratory scale is well documented. However, field application of the extraction methods are dependent upon the results of pilot- or field-scale studies. Developmental status and certain case studies of the various extraction technologies presented are described in the following sections.

3.3.5.1 Solvent Extraction

These extraction processes are favorable for application if the soil to be treated primarily consists of sand particles. Organics, humus-like substances, and clay may pose difficulties in application. Continuing studies are being performed to determine appropriate solvents for mobilizing various classes and types of contaminants. Applicability of this technology in-situ is highly dependent on the ability to flood the soil

with the flushing solution and the installation of collection wells or subsurface drains to recover all the applied liquids.

Currently, this technique is to be used at several hazardous waste sites, including Bridgeport, South Tacoma Channel, and Burnt Fly Bog. Experimental testing is being conducted at other sites. These include the following:

- Volk Air National Guard Base, Juneau County, Wisconsin - performed by the Air Force Engineering and Service Center, Tyndall AFB, FL. Soils contaminated with volatile organics were leached with water containing 2 percent surfactant. The leachate was regenerated by air stripping.
- Lee's Farm Wisconsin - Battery Manufacturing. Contaminants include lead, zinc, copper, etc. Lead-contaminated soils were leached with a solution of water and 5 percent EDTA. The leachate was regenerated by electrolysis.
- Celtor Chemical Works, Hoopa Indian Reservation - Ore Enrichment Plant: Extraction used to treat tailings containing cadmium, copper, and zinc.
- Battery Dumping Pit - Leeds, Alabama. Lead contaminated soils were leached with a solution of water and 2 percent EDTA. The leachate was regenerated by sulfide precipitation.

3.3.5.2 Surfactant Extraction

It has been reported that surfactants may enhance the recovery of subsurface gasoline leaks by groundwater pumping and may also promote the mobilization of crude oil and PCBs from soils (142). However, some studies indicated that no reliable conclusions can be drawn with regard to the effectiveness of the surfactants in removing oil and grease. More detailed laboratory tests are needed.

An EPA study on the use of surfactants was reported (54). The selected surfactants for use in this study were Adsee 799 (Witco Chemical) and Hionic NP-90 (Diamond Shamrock). Shaker-table tests were used to determine the minimum surfactant concentration required to accomplish acceptable soil cleanup. Soil column tests were used to determine the effectiveness of the surfactants in removing the contaminants from the soil.

Equal quantities of each of the selected surfactants were mixed into a 4 percent surfactant in water solution. Freehold soil (at 12 percent TOC) was spiked separately, with 1,000 ppm Murban distillate cut, 100 ppm PCB, and 30 ppm chlorinated phenols with Murban distillate cut. Murban distillate cut is the high boiling point Murban crude oil fraction containing aliphatic and

aromatic hydrocarbons. Results of the column test with Murban distillate cut showed that the initial water wash had little effect; however, with surfactant washing, 74.5 percent of the pollutant was removed after 3 pore volumes were extracted and 85.9 percent was removed after 10 pore volumes. The pollutant concentration in the soil was reduced to 6 percent of the initial spike value after the tenth pore volume of surfactant was flushed through the matrix.

For the PCB spiked soil and 4 percent surfactant solution, after the tenth pore volume, 98 percent of the PCBs were contained in the leachate, leaving only 2 percent in the soil. Similar experiments for a mixture of di-, tri-, and pentachlorophenols showed that 64.5 percent of the chlorinated phenols were removed by the water wash alone, and only 0.56 percent remained in the soil after the tenth pore volume of water.

Results of the column experiments, coupled with the results of the shaker table experiments, indicated that the optimum surfactant concentration for soil cleanup is about 0.75 percent of each surfactant, or 1.5 percent total surfactant. As TOC in the soil increases, the percentage of surfactants will probably also increase.

3.3.5.3 B.E.S.T. Process

The General Refining Site, located near Savannah, Georgia, was selected for the application of this method. There were three operational problem areas: centrifuge seals, the dry solids conveying system, and the control of the solvent stripper. Although the cleanup at the General Refining Site is still in its startup stage, the B.E.S.T. unit has consistently separated the sludge into fractions that meet or exceed contractual requirements.

3.3.5.4 Supercritical Fluid Extraction

Carbon dioxide has been used to demonstrate the capability of supercritical fluid extraction (141). Contamination levels of 100 ppm PCBs, 900 ppm DDT, and 400 ppm toxaphene were tested. Approximately 70 percent of DDT and 75 percent of toxaphene can be leached from the soil in less than 10 minutes by supercritical carbon dioxide extraction. The extraction of the laboratory-contaminated subsoil spiked with PCBs proved to be most promising; with more than 90 percent of the PCB was extracted in less than 1 minute.

3.3.5.5 APEG Process

Galson Research Corporation claims that this process has been demonstrated on both laboratory and drum scales. This process is presently being considered for application at Wide Beach. The results of a scheduled field demonstration may provide

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TABLE 3-4

VENDOR SUMMARY - EXTRACTION TECHNOLOGIES

Technology	Vendor
B.E.S.T.	Resources Conservation Company
APEG	Galson Research Corp.
Critical Fluid System	CF Systems Corp.

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TABLE 3-5

DATA REQUIREMENTS - EXTRACTION TECHNOLOGIES

Pre-Bench/Pilot-Scale Requirements

Concentration of waste constituents
Depth, profile, and areal distribution of contamination
Waste characteristics, such as solubility in water, soil/water partitioning coefficient, vapor pressure
Soil characteristics, such as pH, cation exchange capacity, Eh, organic carbon content, particle size distribution, soil type, hydraulic conductivity, iron and manganese oxide concentration
Mobility of pollutants
Soil moisture content

Post-Bench/Pilot-Scale Requirements

Effect of solvent on the soil physical, chemical, and biological properties
Suitability of the site for flooding with extraction agent
Recharge rate of surfactants
Withdrawal rate of surfactants/solvents
Evaporation rate
Precipitation rate
Achievable concentrations
Retention times
Mass balance information (solvent to soil ratio, etc.)

additional input for possible application at the Douglassville Disposal Site.

3.3.5.6 Critical Fluid System

This method has been fully commercialized to remove soluble organics from water and solids. CF SYSTEMS Corporation has studied this system for oil refinery waste applications. The results of this study are as follows:

	<u>Material</u>	<u>Component</u>	<u>Oil and Grease (%)</u>
1.	Oil Contaminated Refinery Soil	Feed	34.3
		Residue Solids	0.6
2.	Refinery Sludge (60% Solids)	Feed	20.0
		Residue Solids	2.6
3.	API Separator Bottoms	Feed	5.0
		Residue Solids	0.2
4.	Filter Cake from Refinery Pit	Feed	12.0
		Residue Solids	0.5

3.3.6 Vendor Summary

There are few vendors of extraction systems, especially in the area of in-situ soil washing with solvents/surfactants. A list of vendors for the extraction technologies discussed in the preceding sections is provided in Table 3-4.

3.3.7 Data Requirements

Based on a review of existing literature and reports, a preliminary list of data requirements has been generated. Table 3-5 summarizes these requirements. Since the exact data needs are site-specific, this table will be modified whenever new information or results of pilot studies are available.

3.3.8 Bench/Pilot Study Recommendations

Most technologies for contaminant extraction from soil/sludge are still developing, although some have reached more developed stages. In general, the effectiveness of the extraction technologies are highly site-specific, especially for sites with relatively nonuniform characteristics. Waste characteristics at the Douglassville Disposal Site appear heterogeneous. Therefore, both laboratory- and pilot-scale studies for the extraction technologies are recommended.

Because soil extraction is expected to be a complicated endeavor, solicitations for bids will be issued to vendors of extraction technologies who have field experience in its application (subject to EPA approval). Such solicitations will

include a summary of all available chemical-analytical, physical, and hydrogeologic data for the site.

The vendors will be asked to provide the following background information and services:

- A technical description of the proposed extraction technology.
- Case histories and supporting analytical data.
- A description of proposed bench and pilot-scale studies.
- Services for the extraction of oil and grease, polynuclear aromatic hydrocarbons, phthalate esters, phenols, polychlorinated biphenyls, non-halogenated aromatics, and halogenated aliphatics.
- An estimate of achievable levels of treatment (prior to initiation of bench and pilot-scale studies to the extent practicable).
- A conceptual model of a proposed extraction alternative.
- Bench-scale studies designed to demonstrate the effectiveness of handling the waste material. (Techniques will be left to the discretion of the vendor but will be subject to EPA approval.)
- Services or support in the area of underground monitoring for leakage of solvent/surfactant or extracted contaminants.
- Initial unit cost estimates.
- An estimate of the time to complete the operation and capital/operation and maintenance costs (upon completion of bench/pilot scale studies).
- A summary of all findings and conclusions in a report to be submitted upon completion of bench and pilot scale studies.
- Support with regard to compliance with state and Federal ARARs.
- Recommendations for the handling and treatment of wastes streams from the extraction processes.

3.3.9 Costs

Available unit-cost information for the various extraction technologies is summarized in Table 3-6.

TABLE 3-6

EXTRACTION TECHNOLOGY COSTS 1

Method	Cost	Reference	Comments
B.E.S.T.	\$150/yard ³	4	Can lower oil and grease to less than 0.1% and PCB to 1 ppm
APEG	\$150-\$450/yard ³	12	Can lower PCB concentration to 1-10 ppm . For PCB less than 1 ppm, higher cost will be involved
Critical Fluid System	\$7-\$9/barrel	70	

1. Costs converted to consistent units where possible: 1 ton = 2,000 pounds; 1 yard³ = 3,000 pounds.

3.4 BIODEGRADATION

3.4.1 General Description

Biodegradation is a treatment process whereby hazardous chemical substances (primarily organic chemicals) may be transformed to non-toxic or less toxic metabolites through the enzymatic action of microorganisms. Under optimum conditions, and through the use of appropriate organisms, such degradation mechanisms may result in the complete mineralization of organic chemicals to carbon dioxide, water or methane, and biomass (1, 7).

Biodegradation of selected chemicals can be effected through the use of chemical-specific aerobic or anaerobic bacteria, filamentous fungi and yeasts, actinomycetes, algae, and cyanophytes (blue-green algae). Such organisms may be indigenous (native) species present in a solid (soil/sediment) or aqueous environment. Exogenous (non-native) cultured species, adapted indigenous or genetically-engineered (e.g., plasmid transferral) species, may be introduced to a contaminated medium to assist in the degradation of refractory (persistent) chemicals (1, 44, 51, 55, 97).

Prevailing environmental conditions have a pronounced effect on the activity of microorganisms. Studies have shown that the availability of oxygen and macronutrients (particularly phosphorus and nitrogen), the availability of water, the proper pH, and temperature conditions are important parameters for biodegradation systems (1,7,13,15,18-23,26,27,37,43,51,52). Additional factors that also affect the degradation of organics include the availability of micronutrients (trace elements), organic supplements (e.g., sewage sludge, inactive brewers yeast, glucose, lignin, etc.), the presence of toxins, the presence of toxic metabolites or preferred substrates, contaminant concentrations, and the presence of substances that may induce cometabolic activity (e.g., biphenyls to promote the cometabolic degradation of their chlorinated analogs) (15, 16, 19, 27, 31). Often, more than one species of microflora may be required to accomplish the complete degradation of a given substrate; one species may be able to transform the parent compound but may be unable to further degrade the metabolic byproducts, and additional species are required to complete the degradation process (1, 7, 21, 37, 44).

Numerous studies have been conducted to determine the effectiveness of specific classes (e.g., fungi), genera (e.g., fusarium), or species (e.g., oxysporum) for the degradation of specific compounds or classes of compounds. One notable exception in this regard is studies conducted by the petroleum refining industry with respect to the land application of oily wastes (i.e., landfarming). Such studies have generally focused on the capacity of indigenous, non-specific microflora to degrade petroleum wastes (e.g., petroleum hydrocarbons, oil and grease, or alkanes, and aromatics).

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As a result of these historical studies, in view of the fact that several strains of organisms may be required to effect complete mineralization, and as a result of the varied nature of contamination at hazardous waste sites (such as the Douglassville Disposal Site), it has become apparent that a diverse population of microorganisms may best effect the degradation results sought in CERCLA response actions. Such an approach has been referred to as "unity in diversity," which implies that a diverse microbial population can be used to obtain a unified result (detoxification) (101).

Furthermore, it has also been speculated that microorganisms indigenous to hazardous waste sites will be acclimated to the wastes present, have developed the enzymatic capability to rely on the wastes as a carbon source, and require only favorable environmental conditions (e.g., carbon to phosphorus and nitrogen ratios) to enhance degradation mechanisms (44). This appears to be the direction that biodegradation treatment technology is taking, particularly in treatment of contaminated soils; the activity of naturally occurring microflora is enhanced, and supplemental cultured organisms or adapted site-specific organisms are introduced to augment the inherent degradative capacity of the contaminated matrix.

Three general types of biodegradation methods that may be applicable at the Douglassville Disposal Site are available. These include land application (landfarming), in-situ biodegradation (ISBD) through groundwater pumping and biological treatment, and post-excavation liquid solids contact (LSC). A brief description of each of these treatment methods follows. Additional information relative to their application at the Douglassville Disposal Site is included in Section 3.4.3 (Logistical Requirements).

3.4.1.1 Landfarming

Land application or landfarming has been practiced by the petroleum industry for more than 40 years. This approach has been shown to be an effective method of degrading various constituents of petroleum wastes such as aliphatic, aromatic, and some heterocyclic aromatic hydrocarbons.

This method of treatment is essentially an aerobic process that generally involves the application of sludges to the top 1 to 6 inches of the soil matrix. The oxygen demands of the aerobes are satisfied by aeration. Generally, the soil matrix is plowed, disked, or rototilled to maintain aerated conditions (13, 20-23, 26, 37). Rototilling apparently achieves the most favorable results and is reportedly most effective if at least two passes are made perpendicular to one another (22, 37).

Hydrated lime or crushed limestone is added to acidic soil as necessary to obtain optimum pH conditions for bacteria

(approximately 6.5 - 8.0) (19, 22, 23, 37, 51, 55). For a varied waste matrix, optimum pH conditions may be approximately 6.0. Fungi have a demonstrated capacity to degrade refractory substances such as PCBs and PAHs. Although fungi generally prefer acidic soils (pH 4.0 - 5.0), a pH of 6.0 may result in a medium in which the aerobic bacteria, fungi, and actinomycetes can operate. (Actinomycetes are not nearly as sensitive to variations in environmental conditions and function over a broad range of pH values.) (13,44,101). The acidification of basic soils may be accomplished through the addition of inorganic salts, such as aluminum or iron sulfate, although this is not a common requirement.

Soil moisture may be maintained at optimum conditions (anywhere from 30 percent to 90 percent of field capacity) through irrigation systems, although in moist soils this may be unnecessary (13, 19, 20). Irrigation systems require runoff control to prevent erosion and convective transport of water-soluble contaminants and metabolites. The potential for leaching is increased through irrigation. Hence groundwater may be affected if excessive moisture is added. This constitutes a particular problem if anaerobic conditions are sought. (In field applications, anaerobic conditions are generally simulated through either flooding or compaction and mulching) (55).

Nutrients are supplied through the application of inorganic fertilizers such as ammonium nitrate (as a nitrogen source) and potassium dihydrogen phosphate (as a phosphorus and potassium source) (13, 18-23). Optimum carbon-to-phosphorus and carbon-to-nitrogen ratios are approximately 800:1 and 60:1, respectively (19). Nutrient requirements are contingent upon the application rate of the sludge. At the Douglassville Disposal Site, fertilizer requirements would be dictated by the chemical composition of the existing waste matrix. Micronutrient, organic amendment, supplemental microorganism, and analog enrichment requirements are contingent upon the nature of the soil, the soil microflora, and the waste matrix to be treated. Such specific requirements can only be ascertained through bench- and pilot-scale studies.

Although landfarming has been shown to be an effective biotreatment technology (at least for petroleum wastes), the implementability of such a method is currently questionable as a result of the five Resource Conservation and Recovery Act (RCRA) Land Disposal Bans. The first of these bans was promulgated on November 7, 1986, and governs the disposal of wastes containing solvent or dioxin. Since soils at the Douglassville Disposal Site contain organic solvents, application of landfarming at the site may not comply with the RCRA Land Disposal Ban.

3.4.1.2 In-situ Biodegradation

In-situ biodegradation has been used to remediate sites where groundwater contamination and subsurface soil contamination were

the primary problems (See Section 3.4.5, Case Histories). This biotechnology generally involves the use of downgradient or plume-centered groundwater extraction wells to collect contaminated groundwater. The groundwater is pumped to surface-mounted bioreactors.

The reactors may be of either stirred tank suspension or fixed-film, plug flow design. Fixed-film reactors reportedly achieve greater degradation rates than do suspension systems (1, 101). In addition, fixed-film systems also help to prevent washout, and the solid phase of some systems may consist of material capable of adsorbing dissolved metallic species (44, 101). Aeration and pH control can be accomplished using standard process equipment similar to that used in sewage treatment applications. With such surface-based systems it is also possible to use various treatment systems in series (44). Thus both aerobic and anaerobic digesters may be used if it is necessary to degrade both nonhalogenated and halogenated hydrocarbons. (Studies have shown that reductive dehalogenation is a necessary prerequisite to degradation of these compounds, and this apparently occurs only under anaerobic conditions) (1, 44, 102). Although aerobic systems achieve greater reaction rates, anaerobic systems are less energy-intensive (no oxygenation) and produce less sludge.

The primary difference between such a biological treatment system and the more conventional air stripping, ion exchange resin, granular activated carbon (GAC), or powdered activated carbon treatment (PACT) systems is that microbe-rich and nutrient-rich effluent from the system is reintroduced to the subsurface via injection wells or infiltration galleries. Thus, the biodegradation process will continue in the subsurface matrix itself. The supplemental nutrients stimulate the indigenous microbial population. The use of infiltration galleries allows for treatment of the unsaturated zone. Since contaminated subsurface soil (both saturated and unsaturated) acts as a continuing source of groundwater contamination, the treatment of this material is paramount to a successful groundwater renovation program. The advantages of subsurface microbial activity become readily apparent when one considers theoretical aquifer flushing times for standard pump and treat operations.

One of the major limitations to aerobic biodegradation in the subsurface results from the minimal amount of available oxygen in aquifers. Three methods are available to provide the necessary oxygen: the addition of hydrogen peroxide to the groundwater prior to recirculation, the use of injection wells for direct sparging of air into the aquifer, and the addition of ozonation products (1, 17, 48, 51, 105). The applicability of these techniques is contingent upon site-specific chemical and microbial considerations. For example, while direct sparging proved successful at one site, at another site bioslime buildup

on the spargers necessitated continual maintenance and downtime; consequently, the use of hydrogen peroxide was required.

Opponents of ISBD have pointed out that one of the most severe limitations in its application results from the presence of hydrophobic chemicals in the soil matrix (1, 105). The addition of aqueous surfactants or emulsifiers has been proposed to enhance the solubility of such substances. Although favorable results have been obtained for aquifer remediation at the Biocraft Site in Waldwick, New Jersey, (Section 3.4.5), the chemicals present at that site are comparatively water soluble. Furthermore, problems have been encountered at Biocraft in one portion of the aquifer as a result of limited permeability (105). The majority of the waste components at the Douglassville Disposal Site are hydrophobic in nature. The benefits of mobilizing these chemicals through the addition of surfactants are questionable. In addition, the majority of the wastes are apparently present above the water table. In-situ treatment of these wastes would require the use of infiltration galleries or water-table elevation. It is not considered advisable that additional leaching of contaminants be promoted. These factors could limit the effectiveness of any treatment technologies involving extraction wells and infiltration galleries.

Additional problems with ISBD could arise from the need to inoculate the site with exogenous organisms. Microorganisms reportedly colonize and migrate through the subsurface environment at very slow rates (i.e., approximately 1 meter/year). If inocula are necessary, multiple inoculation points at several depths could be required (13).

3.4.1.3 Liquid Solids Contact (LSC)

Various methods of liquid solids contacting have been used for the closure of surface impoundments. The procedure requires that the material to be treated is excavated and added to a reactor. The reactors are generally closed vessels equipped with mixers capable of suspending approximately 10 percent of their volume as solids. The units may be equipped with off-gas collection and treatment systems, which allow for the removal and treatment of volatile organics. Emulsifiers or surfactants may be added as necessary to aid in solubilizing hydrophobic chemicals. Environmental control, such as pH manipulation, may be conducted to promote conditions for microbial degradation. Thus, the activity of indigenous species may be enhanced. The liquor from the suspension vessel is then conveyed to a secondary bioreactor for aerobic biological treatment. Experimental results for such a system have shown that it is particularly effective in the removal of volatile organics and phenols in API separator sludges. However, for the experimental retention time used, the degradation of refractory chemicals (i.e., PAHs) was only 25 percent (101).

Although this technology is still in its developmental stages, it appears promising for the treatment of volatile organics and phenolic compounds. It may be possible that modifications to such systems could be made to include bioreactors utilizing fungi or anaerobic bacteria to degrade refractory substances such as PCBs and PAHs. Studies to date have focused on sludges rather than soils; therefore, bench- and pilot-scale studies would be required to determine the effectiveness of LSC for environmental matrices such as soil and sediment. Because the soil matrix at Douglassville is expected to have a relatively diverse and acclimated microbial population, it is considered possible that more favorable degradation of refractory substances could be obtained at the Douglassville Disposal Site using LSC.

Potential limitations in the applicability of the LSC method include the large retention times (and hence prolonged treatment period) required to effect the degradation of hydrophobic substances (101). In addition, because the contaminated soil matrix at the Douglassville Disposal Site is expected to be low in moisture, considerable quantities of water would be required. Furthermore, the system is expected to produce three waste streams (liquid, solid, and gaseous). All of these streams may require additional treatment prior to discharge or disposal, depending on the effectiveness of the system.

3.4.2 Waste Treatment Capabilities

Naturally-occurring or genetically-engineered microorganisms have been identified that are capable of degrading virtually every class of organic chemical detected at the Douglassville Disposal Site. Halogenated and non-halogenated aliphatic and aromatic hydrocarbons; polycyclic and heterocyclic aromatic compounds; polychlorinated biphenyls; chlorinated dioxins; phthalate esters; organic nitrogen compounds, including nitrosamines, halogenated and non-halogenated phenolics; and halogenated pesticides are subject to biodegradation (1, 44, 103, 104).

The only major limitation in the applicability of biotreatment methods at the Douglassville Disposal Site is with regard to the treatability of inorganic substances. Although some inorganic chemicals (particularly arsenic) are amenable to biological treatment, inorganic substances detected at the site at high concentrations (notably lead) cannot be treated in this manner in most biotreatment systems. Furthermore, lead may be toxic to some organisms if present at concentrations in excess of 10,000 ppm (31). Lead concentrations of 7,500 ppm in crankcase oil had no apparent detrimental effects on microbial activity, however (22).

In addition, biodegradation reactions often follow pseudo first-order reaction kinetics with respect to substrates. Thus, degradation rates diminish as contaminant concentrations

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decrease. It is possible that great intervals of time may be required before target levels are reached.

A general description of the waste treatment capabilities of various classes of microorganisms is included below. Some of the primary differences between the various biological approaches discussed in Sections 3.4.1.1 through 3.4.1.3 are included in Sections 3.4.2.1 through 3.4.2.3. Tabular summaries of particular organisms capable of degrading specific waste constituents are available in the literature (1, 44, 104).

Aerobic Bacteria -

Studies have demonstrated that aerobic bacteria may be used to degrade nonspecific constituents of oil and grease as well as various non-halogenated organic chemicals including alkanes, monocyclic and heterocyclic aromatic compounds, aldehydes, ketones, and organic acids. Some species are also capable of degrading polychlorinated biphenyls, halogenated PAHs, and chlorinated pesticides. Species have also been generated through plasmid insertion that can metabolize numerous chlorinated benzenes. Aerobic surface-mounted groundwater and subsurface soil treatment systems have been used to degrade various alcohols, methylene chloride, nitrosamines, and gasoline and petroleum constituents.

Anaerobic Bacteria -

Anaerobic bacteria have been shown to be capable of degrading refractory chlorinated pesticides such as DDT, methoxychlor, aldrin, and endrin, etc. Evidence suggests that such organisms are capable of effecting the reductive dehalogenation of chlorinated aliphatic compounds such as tetrachloroethylene, trichloromethane, and trichloroethane. Studies have demonstrated that anaerobic bacteria are also capable of degrading some chlorinated and nitrated phenols, nitrosamines, and cyclohexane.

Fungi -

Fungi have been shown to be capable of degrading various polychlorinated biphenyls, polynuclear aromatic hydrocarbons, and halogenated pesticides.

Actinomycetes -

Various actinomycetes are capable of degrading halogenated pesticides, phenol and monochlorinated phenol, polychlorinated biphenyls, naphthalene, and halogenated pesticides.

Algae -

Various algae are capable of degrading phenol, naphthalene, lindane, and DDT.

Cyanophytes -

Blue-green algae have a demonstrated capacity to degrade naphthalene, non-halogenated biphenyls, and lindane.

As alluded to in the general description (Section 3.1), it is apparent from the above discussion that a myriad of microorganisms may be required to degrade the wastes present at the Douglassville Disposal Site. Hence, it is apparent that systems capable of promoting the activity of various classes of microorganisms (including aerobic and anaerobic bacteria, fungi, and actinomycetes) may be required.

3.4.2.1 Landfarming

Because landfarming is essentially a biological treatment technology in which unlimited retention times can be achieved, this approach may result in a greater degree of detoxification over the long term with very little operation and maintenance other than periodic aeration and addition of nutrients. Reaction rates in aerobic systems are reportedly much greater than in anaerobic systems (1, 44). However, since landfarming is generally an aerobic process, those chemicals more amenable to anaerobic treatment (i.e., halogenated aliphatics) may not be treated as effectively as in anaerobic systems. Evidence does suggest that some aerobic bacteria may be capable of metabolizing these substances, however. Furthermore, landfarming can be practiced in a phased approach wherein both aerobic and anaerobic conditions are utilized concatenately.

3.4.2.2 In-situ Biodegradation

ISBD can be conducted under both aerobic and anaerobic conditions. Anaerobic conditions generally exist in groundwater systems under natural conditions. The addition of supplemental nutrients such as nitrogen and phosphorus could enhance the natural biodegradative tendencies of indigenous anaerobic microorganisms. This may be particularly effective in the degradation of the various chlorinated aliphatic hydrocarbons detected in site groundwater. However, it should be noted that the reductive dehalogenation of tetrachloroethene and trichloroethene will result in the formation of vinyl chloride. Vinyl chloride is apparently more resistant to degradation than are the parent compounds (102).

Volatile petroleum compounds such as benzene, toluene, and xylenes, as well as various alkanes, are more amenable to treatment under aerobic conditions. The addition of supplemental oxygen will enhance the degradation of these compounds, as well as the degradation of relatively hydrophobic substances detected in site groundwater (i.e., naphthalene and polychlorinated biphenyls). If an aerobic ISBD program were to be initiated at the Douglassville Disposal Site, it might be possible to

pretreat groundwater using demonstrated air stripping technologies to remove straight-chain halogenated aliphatics prior to entry to the surface-mounted bioreactor. Both halogenated and non-halogenated species can be treated via air stripping. In-situ biodegradation of non-halogenated aliphatics and aromatics could be effected. This will be particularly beneficial for the removal of volatile chemicals such as xylene, which are difficult to remove via air stripping. If it is noted that metals removal is also required, fixed-film reactors packed with chitinous material or other adsorbents could be used for simultaneous metals removal (101).

3.4.2.3 Liquid Solids Contact

Although retention times may severely hamper the degradative capacity of liquid solids contact reactor systems, it is possible that such a system could be used to effectively treat some of the more refractory site chemicals. It is conceivable that stirred tank reactors could be used in series to achieve the desired degradation results. Review of available literature did not indicate that any work has been conducted in this area with regard to hazardous wastes, but such an approach has been used in sewage treatment applications and in the chemical industry. As discussed above, a myriad of microorganisms may be necessary to degrade all of the chemicals present at the Douglassville Disposal Site. Liquid solids contact is not expected to achieve removal of inorganic substances. If this is necessary, additional treatment of soils may be required for metals removal.

3.4.3 Logistical Requirements

Although the logistics of any proposed biotreatment method are highly dependent upon the outcome of bench- and pilot-scale studies, some general aspects of each can be identified. Each of the potential treatment methods is discussed in the sections that follow.

3.4.3.1 Landfarming

At the Douglassville Disposal Site, landfarming cannot be practiced in-situ on the former waste disposal areas (particularly the former sludge lagoons) because contamination ranges to depths of 10 feet or more. Thus, it is anticipated that a land application approach would require the excavation of the contaminated soil material, followed by application in a designated area. The majority of the waste is expected to lie above the water table; thus dewatering would not be required prior to excavation.

Based on available analytical data, it has been determined that the majority of the site is contaminated with hazardous substances. For a landfarming approach, it is considered reasonable that at least one of several such contaminated areas

can be used as acreage for the land application of the excavated wastes. Obviously, the former landfarming area itself is a candidate for such use.

It may be necessary to perform aeration and fertilization in this area as an initial activity to degrade a portion of the wastes that are already present. Erosion control, such as berms and sedimentation basins, would be required before such activities commence (21, 22, 48). Since aeration makes the soil more amenable to erosion, and since the site floods on occasion, some form of flood control would also be required (i.e., dikes or levees).

Once conditioning of the former landfarm is complete, application of material from the former sludge lagoons could commence. Landfarms apparently function best under conditions in which small waste loads are applied at frequent intervals rather than large waste loads at infrequent intervals. Thus a phased excavation and application approach would be necessary. Excavation could be conducted at one time, but a large staging area would be necessary for storage.

Because the excavated material is expected to contain not only wastes, but also a great deal of soil (as a result of the backfilling of the lagoons), continued use of the landfarm will result in a buildup of material in the area. Studies have shown that landfarms generally operate best under nonintensive, rather than intensive, conditions. Intensive use constitutes the continued application of large waste loads over a relatively small parcel of land, whereas nonintensive use involves more acreage and smaller waste allocations (19, 37). Based on the large amount of material that must be treated, it is considered advisable that areas other than the landfarm itself also be used for land application. With the exception of the former cornfield, located between the landfarm and the railroad right-of-way, virtually all of the site property north of the tracks could be used for this purpose.

In the event that both aerobic and anaerobic (flooded) landfarming techniques are necessary, it would be best to designate distinct areas for the aerobic and anaerobic treatment plots. While both methods could be employed in the same location (one after the other), it would probably be better to maintain constant aerobic or anaerobic conditions in distinct areas so that healthy aerobic or anaerobic microfloral populations could be maintained. Flooding a formerly aerobic land application area would be detrimental to its continued use. However, such an approach would require additional materials handling. In addition, it is probably advisable that only a portion of the material in the aerobic landfarm be removed to the anaerobic landfarm at any one time under such a scenario to maintain continuity of the microbial population. An anaerobic landfarm would require the installation of relatively impermeable berms and some form of liner to retain the

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floodwaters and to protect the groundwater from leachate (13, 21, 37).

In the case that alternative treatment technologies are employed in other portions of the site, the landfarm could be conditioned and used for the land application of residual solids. For example, the landfarm may be used for continued treatment of solid or semisolid residuals from surface-mounted bioreactors, filter press operations, or solvent extraction systems.

3.4.3.2 In-situ Biodegradation

Biological treatment of contaminated soils and groundwater would be most applicable to portions of the site contaminated with water soluble organics. Since none of the former lagoons, the landfarm, nor the soils in the vicinity of the former plant are expected to be contaminated solely with water-soluble substances, the use of infiltration galleries at these locations may be of limited effectiveness. However, since analytical results for groundwater samples indicate that water-soluble chemicals have leached from the waste matrix, it may be possible to treat the subsurface areas below the waste disposal areas (i.e., contaminated material in both the unsaturated zone and below the water table). If coupled with additional source control measures (i.e., excavation and treatment), the use of groundwater pumping and treatment through biological methods may be the most effective method of handling the residual contamination in the aquifer.

An in-situ biodegradation approach could be designed to treat the solid and aqueous aquifer phases. For example, if a source that is releasing water-soluble chemicals is identified, perimeter and downgradient extraction wells could be installed and pumped to create cones of depression surrounding the source. (Some existing monitoring wells could probably be used for this purpose.) Extracted groundwater could be treated using air strippers to remove the refractory halogenated aliphatic hydrocarbons prior to additional aerobic treatment, or both aerobic and anaerobic digesters could be used. Treated groundwater could then be returned to the interior of the treatment zone in a fashion that would elevate the water table to assist in the treatment of the unsaturated zone. If such a pump and treat/ISBD option were implemented prior to any source control measures, injection wells would probably be required, since it is unlikely that adequate percolation through the waste would be achieved. Such an approach would of course impede source control operations, and a phased approach would be necessary. For example, injection wells could be used in 75 percent of a source area while excavation and treatment operations are conducted in the remaining 25 percent. Once the excavation and treatment is completed, this area could then be used for the construction of an infiltration gallery or installation of groundwater injection wells. Such an approach

would probably be easier if hydrogen peroxide addition rather than direct sparging is used to supply the necessary oxygen.

It is anticipated that such an approach would also require the handling and treatment of residual solids or semi-solids (sludges) from surface-mounted biological reactors.

3.4.3.3 Liquid Solids Contact

The use of this approach for the treatment of wastes from the former sludge lagoons, the landfarm, the filter cake sludge disposal area, or the plant itself would require that excavation and material handling be implemented. Excavation logistics would be contingent upon the quantity of material that can be treated by the contactors and the residence time required for adequate biodegradation. Some sorting and sizing of materials may be required under such a treatment scenario so that adequate suspension of solids is attained.

Residual solids from the LSC process could be handled via landfarming, solidification, incineration, or extraction techniques, if necessary. In addition, since this process involves the use of an off-gas collection and treatment system, it is likely that carbon regeneration or disposal will be necessary. Lead-lag carbon adsorption units for off-gas treatment would allow for continuous operation of the process.

3.4.4 Public Health and Environmental Concerns

Worker exposure during remedial action probably constitutes the greatest threat to the public health under the biodegradation treatment methods. Exposure could occur via direct dermal contact with contaminated wastes or soil, or through inhalation of volatilized contaminants or fugitive dust. Adequate health and safety measures would be required to mitigate exposures through these routes. Protective clothing, respiratory protection, and dust control measures could be required to prevent worker exposure, particularly for any biotreatment methods involving excavation operations.

Contingency plans should be generated for each of the various methods. For example, adequate planning and response actions should be developed to prevent exposure through volatile release in the event of off-gas collection system failure (liquid solids contact).

Both the ISBD and LSC methods afford a great deal of control over the overall process. However, under a landfarming approach, some form of erosion control would be required. In addition, since biodegradation processes may result in the formation of water-soluble metabolites, it is conceivable that some impact on groundwater is possible (21, 22, 37). Previous studies have shown that such metabolites (e.g., organic acids) do not migrate through the unsaturated zone to any great extent.

Under a landfarming approach, a pilot-scale study, coupled with lysimeter monitoring or some other form of leachate mensuration, should be conducted to verify that contaminants do not migrate from the treatment zone. These elements are also necessary to monitor leaching of nitrite/nitrate after addition of inorganic fertilizers (55).

3.4.5 Case Histories/Description of Developmental Status

Although biodegradation through landfarming practices has been conducted by the petroleum industry for years, the application of this and other biodegradation processes for the heterogeneous wastes encountered at disposal sites is still in the formative stages. It is acknowledged that the applicability of such methods is highly contingent upon a variety of site-specific conditions, and the applicability of biotreatment can only be determined through bench- and pilot-scale studies. Several applications of biotreatment processes have been initiated, and these are discussed briefly below.

Biocraft Laboratories (1, 102)

At present the most notable case history with regard to biodegradation is a groundwater and subsurface soil ISBD process initiated at the Biocraft Laboratories Plant in Waldwick, New Jersey. It is estimated that approximately 300,000 lbs. of methylene chloride, n-butyl alcohol, dimethyl aniline, and acetone were released from underground process lines at this site. Although some problems have been encountered in areas of low permeability, it has been estimated that 95 percent of the contamination has been successfully treated at the Biocraft Site. This response was a PRP-led action, and Biocraft Laboratories has since formed a subsidiary (Groundwater Decontamination Systems) to market its biological process for aquifer renovation. Capital cost for the operation were approximately \$400,000, and reported treatment costs are \$1.65/gallon. The cleanup operation has been in operation for approximately 5 years, and 13,600 gallons are treated on a daily basis. A great deal of money was invested in research and development to devise the treatment methodology (\$520,000).

Old Inger Superfund Site (101)

In many respects the Old Inger Site is very similar to the Douglassville Disposal Site. The site was a former lubricating oil recycling facility located directly adjacent to the Mississippi River in Darrow, Louisiana. Two large waste lagoons are present on the site and contain an estimated 70,000 yd³ of waste oil and contaminated soil. One of these lagoons is backfilled, as are the sludge disposal lagoons at the Douglassville Disposal Site. Waste components are primarily oil and grease and methylene chloride.

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Excavation and offsite disposal was originally selected as the most feasible method of handling the wastes at the Old Inger Site. Costs for the excavation and offsite disposal operation were estimated to be between 30 and 40 million dollars. However, the U.S. Army Corps of Engineers raised concerns regarding the large-scale excavation operation in such close proximity to the river, and a reevaluation of other methods was conducted. The feasibility of biodegradation through landfarming of excavated wastes was investigated, and it was decided that land application was a much more cost-effective and environmentally acceptable approach. The biotreatment approach was developed by Environmental Solutions, Inc. (ESI), of Baton Rouge, Louisiana. Studies were conducted to determine the effectiveness of exogenous microorganisms, but ESI found that the indigenous microorganisms achieved the most favorable results under optimum field-oriented environmental conditions. Estimated costs for the process range from \$10 to \$20 per yd³ (including excavation). It is estimated that the completed site clean-up, including dismantling of the process facility itself, will cost \$7.2 million.

A waiver of the RCRA Land Disposal Ban was obtained for the initiation of the bioreclamation operation. The process involves the land application of the excavated waste to the top 10 cm of a designated landfarming area. Waste application rates of 4 percent oil and grease will be used. Pilot-scale studies have shown that oil and grease concentrations are reduced to less than 1 percent within a 6 - 8 week period. Monitoring of a pilot-scale plot was conducted, and no migration of contaminants beyond the treatment zone has been observed.

Murkle Field, Naval Communications
Station, Thurso, Scotland (17)

The Naval Facilities Engineering Command evaluated the technical feasibility of in-situ biodegradation to remove oil pollution from groundwater and subsurface saturated and unsaturated soils at Murkle Field. The contamination resulted from leakage of 2,000 gallons of No. 2 diesel oil from an underground storage tank and lines. The ISBD treatment system consisted of a surface-mounted aerobic bioreactor, groundwater extraction and injection wells, a sprinkler system, an infiltration gallery, and a downgradient leachate collection trough. One thousand gallons of the fuel oil was recovered through surface collection and from the leachate collection trough. It is estimated that approximately 24 percent of the remaining oil was degraded, either in-situ or in the surface-mounted reactor, over the 100-day test period. It was estimated that the surface-mounted biodegradation system was four times more effective than the ISBD portion of the operation.

Wheat Field, Crosswicks, New Jersey (28)

A pipeline rupture resulted in the release of 1.9 million gallons of kerosene to a New Jersey wheat field. A rehabilitation program similar to those conducted in the petroleum industry was initiated at the site of the leak. Liming, fertilization, and tilling were employed to provide adequate soil reaction, nutrients, and oxygen conditions for aerobic biodegradation. Significant loss of kerosene constituents was noted over the 2-year recovery operation. Disappearance was particularly great during warm weather. It is believed that this occurrence was a manifestation of both increased volatilization and enhanced microbial activity. Winter wheat and soybeans were planted upon completion of rehabilitation. Although yields were lower from the affected area, and plants were somewhat stunted, no evidence of phytotoxicity was evident, and the field was returned to near-normal operation.

Leaking Underground Storage Tank, Unknown Location (48)

An undetermined amount of gasoline leaked from an underground storage tank at a service station. An aquifer restoration program was initiated using air strippers and other physical/chemical treatment methods. An in-situ biodegradation procedure was implemented through the addition of macronutrients and air spargers. Bioslime build-up continually fouled the spargers, and hydrogen peroxide was subsequently used for supplemental oxygen supply. Total hydrocarbon concentrations in the aquifer were reduced from 15 ppm to 2.5 ppm within 10 months after start-up.

The effectiveness of biological treatment methods has been demonstrated in all of the above case histories. However, in each case, the contamination is not nearly as heterogeneous as the contamination present at the Douglassville Disposal Site. Biological treatment and closure of the Douglassville Disposal Site is expected to be more complicated than was the case with any of these case histories as a result of the presence of organic solvents, PCBs, phthalate esters, oil and grease, and lead. Given the appropriate indigenous or exogenous microorganisms and environmental conditions, there appears to be no sound technical justification for eliminating biotreatment from consideration for remedial action at the Douglassville Disposal Site. The greatest foreseeable limitation in a biological approach is the achievable level of treatment. This can only be determined through bench- and pilot-scale studies.

3.4.6 Vendor Summary

Very few vendors presently market biotreatment technologies. Furthermore, there is no available evidence that any of these firms have dealt with a problem as extensive as that at the Douglassville Disposal Site. Various vendors of the treatment

technologies discussed in this section are identified in Table 3-7.

3.4.7 Data Requirements

A preliminary listing of data requirements for the evaluation of the feasibility of biotreatment at the Douglassville Disposal Site is included in Table 3-8. This table includes a summary of data that will be collected during the Phase I RI. These data will allow for further evaluation of the feasibility of biodegradation at the Douglassville Disposal Site. In addition, information to be obtained from bench- and pilot-scale studies (if they are conducted) is also included in Table 3-8. This additional information will directly support the FS. An attempt has been made to make this compendium as complete as possible, although additional requirements may become apparent at a later date. Vendors may have particular data requirements that they will satisfy through preliminary laboratory testing or bench-scale studies.

3.4.8 Bench/Pilot Scale Study Recommendations

Because of the heterogenous nature of the wastes to be treated at the Douglassville Disposal Site, it is recommended that both bench- and pilot-scale studies be conducted to determine the feasibility of biotreatment.

Because such a treatment is expected to be a complicated endeavor, solicitations for bids will be issued to vendors of biotreatment technologies who have field experience in its application (subject to EPA approval). Such solicitations will include a summary of all available chemical-analytical, physical, and hydrogeologic data for the site.

TABLE 3-7

VENDOR SUMMARY - BIODEGRATION TECHNOLOGIES

Technology	Vendor
Landfarming	Bioscience Management, Inc. Detox, Inc. Detox Industries, Inc. Environmental Solutions, Inc. Flow Laboratories Environmental Cultures Division Polybac/Cytox Corporation Sybron Biochemical
In-situ Biodegradation	Bioscience Management, Inc. Dorr-Oliver, Inc. Environmental Solutions, Inc. FMC Corporation ¹ Groundwater Decontamination Systems, Inc. Groundwater Technology, Inc. Zimpro, Inc.
Liquid Solids Contact	Bioscience Management, Inc. Environmental Solutions, Inc. General Environmental Science

1. FMC recently sold. New owner unknown.

TABLE 3-8

DATA REQUIREMENTS - BIODEGRADATION TECHNOLOGIES

Pre-Bench/Pilot-Scale Requirements (Soil/Waste)

Chemical-analytical data (waste and soil/waste composition)
Vertical and horizontal extent of contamination
Soil reaction (pH)
Soil moisture content and field capacity
Microbial populations/activity (soil and waste, ATP Test)
Nutrient balance (primarily nitrogen and phosphorus)

Pre-Bench/Pilot-Scale Requirements (Groundwater)

Chemical-analytical data (groundwater and subsurface soil)
Vertical and horizontal extent of contamination
Soil permeability
Groundwater pH and dissolved oxygen content
Aquifer permeability
Microbial populations/activity (groundwater, ATP Test)
Nutrient balance (primarily nitrogen and phosphorus)

Post-Bench/Pilot-Scale Requirements (All matrices)

Degradation Rates/Reaction Kinetics
Nutrient Requirements
Oxygen Requirements (Aerobic/Anaerobic)
Retention Times
Off-gas evolution rates
Effluent concentrations (all waste streams)
Metabolite identities
Toxicity information (Microtox, Ames Test)
Water Requirements (LSC)

The vendors will be asked to provide the following background information and services:

- A technical description of the proposed biotreatment technology.
- Case histories and supporting analytical data.
- A description of proposed bench- and pilot-scale studies.
- Services for the degradation of oil and grease, polynuclear aromatic hydrocarbons, phthalate esters, phenols, polychlorinated biphenyls, non-halogenated aromatics, and halogenated aliphatics.
- An estimate of achievable levels of treatment (prior to initiation of bench- and pilot-scale studies to the extent practicable).
- A conceptual model of a proposed biotreatment alternative.
- Bench-scale studies designed to demonstrate that degradation occurs through respiration and analytical techniques. (Techniques will be left to the discretion of the vendor but will be subject to EPA approval).
- Ames, Microtox, or other bioassays to confirm that nontoxic metabolites are formed. Metabolites will be identified through laboratory analyses to the extent possible.
- Services or support in the area of leachate monitoring for land-application approaches (i.e., lysimeter/surface collection systems and sampling and analysis).
- Initial unit-cost estimates.
- An estimate of the time to complete the operation and capital/operation and maintenance costs (upon completion of bench/pilot scale studies).
- A summary of all findings and conclusions in a report to be submitted upon completion of bench- and pilot-scale studies.
- Support with regard to compliance with state and Federal ARARs.
- Recommendations for the handling and treatment of waste streams from any biotreatment processes.

3.4.9 Costs

Although costs are highly dependent upon site-specific conditions and processes, a general indication of the economic feasibility of biological treatment is provided by the unit costs presented in Table 3-9.

3.5 SOLIDIFICATION/FIXATION

3.5.1 General Description

The purposes of solidification/fixation are to improve waste-handling characteristics, immobilize highly soluble compounds, minimize the potential for leaching, and/or detoxify the waste (6, 8).

Since solidification/fixation systems vary widely in their applicability, cost, and pre-treatment requirements, many are limited as to the types of waste that can be economically processed. Selection of any particular technique for waste treatment must include careful consideration of the containment required, the cost of processing, the increase or decrease of bulk material, and the changes in the handling characteristics. The design and location of any placement area or landfill that eventually receives the treated wastes is also a major consideration in deciding on the degree of containment and the physical properties that will be required (40).

Most solidification systems being marketed are proprietary processes involving the addition of absorbents and solidifying agents to a waste. Often the marketed process is changed to accommodate specific wastes. Since it is not possible to discuss completely all possible modifications to a process, discussions of most processes have to be related to a generic process type (95).

Solidification/fixation systems discussed include the following:

- Cement- and lime-based methods
- Thermoplastic methods
- Organic polymer methods
- Macroencapsulation/jacketing
- Glassification and in-situ vitrification

3.5.1.1 Cement- and Lime-Based Methods

Cement-based methods involve sealing the waste in a matrix of Portland cement. Waste constituents are physically and/or chemically bound into the matrix, depending on the type of waste.

A number of additives have been developed for use with cement to improve the physical characteristics and decrease the leaching loss from the solidified waste. Many of these additives are

TABLE 3-9
 BIODEGRADATION TECHNOLOGY COSTS ¹

Method	Cost	Reference	Comments
Landfarming	\$75-\$150/yard ³	48	General approach
Environmental Solutions, Inc.	\$10-\$20/yard ³	101	Old Inger Site
Flow Laboratories	\$263-\$395/acre	55	Cultured Bacteria Addition of mutant bacteria nutrients, growth stimulator and detoxifying agents.
Sybron Biochemical	\$9,801/acre	55	
In-situ Biodegradation			
Groundwater Decontamination Systems	\$40/yard ³	105	Biocraft site \$405,000 R&D \$520,000 Capital Cost
Liquid Solids Contact			
General Environmental Science	\$32,000/yard ³	55	7 exogenous micro-organisms

1. Costs converted to consistent units where possible: 1 ton = 2,000 pounds; 1 yard³ = 3,000 pounds; 10:1 liquid to solids ratio assumed for liquid solids contact (1 gallon = 4.951 x 10⁻³ yard³).

proprietary. Common additives include clay, vermiculite, soluble silicates, sodium silicate, and fine-grained silica (8, 40, 95, 118).

Lime/pozzolanic-based methods are similar to cement-based. The method involves the reaction of lime with fine-grained siliceous materials plus water to produce a concrete-like end product (sometimes referred to as pozzolanic cement). Common materials used are fly ash, blast furnace slag, and cement kiln dust (8, 40). The chemical reactions involved are well defined; however, the solidification reactions may be slow (35). The end product is generally a solid with improved handling and permeability characteristics (40).

Standard cement mixing and handling equipment is generally used for these methods (6, 8, 40). However, some vendors use patented mixing and material-handling equipment (9). Companies that perform in-situ solidification use special equipment for subsurface injection and mixing (6). Standard construction equipment (dozers, loaders, etc.) can also be used. The waste can be spread in thin layers at a designated onsite area with solidification agent addition by spraying or plowing. After allowing sufficient reaction time, the next layer of waste is placed on top of the treated soil, and the process is repeated (35). With any method of mixing, the effectiveness depends on the ability of the additives to react with the waste to achieve solidification (35).

Key operating parameters are fixative to waste ratio (usually 1:1), length of time for setting and curing (generally 1 to 2 days), required structural integrity, and minimized potential for leaching (6, 8).

3.5.1.2 Thermoplastic Methods

Thermoplastics form liquids when heated and solids when cooled, regardless of the number of heating and cooling cycles (8). The waste is dried, heated, and dispersed into a heated thermoplastic matrix (asphalt, bitumen, polyethylene, polypropylene, or nylon) and is then cooled and placed in containers (8, 40, 78, 95). This method requires special equipment for heating and mixing. Highly specialized labor is also required (8, 35, 40, 78, 95). Mixing is performed at temperatures of 266 to 446°F (8, 35, 40, 95). The thermoplastic-to-waste ratio is generally 1:1 to 1:2 (8, 40).

3.5.1.3 Organic Polymer Methods

The following organic polymers may be used for these methods: urea-formaldehyde, polyesters, phenolics, and melanine. These polymers are thermosetting resins. Thermosets are materials that become solid and hardened when heated. They remain solid after subsequent heating and cooling cycles. The waste (wet or dry) is mixed with the polymer and a catalyst. The catalytic

action promotes cross-linking reactions in the polymer, and the waste becomes trapped in the spongy mass that develops. The polymer does not react chemically with the waste and may require the use of containers (8, 40). Any liquid associated with the waste will remain after polymerization. The polymer mass must often be dried before final disposal (40).

3.5.1.4 Macroencapsulation/Jacketing

This method involves the use of coatings or jackets to encapsulate a given volume of waste or containers. Common materials are polyethylene, fiberglass-reinforced polyethylene, asphalt, asphalt emulsion, and vinyl. The coatings are usually applied to a waste that has been previously solidified. The process is complicated, expensive, and energy intensive (8, 40). Waste contained within the jacket never comes in contact with water, unless the jacket is damaged (40). The solidified waste may need to be dried prior to encapsulation (95).

3.5.1.5 Glassification and In-Situ Vitrification

Glassification uses glass-making furnaces, which are large, refractory-lined vessels containing a pool of molten glass in the lower portion of the furnace. Space is provided above the molten glass for the oxidation of gases. Heat is supplied by electrodes submerged in the molten glass. Solids can be added through a screw conveyor, and they are pyrolyzed in the molten glass. The resulting gases are then oxidized in the turbulent zone above the glass. Solid residues are trapped in the molten glass, which is periodically removed from the furnace and allowed to cool and solidify. The non-leachable glass matrix is then landfilled (8). This method offers a high degree of containment (40). Temperatures of 2,200 to 2,300°F and residence times of up to 2 hours are required (8). Specialized equipment and trained personnel are needed for these operations (40).

In-situ vitrification also provides a high degree of containment (35). At sufficiently high temperatures, any soils or rock will melt (35). Energy is applied through electrodes inserted around the area to be melted. Temperatures up to 1,350°C may be required. The electrodes are placed by drilling or other appropriate methods. Then graphite, in contact with the waste material, is connected across the electrodes to act as a "starter" in melting the waste (35, 119). The molten zone grows downward as the energy is applied, encompassing the contaminated material and producing a vitreous mass. Convective currents distribute the contaminants uniformly within the melt. When the power is turned off, the molten material begins to cool. The final product is a glass-like material resembling natural obsidian. Any subsidence due to volume reduction can be backfilled to original grade (116).

A cover or hood must be placed over the the surface of the area being fused. The cover is used to collect gaseous effluents, which are routed to an off-gas treatment system (35, 116, 119). The melt depth is limited as the heat losses from the melt approach the energy deliverable to the molten soil by the electrodes. An increase in soil moisture increases the power requirements and the run time, but has a small effect on the melt depth attainable (116).

3.5.2 Waste Treatment Capability

3.5.2.1 Cement- and Lime-Based Methods

Cement-based methods are well suited for heavy metals and possibly for organics (generally no more than 20 percent by volume) (6). It is well known that organics can alter the setting characteristics of cement. It is not clear whether, and at what concentrations, organics can interfere with the relatively complex setting reactions, which would result in a significantly altered cement matrix (126).

Fine organic particles (silt, clay, etc., passing a No. 200 sieve) can weaken cement bonds by coating large particles with a dust layer. Organics (such as solvents and oil) can interfere with the set and cure of cement. Some vendors have processes that can handle 100 percent organics, but more typical values are 20 to 40 percent. Sulfates can retard setting and cause swelling. Soluble salts of many metals can also interfere with the set/cure of cement and can reduce the ultimate strength (6, 8, 40, 95).

When attempting to fix organics in a cement matrix, little, if any, chemical bonding takes place. The physical encapsulation obtained may be insufficient, which may allow organic molecules to move through the solidified matrix (88). The decomposition of organic materials after curing can result in an increase in permeability along with a decrease in strength (8).

Pretreatment may possibly be used to remove interfering materials (40, 95).

The contaminants controlled and the "problem" contaminants for lime-based methods are the same as for cement-based methods, except that sulfates will not retard setting or cause swelling (8).

3.5.2.2 Thermoplastic Methods

These methods are generally used for inorganic waste containing heavy metals (8). Wastes with a low water content are preferred, since the waste must be dewatered to a dry condition before processing (8, 35, 40, 78). Organic wastes with contaminant loadings in excess of 30 percent by weight have not been successfully stabilized (8). Wastes containing organic

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contaminants with the following properties are not amenable to these methods:

- Low molecular weight (8, 78)
- High vapor pressure (8, 78)
- Hygroscopic (absorb water) (8)
- Act as a solvent on the fixative (8, 40)

Inorganics that are difficult to stabilize include strong oxidizing salts, sulfates, and anhydrous salts that can rehydrate when exposed to water (8, 40, 78).

Some solvents and grease can cause asphalt materials to soften and never become rigid solids. Xylene and toluene diffuse quite rapidly through asphalt. Chelating and complexing agents (cyanide and ammonia compounds) have been shown to seriously compromise containment of heavy metal wastes (95).

3.5.2.3 Organic Polymer Methods

Inorganic wastes, especially radioactive wastes, are amenable to these methods, but not heavy metals or oxidizers. Organic waste tends to retard the set of most polymers. Since the catalysts used are usually acidic, metals go into solution prior to being "fixed" in the polymer matrix and are not stabilized. Oxidizers can break the polymer matrix formed (8, 40).

3.5.2.4 Macroencapsulation/Jacketing

Any contaminants that can be fixed in a stabilized matrix or that can be containerized can potentially be encapsulated. However, the success of coating cement-type products has not been good. Also, oxidizers and acid wastes can cause deterioration of the coating (8). These methods are more appropriate for nuclear waste (8) and for very soluble toxic wastes (95).

3.5.2.5 Glassification and In-Situ Vitrification

These technologies are applicable to organic wastes, including halogenated organics (8, 35). Organics and cyanide are destroyed by the processes (58). Inorganics are incorporated into the glass matrix (8, 35, 58).

3.5.3 Logistical Requirements

Required onsite facilities include access roads, safety facilities for operations and decontamination, chemical storage facilities, and possibly on onsite or nearby offsite laboratory for quality control tests (6). Utilities required include electricity and water.

Staging areas are required to prepare the waste prior to treatment and to allow the solidified material to set and cure

prior to final disposal (not applicable to in-situ techniques). Waste preparation may include size separation, grinding, and/or mixing (58). Treated soil can be placed back into the excavation, hauled to an offsite non-RCRA landfill, or hauled to an offsite RCRA landfill. An onsite landfill could also be constructed for final disposal.

If the solidified material is to be used as backfill, good structural integrity is required, and the solidified matrix must be rendered virtually non-leachable. Solidified material must be "delisted" before it can be placed in a non-RCRA landfill.

The Douglassville Disposal Site is in the 100-year floodplain of the Schuylkill River. This is an important consideration in evaluating onsite disposal options. The scheduled land disposal bans of certain RCRA hazardous wastes by EPA should also be evaluated.

Requirements specific to the various solidification/fixation methods are presented in the following sections.

3.5.3.1 Cement- and Lime-Based Methods

The volume and weight of wastes solidified by these methods could be double that of the raw waste (6, 35, 40). Products from uncoated cement and lime-based methods may require specially designed landfills to guarantee that the material does not lose potential pollutants by leaching (40). Experience in radioactive waste solidification indicates that some wastes are leached from concrete, especially by mildly acidic leaching conditions (40).

As previously mentioned in Section 3.5.1.1, the solidification agents can be mixed in-situ, in a mobile plant using conventional mixing equipment, or at a designated area using heavy equipment. The quality control of in-situ techniques is limited by the present technology (95). Complete contact and mixing of the contaminants and the solidification agent must be ensured. It may be difficult to determine the effectiveness, once the operations have been completed (117). Large portions of the site are required for area mixing. The waste is placed in a thin layer, reagents are added and mixed, and the resulting material is allowed to cure. The process is then repeated over the previously treated area (95). Mobile plants require less area and offer the best quality control among the methods discussed (95).

The water content of waste may have to be adjusted for cement-based methods, since water is needed to hydrate all of the cement added (8).

3.5.3.2 Thermoplastic Methods

Careful process control is required, especially with respect to temperature conditions since thermoplastic materials are flammable. The heating process may also result in the release of objectionable oils and odors (8, 40). The treated waste may need to be placed into containers for cooling (8,40, 95).

3.5.3.3 Organic Polymer Methods

Special equipment and lined containers are required to accommodate the corrosivity of the acidic catalysts used for this method (8). The polymerized material does not bond with water during processing. Sometimes after hardening, polluted weep water is generated (8, 40).

3.5.3.4 Macroencapsulation/Jacketing

These techniques require the use of molds, so that the jacketing material can be tightly fused to the previously solidified material.

3.5.3.5 Glassification and In-Situ Vitrification

For glassification, an area is needed on site for installation of a glass-making furnace. Site preparation for in-situ vitrification is minimal and involves the placement of the electrodes and the hood (58). Once an area has been vitrified in-situ, the equipment is moved to an adjacent area. The process is repeated until the entire area of concern has been vitrified.

3.5.4 Public Health and Environmental Concerns

3.5.4.1 Cement- and Lime-Based Methods

Dust and noise may be generated during the excavation and/or mixing operations (6). Volatile organics may be released during mixing (40). Weathering and aging of the solidified material may reduce the effectiveness and cause an increase in leaching potential (35).

3.5.4.2 Thermoplastic Methods

The heating process can cause air emissions and a fire hazard, which may limit the applicability for wastes that decompose at high temperatures (8, 35, 40). Organics may be vaporized and released to the atmosphere upon heating (40, 95). Objectionable oils and odors may also be released (8, 40). If applied to a compatible waste, the resulting material has low leachability and biodegradability and is fairly resistant to most aqueous solutions (35).

3.5.4.3 Organic Polymer Methods

Fumes from the reaction producing the polymers may be emitted. The fixatives used are typically biodegradable, which can cause future release of contaminants (8, 40).

3.5.4.4 Macroencapsulation/Jacketing

Many jacketing materials are combustible. Therefore, use of this method can create a potential fire hazard if heating is required (40). However, as long as the jacket is intact, the waste and any weep products are contained in the jacket and are protected from leaching media (8, 40).

3.5.4.5 Glassification and In-Situ Vitrification

Residual materials generated during glassification include spent molten glass, fly ash, and residues from air pollution control equipment (8). These operations can generate fumes that are extremely difficult to remove from the off-gases. The air pollution control equipment may need to be sophisticated for removal of fumes and small-size particulates (58).

In-situ vitrification can be performed without close contact between the workers and the waste (35). Most organics will decompose, and metals will fuse or vaporize. The gases and vapors will require further treatment, such as scrubbers or filters, that will create secondary liquid and/or solid residuals for disposal (35, 40). There is a potential for formation of dioxins (35). There may also be lateral gas movement when volatiles are present in the waste.

3.5.5 Case Histories/Description of Developmental Status

3.5.5.1 Cement- and Lime-Based Methods

These methods have been used for many nuclear and hazardous wastes. Many commercial RCRA-permitted treatment, storage, and disposal facilities perform some type of inorganic solidification of waste; however, their methods are kept proprietary (8). Few vendors of solidification systems are willing to identify the type and amount of their proprietary additives (6), so it is difficult to relate case histories to conditions at the Douglassville Site. However, several examples are presented in this section. Refer to Section 3.5.6 for a vendor summary.

Chemfix Technologies, Inc. and Stablex Corporation (Seal-O-Safe) have had success in immobilizing heavy metals. Concentrations in the waste were hundreds to thousands of parts per million; the leachate contained tenths of parts per million (8). Chemfix has processed aqueous waste containing as much as 60 percent solids (9).

Envirite Field Services (Permix Process - High Solids Stabilization System) has been used to treat the following waste streams (9):

- PCB waste (1 to 1,000 ppm) with high solids content was solidified for placement in a lined disposal cell.
- Mercury-contaminated sludge (150 to 450 ppm) was solidified for placement in a disposal cell to be capped.
- An oil-emulsion sludge (40 to 50 percent oil) was successfully stabilized.

Hazcon, Inc. has solidified an oil sludge containing 100 to 2,000 ppm of heavy metals. Reportedly the resulting material is leach-resistant and can be landfilled (9).

Solidtek has successfully handled PCB, metal, and solvent wastes as well as all types of sludges (9).

Velsicol Chemical Corporation has successfully handled organic, oily sludges and semi-solids with organic contents of as high as 45 percent (9).

Florida Power and Light used a mixture of cement and fly ash for a soil contaminated with PCBs and lead. The permeability was less than 10^{-7} cm/sec, and the bearing capacity was 3,000 psf (10).

I.U. Conversion Systems has solidified flue gas desulfurization sludge and heavy metal sludge (8). The firm has also treated the following organic wastes: petroleum sludge, acrylic emulsion waste, and coking tar. If a waste contains greater than 8 percent of any single organic compound, it may take longer than 28 days for the solidified material to reach its maximum strength (122).

At the Pepper Steel Site in Florida, soils contaminated with PCBs, lead, and arsenic are to be treated with a Portland cement/fly ash mixture. Laboratory tests on soil spiked with 2,000 ppm of PCBs met the leaching performance criteria (124).

At the College Point Site, PCB-contaminated oil and water was solidified with fly ash prior to disposal at a RCRA-approved landfill (60).

At the Gallup Site, acidic soil was treated in-situ using lime (60). The long-term effectiveness of this action is unknown.

At the Quanta Resources Site, sludges containing PCB, cyanide, heavy metals, and solvents were solidified, using lime, prior to transport to a RCRA-approved landfill (60).

Cement kiln dust was used to solidify an oily sludge at the Trammel Crow Site. Solidified waste was landfilled on site (60, 67). The long-term effectiveness of this action is unknown.

At the Vertac Site, wastewater treatment sludge containing pesticides was solidified by lime addition in-situ in the treatment basin. The basin was backfilled and revegetated (60). The long-term effectiveness of this action is unknown.

Enreco, Inc. has treated oil-field drilling mud and a PCB waste impoundment. The material was disposed of in an offsite landfill after it was stabilized to a soil-like material (71).

HWT chemicals (marketed by International Waste Technologies) have been tested on PCB in soil, pentachlorophenol in soil, API separator bottoms, sludge containing heavy metals and organics, and PCB in oily liquid. HWT treatment appears to produce a solidified product that is very resistant to the standard EP toxicity and Toxic Characteristic Leaching Procedure (TCLP) tests (82).

3.5.5.2 Thermoplastic Methods

Radioactive wastes have been successfully stabilized with bitumen (8, 95).

More than 2,000 extruder/evaporators (equipment used for these methods) are in use at present. For 50 years this equipment has been used for specific applications (not necessarily waste treatment). However, the equipment is not readily available in mobile systems and is difficult to use with soils highly contaminated with organics (8).

One company (Wastechem) utilizes an extruder/evaporator that evaporates organics in solids, collects the evaporated liquids, and encapsulates the residues with asphalt (8).

3.5.5.3 Organic Polymer Methods

These are relatively new solidification processes and have only been used recently, primarily with radioactive wastes. They are not available in mobile systems and are difficult to use with soils highly contaminated with organics (8).

Dow Chemical is developing a vinyl ester-styrene system for use with radioactive wastes (40).

Washington State University has developed a polyester resin system, now in the pilot-plant stage, to be used for hazardous waste (40).

The Tiger-Lock Radwaste Solidification System utilizes a sodium bisulfate (NaHSO_4) catalyst with urea-formaldehyde as a

fixative. The system includes equipment, a control panel, a power panel, and material-handling equipment (8).

3.5.5.4 Macroencapsulation/Jacketing

Many jacketing materials have been presented, although none are marketed for coating cement products. Many solidification systems use drums rather than encapsulates (8). TRW Corporation, a research group, has performed laboratory-scale testing on heavy metal sludges (8, 40).

3.5.5.5 Glassification and In-Situ Vitrification

At present, there are no commercial facilities using a molten-glass furnace for hazardous waste destruction and residuals solidification (8, 40). A proprietary system is being used by a chemical manufacturer to destroy chlorinated organics and produce hydrochloric acid (8).

In-situ vitrification is a research method (35, 58) being developed for the Department of Energy for radioactively-contaminated soil (63). Numerous demonstration tests have been conducted (35, 58, 63, 116, 119, 123). One study claims that this technology used on a soil containing 500 ppm of PCBs has achieved a reduction of 99.9999 percent, which includes the amount removed by off-gas treatment (123). It is expected that with additional development, this process could be applied to a variety of chemical waste sites (63). With currently available equipment, the effective volume for any given application is a cube with 6 meter sides. The nominal rate for a full-scale system is approximately 3 to 5 yd³/hour (123).

3.5.6 Vendor Summary

There was a wide variety of information on vendors in the reference material reviewed for this task. Some documents listed company names and addresses, while others provided more details. In some cases it is not known whether a particular company is an equipment vendor or a vendor of a solidification process. A listing of the vendors for the various technologies and their location is presented in Table 3-10. More details (if available) are provided in the following sections.

3.5.6.1 Cement- and Lime-Based Methods

1. American Resources Corporation, Valley Forge, PA: markets proprietary technology developed by AMAX, Inc.; can treat contaminated soil (8).
2. Atcor Washington, Inc., Peekskill, N.Y.: cement based, primarily designed for radioactive waste; cannot treat sludges that do not combine with cement (8, 40, 78).

TABLE 3-10

VENDOR SUMMARY - SOLIDIFICATION/FIXATION TREATMENT TECHNOLOGIES

Technology	Vendor
Organic Polymer Methods	Aerojet Energy Conversion Company ANEFECO, Inc. Chem-Nuclear Systems, Inc. Dow Chemical Company Energy, Inc. Hittman Nuclear and Development Corporation Protective Packaging, Inc. Todd Shipyards Corporation United Nuclear Industries United Technologies
Macroencapsulation/Jacketing	TRW Corporation
Glassification	Penberthy Electromelt International, Inc.
In-situ Vitrification	Batelle Pacific Northwest Laboratory
Cement-and-Lime-Based Methods	Aerojet Energy Conversion Company American Resources Corporation Atcor Washington, Inc. ATW/Caldwell Canadian Waste Technology Chemfix Technologies, Inc. Chemical Waste Management Chem-Nuclear Systems, Inc. Delaware Custom Materials Energy, Inc. ENRECO, Inc. Envirite Field Services Envirochem Waste Management Services General Electric Company Hazcon, Inc. Hittman Nuclear and Development Corporation IU Conversion Systems Industrial Waste Management, Inc. International Waste Technologies Kipin Industries Lopat Industries, Inc.

TABLE 3-10
VENDOR SUMMARY - SOLIDIFICATION/FIXATION TREATMENT TECHNOLOGIES
PAGE TWO

Technology	Vendor
Cement-and-Lime-Based Methods	Petrofix Solidtek Stabatrol Corporation TJK, Inc. United Nuclear Industries Velsicol Chemical Corporation Westinghouse Electric Company
Thermoplastic Methods	Aerojet Energy Conversion Company Newport News Industrial Corporation Wastechem Werner A. Pfleiderer Corporation

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3. Canadian Waste Technology, Markham, Ontario: silicate-based; treats all inorganic wastes; process ineffective for some organic wastes, but organic wastes of up to 20 percent volume have been treated successfully on a case-by-case basis (40, 118).
4. Chemfix Technologies, Inc., Kenner, LA: cement and silicate based; prefers aqueous waste (less than 60 percent solids); treats most wastes (process is custom designed for each type of waste); some wastes containing certain organic compounds and/or toxic anions are not normally treated; end product is a friable, clay-like material (6, 9, 35, 40, 118).
5. Envirite Field Services, Plymouth Meeting, PA: treats inorganic wastes and up to 50 percent organic wastes; end product is a stabilized, landfillable material (6, 9).
6. Envirochem Waste Management Services, Raleigh, NC: treats waste oil, PCB solids, and contaminated soil (8).
7. Hazcon, Inc., Katy, TX: prefers organics (up to 100 percent), oily sludges, metals; end product is a solid with a low permeability (6, 9).
8. Hittman Nuclear and Development Corporation, Columbia, MD: cement and silicate based; uses a variety of volume reduction and binding techniques for containment of radioactive wastes (8, 40, 78, 118).
9. IU Conversion Systems, Horsham, PA: lime-pozzolanic process; treats various industrial wastes, but not some organics (35, 40, 122).
10. Industrial Waste Management, Inc., New York, NY (Enviroclean process): cement and pozzolan based; treats industrial, utility, and municipal waste; not suited for organics (40).
11. International Waste Technologies, Wichita, KS: uses proprietary HWT compounds and waste specific additives; also uses advanced ground engineering equipment to perform in-situ solidification of contaminated soil (82).
12. Kipin Industries, Aliquippa, PA: distillation with solidification of residue (8).
13. Lopat Industries, Inc.: uses silicate with cement and/or lime (121).
14. Petrofix: cement and pozzolan based (35).
15. Solidtek, Morrow, GA: cement, lime, and silicate based; no restrictions on waste; end product can be varied according to specifications and ultimate disposal method (6, 8, 9).

16. Stabatrol Corporation, Norristown, PA (Terra-Tite process): cement based, treats many industrial wastes (40).
17. Stablex Corporation, Radnor, PA (Sealosafe): silicate based; suitable for inorganic wastes and some organics; not suitable for immiscible oils, solvents, or greases (35, 40, 118).
18. TJK, Inc., North Hollywood, CA: cement based; suitable for most heavy metals; not suitable for waste containing more than 20 percent oil or constitutes of paint waste (40).
19. Velsicol Chemical Corporation, Memphis, TN : treats sludge with up to 45 percent organics; end product is a stabilized, heavy, clay-like substance; not used for soil (6, 9, 115).

3.5.6.2 Thermoplastic Methods

1. Newport News Industrial Corporation, Newport News, VA: uses thermoplastics and organic polymers for volume reduction and handling of radioactive waste (8, 40, 78).
2. Werner A. Pfleiderer Corporation, Waldwick, NJ (VRS System): manufacturers equipment for thermoplastic solidification of radioactive wastes (8, 40, 78).

3.5.6.3 Organic Polymer Methods

1. Hittman Nuclear and Development Corporation, Columbia, MD: uses a variety of volume reduction and binding techniques to provide containment of radioactive waste (8, 40).
2. Todd Shipyards Corporation, Galveston, TX: organic polymer (not urea-formaldehyde) for radioactive waste.

3.5.7 Data Requirements

The physical and chemical characteristics of both the raw waste and the solidified waste must be determined prior to field application of any solidification/fixation process. The variability of the raw waste also must to be evaluated (9, 35, 48 120). The properties of the desired end product must then be defined, based on the method of ultimate disposal (9) and the degree of site decontamination desired (8).

Physical characteristics are used to determine handling requirements, such as transporting, storing, and mixing methods (95).

Chemical characteristics are used to determine the degree of hazard involved in handling and treating wastes, the presence of interfering compounds, and waste compatibility (if different wastes are to be mixed prior to treatment) (95). Chemical tests

should determine the organic content, heavy metal and organic hazardous substances present, and other inorganics that may interfere with solidification (8).

A preliminary listing of data requirements for the evaluation of the feasibility of solidification/fixation at the Douglassville Disposal Site is included in Table 3-11. Additional requirements may become apparent at a later date.

In addition, there are other parameters which may affect in-situ vitrification operations. These include soil properties (thermal conductivity, fusion temperature, specific heat, electrical conductivity, viscosity, chemical composition, and bulk density), site geometry, moisture content, and waste inclusions (debris, containers, and combustibles) (64).

3.5.8 Bench/Pilot Scale Study Recommendations

The use of a solidification/fixation technique should be made only after the chemical and physical properties of the solidified waste have been extensively tested to ensure that the required properties have been attained (8).

Vendors universally prefer to determine the treatability of the waste by their method(s) after sampling the raw waste and subjecting the samples to laboratory testing (6, 9). Each waste has its own particular set of chemical requirements. Slight alterations in chemical additives may be required to achieve the most stable product. If different wastes are mixed, this can create problems when designing a specific mix for treatment (88). Soils contaminated with a large number of compounds cannot be treated without prior extensive tests (35).

Bench-scale testing of solidified samples is needed to provide data on expected leaching rates, waste/solidification agent ratios, and durability. Field testing may be needed to test the long-term durability and the acceptability of the treatment approach (88). Such testing will also allow vendors of successful solidification methods to formulate cost-effective waste to chemical ratios (9).

The following evaluation procedure can be used to judge the acceptability of solidification procedures (40, 95):

- Evaluate the hazardous nature of the solidified waste.
- Determine the maximum toxic hazard under normal conditions.
- Determine the physical integrity and durability of the end product.
- Estimate leaching losses over the long-term.

TABLE 3-11

DATA REQUIREMENTS - SOLIDIFICATION/FIXATION TECHNOLOGIES

Pre-Bench/Pilot-Scale Requirements

Chemical-analytical data (waste and soil/waste composition)
Vertical and horizontal extent of contamination
Solids and/or moisture content
Grain-size distribution (fine-grained materials can cause problems with waste handling, wind dispersion, and ultimate strength)

Post-Bench/Pilot-Scale Requirements

Bulk and dry unit weight (measure of density and void volume; used to convert weight to volume in material handling calculations)
Unconfined compression strength (determines ultimate bearing capacity of treated waste)
Permeability (influences rate of contaminant release)
Wet/dry durability and freeze/thaw resistance (evaluates resistance to natural weathering)
Compaction
Atterberg limits (determine how material will act when stressed)
Triaxial compression (determines shear strength under controlled drainage conditions)
Trafficability (needed if treated waste will be subject to vehicle traffic, especially prior to ultimate hardening)
Strength versus cure time relationship
Leaching tests (determines resistance to leaching; to be specified by regulatory agencies)
Cone index or other in-situ test (determines ability to support load; valuable in examining strength of in-place wastes)

- Assess the ultimate disposal area.
- Determine the quality control requirements needed for waste processing.

Vendors should always be consulted, since they may have specific data or testing needs for a particular solidification/fixation process.

Solicitations for bids will be issued to vendors of solidification/fixation technologies who have field experience in its application (subject to EPA approval). Such solicitations will include a summary of all available chemical-analytical, physical, and hydrogeologic data for the site.

The vendors will be asked to provide the following background information and services:

- A technical description of the proposed solidification/fixation technology.
- Case histories and supporting analytical data.
- A description of proposed bench and pilot-scale studies.
- Services for the solidification/fixation of waste contaminated with oil and grease, polynuclear aromatic hydrocarbons, phthalate esters, phenols, polychlorinated biphenyls, non-halogenated aromatics, and halogenated aliphatics, and lead.
- An estimate of achievable levels of treatment (prior to initiation of bench and pilot-scale studies to the extent practicable). This includes expected leaching rates.
- A conceptual model of a proposed solidification/fixation alternative.
- Bench-scale studies designed to demonstrate that solidification/fixation occurs through physical and chemical techniques. (Techniques will be left to the discretion of the vendor but will be subject to EPA approval.)
- Quality-control requirements for waste processing.
- Services or support in the area of leachate monitoring for in-situ or onsite land disposal approaches (i.e., lysimeter/surface collection systems and sampling and analysis).
- Initial unit-cost estimates.

- An estimate of the time to complete the operation and capital/operation and maintenance costs (upon completion of bench/pilot scale studies).
- A summary of all findings and conclusions in a report to be submitted upon completion of bench-and pilot-scale studies.
- Support with regard to compliance with state and Federal ARARs, (e.g., land disposal bans).
- Recommendations for the handling and treatment of waste streams from any solidification/fixation processes.

The following items need to be determined to evaluate the feasibility of in-situ vitrification: melt depth attainable, uniformity of vitrification, stability and leach resistance, procedures to prove the leach resistance of the vitrified mass to regulatory agencies, and the type of air pollution control needed (58).

3.5.9 Costs

Cost depends on the type and concentration of the contaminants, the type and amount of soil, the uniformity of the contamination, the need for special precautions, and the degree of contaminant reduction (in leachate) required (35). Cost is also dependent on the proprietary additives that may be required to achieve stabilization.

Cost data available in the references reviewed are presented in Table 3-12. Cost data in the references were generally obtained from vendor information. Many costs may be outdated, and updating of specific applicable costs will have to be done.

3.6 PHYSICAL TREATMENT

3.6.1 General Description

Physical treatment methods are generally used for separatory purposes and may be applicable for the dewatering of the unlined surface impoundment and material from the facility drainage channel. Physical treatment could be used to separate material from these areas into aqueous and solid phases. After separation, the residual liquids and solids could be treated and/or disposed of as appropriate.

Conventional sludge dewatering technologies provide a starting point for the evaluation of physical separation methods. Physical separation may be effected using vacuum, centrifugal, or compression methods. Each of these methods is discussed briefly below. Gravity-induced separation methods are often used for sludge dewatering, but the oil-saturated filter cake is

TABLE 3-12
SOLIDIFICATION/FIXATION TECHNOLOGY COSTS 1

Method	Cost	Reference	Comments
Cement/Lime Based			
Chemfix Technologies	\$30-\$75/yard ³	6,9	Lower cost for soil with heavy metals, higher costs for soil with PCBs
Canadian Waste Technology	\$6/yard ³	40	
Envirite Field Services	\$0.10-\$0.25/gallon	6,9	
Hazcon	\$65-\$150/yard ³	6,9	
Industrial Waste Management	\$12-\$20/yard ³	40	
Lopat Industries, Inc.	\$38-\$150/yard ³	121	
Stablex Corporation	\$8-\$525/yard ³	40	
TJK, Inc.	\$8-\$16/yard ³	40	
Velsicol Chemical Corporation	\$0.15-\$0.50/gallon	6,9	
Thermoplastic	\$18.60/100 pounds	8	
Organic Polymer	\$28/100 pounds	8	Materials only
Macroencapsulation	\$4.50/100 pounds	8,40	Materials only
Glassification	-	58	Moderate to high capital investment
In-situ Vitrification	\$164-\$432/yard ³	35,63	

1. Costs converted to consistent units where possible: 1 ton = 2,000 pounds; 1 yard³ = 3,000 pounds; 1 m³ = 1.308 yard³.

not amenable to gravimetric separation, and this method has not been considered for application at the Douglassville Disposal Site.

3.6.1.1 Vacuum Methods

Vacuum filtration is generally conducted using a horizontal rotating drum covered with a filtration medium. A vacuum is applied in the interior of the drum, and the pressure differential thus induced draws the liquid phase from the sludge material, leaving a high solid-content filter cake on the outside of the drum. Filtrate is drained from the drum, and the filter cake is removed using a fixed scraper blade (147). The vacuum filtration system is particularly suited for filtering aqueous streams containing suspended solids.

3.6.1.2 Centrifugal Methods

Various types of centrifugal separators have been developed for specialized applications. Such systems separate solid and liquid phases as a result of density differences. These systems are conceptually similar to gravimetric systems; however the separation is induced by centrifugal rather than by gravitational acceleration. Mechanisms such as counter-rotating screw conveyers are used to remove separated solids from a centrifugal shell. Selection of specific equipment can be influenced by material feed rate, solid characteristics, temperature, and conditioning processes.

3.6.1.3 Compression Methods

Unlike vacuum filters and centrifuges, plate and frame filter presses (compressions systems) are operated in batch rather than continuous modes. In the most common plate-filter systems, input material is pumped into spaces between adjacent vertical plates. Filtrate passes through a cloth filter medium and is drained out of the bottom of the plate. Solids are held between the plates and are released onto a conveyor or into a collection receptacle when the plates are separated. A variation on this technology is the belt filter press, which combines features of gravity and compression filtration methods. Belt filter presses can be operated continuously.

It is often necessary to condition a material prior to the application of separation technologies. This may be done to improve the porosity of a filter cake or to avoid filter blinding (e.g., addition of an inert solid such as lime or flyash). Polymeric materials are sometimes added to improve agglomeration of solids or to break oil emulsions. Vacuum filter media may need to be precoated for some applications. Hence, total solids volume may increase through the use of filtration methods.

3.6.2 Waste Treatment Capabilities

Conventional applications of vacuum and pressure filtration technology generally deal with input solids concentrations of 10 percent or less, while producing filter cakes with as much as approximately 55 percent solids (147, 149). Centrifugation systems normally achieve up to approximately the same range of solids concentrations, but specially designed systems reportedly can achieve as much as 80-90 percent solids concentration.

With regard to plugging/blinding problems, it may be necessary in the case of vacuum and pressure filtration, to add a volume of inert solids to provide porosity. This volume could be as much as the initial solids volume in the sludge. Also, for vacuum filtration, it may be necessary to pre-coat the filter medium with an inert substance. This coating would add to the solid volume for disposal but is expected to add less than 10 percent to the total volume (148).

The application of such physical treatment methods is expected to result in overall volume reduction of the surface impoundment and drainage channel wastes. The solid and liquid waste streams would require additional treatment, such as incineration, solvent extraction, solidification, etc. It may be possible to use a land application approach to deal with residual solids.

3.6.3 Logistical Requirements

Activities that could be involved for physical treatment of the surface impoundment and drainage channel material are as follows:

- Establishment of conditioning material staging areas.
- Pumping/dredging of the sources.
- Mixing of the waste and conditioners.
- Dewatering.
- Liquid and solid storage.
- Liquid and solid stream treatment or disposal.

The biggest concern for a dewatering operation is providing a uniform feed so that the conditioning chemical feed requirements do not have to be continually adjusted. Feed heterogeneity results in poor dewatering and downtime.

Depending on the results of bench and pilot tests, it may be possible to delete or modify some of the steps. Specific facilities, such as storage tanks and silos, and mixing vessels, would have to be sized and installed based on projected schedules, throughputs, and site layout. Separation equipment may be truck mounted. Necessary utilities would have to be provided. Treatment/disposal of the separated streams could occur either on or off site, and will be addressed elsewhere.

3.6.4 Public Health and Environmental Concerns

Worker protection is a key consideration in completion of physical treatment activities. Exposure could occur via direct dermal contact with contaminated wastes, or through inhalation of organic vapors or dust, such as from handling of inert solids. Adequate health and safety measures would be required to mitigate exposures through these routes. Protective clothing, respiratory protection, and dust-control measures could be required to prevent worker exposure.

Since considerable quantities of both contaminated and uncontaminated liquids could be involved, adequate spill prevention and containment plans will be needed.

Following the separation process, adequate treatment/disposal of the solid and liquid streams will be needed.

3.6.5 Case Histories/Description of Development Status

All of the physical separation technologies discussed in this section are well-developed, and commercial mobile units are available. Various physical separation processes have been utilized for sludge dewatering at many sites.

3.6.6 Vendor Summary

Numerous vendors market the various types of separation systems discussed above. Table 3-13 provides a summary of vendors of the systems discussed in this section.

3.6.7 Data Requirements/Bench- and Pilot-Scale Studies

To adequately assess the feasibility of using solids/liquids separation methods for handling the appropriate wastes present at the Douglassville Disposal Site, the following information will be required.

- Need for conditioning and/or emulsion-breaking agents.
- Need for body feed material.
- Throughput data to size facilities and establish schedule.
- Physical and chemical characteristics of separated waste streams to identify treatment/disposal options.

Representative samples of the waste may be sent to vendors for bench and pilot tests to establish the suitability of a particular technology and to develop more precise cost estimates. A complete chemical characterization of the waste, including all hazardous constituents, is needed to evaluate the

TABLE 3-13

VENDOR SUMMARY - PHYSICAL TREATMENT TECHNOLOGIES

Technology	Vendor
Centrifuge	Tetra Recovery Systems IT Corporation Industrial Innovations, Inc.
Filter Press	IT Corporation Sanitary Systems Services, Inc. Central New York Industrial Services BioNomic Resources, Inc. Jones Environmental Pressure Filtration Specialists Bird Environmental Systems EVER Environmental, Inc. Tetra Recovery Systems
Vacuum Filtration	Industrial Innovations, Inc.

potential for separation to provide cost-effective disposal options.

3.6.8 Costs

Table 3-14 summarizes representative unit cost data for the various physical separation processes considered in this section.

TABLE 3-14
PHYSICAL TREATMENT TECHNOLOGY COSTS 1

Method	Cost	Reference	Comments
Centrifuge	\$67.50-\$105/yard ³	147	Dry solids basis
Filter Press	\$105-\$195/yard ³	147	Dry solids basis
Vacuum Filtration	\$67.50-\$127.50/yard ³	147	Dry solids basis

1. Costs converted to consistent units where possible: 1 ton = 2,000 pounds; 1 yard³ = 3,000 pounds.

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4.0 EVALUATION OF SOURCE CONTROL TECHNOLOGIES

The source control technologies discussed in Section 3.0 (Description of Source Control Technologies) are evaluated (to the extent possible) in this section. Section 4.1 provides a general discussion of the basis for this evaluation. Brief descriptions of the advantages and disadvantages of the various source control technologies and tabular summaries of the feasibility criteria and costs are provided in Section 4.2.

4.1 BASIS FOR EVALUATION

Seven categories of evaluation criteria have been considered for the source control technologies discussed in the preceding sections of this document. The criteria considered include the following:

- Compatibility with site conditions
- Waste treatment capability
- Public health and environmental protection
- Implementability
- Developmental status
- Effectiveness
- Reliability

Brief descriptions of each of the evaluation criteria follow. Each description includes a rhetorical question that the criterion is designed to answer. It should be apparent that some overlap exists between these screening criteria.

Compatibility With Site Conditions - "Can this technology be used to deal with site-specific problems?" This criterion is the most fundamental factor that must be considered when technologies are screened during the feasibility study process. It is often taken for granted in the screening of technologies and assembly of alternatives. It is based on the nature of the site problems, the mechanisms of chemical releases, and technical limitations arising from physical constraints imposed by site wastes, hydrology, geology, etc.

Waste Treatment Capability - "Can this technology be used to treat site-specific wastes to action levels?" This consideration is based on the technical feasibility of treating particular wastes and achieving desired levels of cleanup. For example, landfarming may be technically feasible for treatment of site wastes (compatible with site conditions), but the endpoint concentrations achieved using such a method may be unacceptable with regard to action levels. In some circumstances, a technology might provide only partial treatment (not to the action level) and could still be considered feasible as a pretreatment step. For example, thermal treatment could be implemented prior to subsequent treatment or disposal to reduce volatiles. These applications are noted when possible.

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Public Health and Environmental Protection - "Can a remedial alternative using this technology be developed that affords adequate protection of public health and the environment?" Generally, technologies that do not result in the attainment of action levels will not afford a solution that provides adequate protection of human health and/or the environment. In addition, potential exposures or releases that could occur as a result of the use of a particular technology must also be considered.

Implementability - "Can a remedial alternative developed using this alternative be implemented and can desired results be achieved in a reasonable time frame?" This criterion includes such considerations as construction requirements, the availability of required equipment, and the time necessary both to install the remedial equipment and to achieve the desired level of response. If long time periods are required for cleanup operations, additional interim measures may be necessary to mitigate contaminant release and exposures.

Developmental Status - "Is the technology under consideration innovative, emerging, demonstrated, or commercially available?" Although the developmental status of a technology is no longer considered a sound basis for screening it from further consideration, it is apparent that some technologies may be screened on this basis. It is difficult to evaluate the technical viability of a technology that is at an innovative or emerging stage. Available data is usually very limited or proprietary. For example, if two technologies are available that achieve the same results and have the same relative costs, the demonstrated or commercially available technology would be favored over the technology that does not have a proven track record. Innovative, or emerging, technologies may incur additional cost through extensive bench- and pilot-scale studies and field demonstrations.

Effectiveness - "Will a remedial alternative developed using this technology be effective in solving site problems over the long term?" If a technology is capable of achieving the desired action levels, it will generally be considered effective. For the treatment technologies considered in this document, this will be the case. Effectiveness considerations are generally more applicable for the consideration of containment options. For example, installation of a cap and groundwater containment barriers may be capable of mitigating releases, but their useful life may be limited, and replacement cost would be incurred in the future.

Reliability - "Has this technology been shown to be dependable at other similar sites and can a remedial action involving the technology be operated and maintained effectively?" The potential impacts of system failures must always be considered. For example, failure of the off-gas collection system associated with an in-situ vitrification system may make such a technology unreliable, although it has been shown to be effective. 000108

4.2 EVALUATION OF REMEDIAL TECHNOLOGIES

Table 4-1 presents a technology-versus-criteria matrix for each of the remedial technologies discussed in Section 3.0 of this report. Three qualitative descriptors have been used for the majority of the criterion, as follows:

- Acceptable - technology meets criteria.
- Questionable - technology may or may not meet criteria: technical data base is limited and bench- and pilot-scale studies are required for further evaluation.
- Unacceptable - past performance or inapplicability for site conditions indicates that technology will not satisfy criteria.

For the most part, Table 4-1 is self-explanatory. Brief discussions of the reasons why some technologies have been considered unacceptable are included below. In addition, some aspects of the table that may require some clarification are also included.

Molten Salt, Wet-Air Oxidation, Supercritical Water Oxidation, Multiple Hearth, In-situ Radio Frequency, Cement Kiln - These thermal treatment methods are considered unacceptable in view of their waste-treatment capabilities. These systems are limited in dealing with persistent organic chemicals, such as PAHs and PCBs. Molten salt combustion is considered infeasible for the treatment of contaminated soil. Continuous regeneration or replacement of the salt pool would be expected because of the presence of non-combustible material in the soil. Cement kilns are not well-suited for treatment of contaminated soil. Normal operating temperatures in multiple hearths are considered too low for the destruction of PCBs. Wet-air and supercritical water oxidation are primarily designed for the treatment of aqueous waste streams and are not well suited for waste present at the Douglassville Disposal Site.

Organic Polymers - This solidification/fixation approach is primarily used for the immobilization of nuclear waste materials. The presence of organic wastes inhibits the setting of the the solidification/fixation material.

As shown in Table 4-1, virtually all of the technologies reviewed (with the exception of the rotary kiln) are considered questionable with regard to waste treatment capability, public health and environmental protection, effectiveness, and reliability. It is apparent that bench/pilot-scale studies and field demonstrations are necessary for a number of the technologies. Although the applicability of the technologies is questionable at this point, it is worthwhile to consider some of the advantages and disadvantages of each. Table 4-2 provides a

TABLE 4-1
EVALUATION OF SOURCE CONTROL TECHNOLOGIES
DOUGLASSVILLE DISPOSAL SITE

Technology	Criteria						
	Compatibility with Site Conditions	Waste Treatment Compatibility	Public Health & Environmental Concerns	Implementability	Developmental Status	Effectiveness	Reliability
INCINERATION							
Fluidized Bed	Acceptable	Questionable	Questionable	Acceptable	Demonstrated	Questionable	Questionable
Rotary Kiln	Acceptable	Questionable	Questionable	Acceptable	Commercial	Questionable	Questionable
Multiple Hearth	Acceptable	Unacceptable	Unacceptable	Acceptable	Demonstrated	Unacceptable	Unacceptable
Molten Salt	Acceptable	Unacceptable	Questionable	Acceptable	Emerging	Questionable	Questionable
Plasma Arc	Acceptable	Questionable	Questionable	Acceptable	Emerging	Questionable	Questionable
Fluid Wall/Electric	Acceptable	Questionable	Questionable	Acceptable	Commercial	Questionable	Questionable
Infrared	Acceptable	Questionable	Questionable	Acceptable	Emerging	Questionable	Questionable
Wet-Air Oxidation	Acceptable	Unacceptable	Unacceptable	Acceptable	Emerging	Unacceptable	Unacceptable
Supercritical Water Oxid.	Acceptable	Unacceptable	Questionable	Acceptable	Emerging	Questionable	Questionable
Cement Kiln	Acceptable	Unacceptable	Unacceptable	Acceptable	Demonstrated	Unacceptable	Unacceptable
In-Situ Radio Frequency	Acceptable	Unacceptable	Unacceptable	Acceptable	Emerging	Unacceptable	Unacceptable

EXTRACTION							
Technology	Compatibility with Site Conditions	Waste Treatment Compatibility	Public Health & Environmental Concerns	Implementability	Developmental Status	Effectiveness	Reliability
Water/Solvent	Acceptable	Questionable	Questionable	Acceptable	Demonstrated	Questionable	Questionable
Surfactant	Acceptable	Questionable	Questionable	Acceptable	Demonstrated	Questionable	Questionable
B.E.S.T.	Acceptable	Questionable	Questionable	Acceptable	Commercial	Questionable	Questionable
Supercritical Fluid	Acceptable	Questionable	Questionable	Acceptable	Emerging	Questionable	Questionable
APEC	Acceptable	Questionable	Questionable	Acceptable	Commercial	Questionable	Questionable
Critical Fluid	Acceptable	Questionable	Questionable	Acceptable	Commercial	Questionable	Questionable

TABLE 4-1
EVALUATION OF SOURCE CONTROL TECHNOLOGIES
DOUGLASSVILLE DISPOSAL SITE
PAGE TWO

Technology	Criteria						
	Comatability with Site Conditions	Waste Treatment Comatability	Public Health & Environmental Concerns	Implementability	Developmental Status	Effectiveness	Reliability
BIODEGRADATION							
Landfarming	Acceptable	Questionable	Questionable	Acceptable	Commercial	Questionable	Questionable
In-Situ Biodegradation	Acceptable	Questionable	Questionable	Acceptable	Commercial	Questionable	Questionable
Liquid Solids Contact	Acceptable	Questionable	Questionable	Acceptable	Emerging	Questionable	Questionable
SOLIDIFICATION							
Cement/Lime Based	Acceptable	Questionable	Questionable	Acceptable	Commercial	Questionable	Questionable
Thermoplastic	Acceptable	Questionable	Questionable	Acceptable	Demonstrated	Questionable	Questionable
Organic Polymer	Acceptable	Unacceptable	Questionable	Acceptable	Emerging	Questionable	Questionable
Macroencapsulation	Acceptable	Questionable	Questionable	Acceptable	Innovative	Questionable	Questionable
Classification	Acceptable	Questionable	Questionable	Acceptable	Emerging	Questionable	Questionable
PHYSICAL TREATMENT							
Filter Press	Acceptable	Questionable	Questionable	Acceptable	Commercial	Questionable	Questionable
Centrifugation	Acceptable	Questionable	Questionable	Acceptable	Commercial	Questionable	Questionable
Compaction	Acceptable	Questionable	Questionable	Acceptable	Commercial	Questionable	Questionable

TABLE 4-2

ADVANTAGES AND DISADVANTAGES OF SOURCE CONTROL TECHNOLOGIES
DOUGLASSVILLE DISPOSAL SITE

Technology Type	Advantages	Disadvantages
Thermal	<ul style="list-style-type: none"> • Can achieve destruction of organics (detoxification). • Mobile units are available. • Volumetric decrease may be obtained. • Good control over operations achieved. 	<ul style="list-style-type: none"> • Inorganics cannot be treated. • Excavation and materials handling required. • Off-gases and particulate emissions require treatment. • Energy or supplemental fuel requirements for wastes with low BTU-value.
Extraction	<ul style="list-style-type: none"> • Both organics and inorganics can be treated (various solvents). • Some approaches could be conducted in-situ (effectiveness may be limited). • Control can be maintained over surface-mounted systems. • 100% (theoretical) removal can be achieved (detoxification). 	<ul style="list-style-type: none"> • Overall volume of wastes (liquid and solid) will increase. • Liquid/gaseous waste streams will require treatment (ancillary equipment required). • Control over in-situ applications may be limited. • Physical properties of soil may be altered. • Multiple solvents may be required for heterogeneous wastes. • Systems failure (e.g., groundwater extraction systems) could result in adverse impacts as a result of enhanced solubility of organics (in-situ approach). • Excavation and materials handling may be necessary.

TABLE 4-2
 ADVANTAGES AND DISADVANTAGES OF SOURCE CONTROL TECHNOLOGIES
 DOUGLASSVILLE DISPOSAL SITE
 PAGE TWO

Technology Type	Advantages	Disadvantages
Biodegradation	<ul style="list-style-type: none"> • Some approaches can be effected in-situ. • Complete degradation (mineralization) of organics may be possible. • Volumetric increase not anticipated. • Equipment and fertilizers readily available for landfarming approach. 	<ul style="list-style-type: none"> • Control over in-situ applications may be limited. Operational problems common with biofouling of soil/aquifer. • Pseudo 1st-order kinetics may result in long operational period. • Large-scale production of exogenous microorganisms may be infeasible. • Minimum concentration at which microorganisms will act may exist as a result of preferred substrates. • Inorganics cannot be treated. • Landfarming and liquid solids contact could entail large excavation operations.
Solidification/ Fixation	<ul style="list-style-type: none"> • Some applications may be conducted in-situ. • Some chemical additives may result in both detoxification and immobilization. • Inorganic and organics can be treated. 	<ul style="list-style-type: none"> • Volumetric increase may occur. • Most approaches will require excavation and materials handling. • Long-term effectiveness with regard to leachability and structural integrity unknown.
Physical	<ul style="list-style-type: none"> • Volume reduction may be achieved. 	<ul style="list-style-type: none"> • Liquid and solid streams require further treatment. • No detoxification or immobilization achieved.

summary of these aspects for each of the general categories of treatment considered.

It is obviously impractical that bench/pilot-scale studies and field demonstrations be conducted for all of the technologies that have been considered. Data collected during the Phase I RI and vendor responses should aid in the identification of applicable processes and focus bench- and pilot-scale studies. Some qualitative conclusions can be reached at this point, to focus field investigations and bench- and pilot-scale studies.

Based on the nature of site conditions (both hydrogeologic and waste-specific) and engineering judgment, it is felt that in-situ extraction approaches will not effect the desired results at the site. Waste deposits such as the backfilled lagoons are expected to be relatively impermeable. This will limit the effectiveness of flooding or the use of infiltration galleries. In addition, groundwater flow in the bedrock groundwater regime is largely dictated by secondary permeability. The use of extractants will mobilize contaminants, or they may be pollutants themselves. Their use may have adverse affects unless great control can be effected in both the overburden and bedrock. It may not be possible to control groundwater flow in all discrete bedrock fractures.

Based on the nature of site conditions, it is apparent that all of the biodegradation technologies discussed in Section 3.0 may be applicable at the site. For example, liquid solids contact might be used to handle the filter cake material and the soil/waste matrix from the backfilled lagoons; landfarming could be continued in the portions of the site where land application has been conducted in the past; in-situ biodegradation could be used to treat contaminants present in the aquifer (if coupled with surface mounted air-strippers or dual aerobic and anaerobic digesters).

A field application of a solidification process has already been scheduled at the site under the Superfund Innovative Technologies Evaluation Program. Information gleaned from this study will be incorporated into the feasibility study, and it is conceivable that this information will provide all the necessary information for an evaluation of this approach. It is apparent that the in-situ applications of the solidification/fixation technology are worthy of investigation.

Of the physical separation technologies considered in this document, plate and frame or belt filter presses are probably most applicable for the Douglassville Disposal Site. These units apparently achieve the greatest degree of dewatering. The use of this technology would also entail the use of additional technologies to treat the liquid and solid residuals. This is primarily a pretreatment technology and would be most applicable for dewatering of material from the facility drainage channel or the unlined surface impoundment in the filter cake area.

Individual costs for particular treatment technologies were provided in Section 3.0 (Description of Source Control Technologies). Representative costs for the general categories of treatment considered in this report are summarized in Table 4-3.

TABLE 4-3

REPRESENTATIVE UNIT COST RANGES
SOURCE-CONTROL TREATMENT TECHNOLOGIES

Technology	Representative Cost Range
Thermal Treatment (Rotary Kiln)	\$225 - \$700/Yard ³
Extraction-Based Treatment	\$150 - \$450/Yard ³
Biodegradation (Landfarming)	\$20 - \$100/Yard ³
Solidification/Fixation (Cement-Based)	\$65 - \$150/Yard ³
Physical Treatment (Filter Press)	\$105 - \$195/Yard ³

5.0 RECOMMENDATIONS FOR BENCH- AND PILOT-SCALE STUDIES

As pointed out in Sections 3.0 and 4.0, virtually all of the remedial technologies discussed in this document require bench- and pilot-scale studies. As discussed in Section 4.2 (Evaluation of Remedial Technologies), some of the technologies are not considered promising enough to warrant any detailed investigation at this point. Those technologies to be more thoroughly investigated to support the FS include land application, liquid solids contacting methods (both biodegradation- and extraction-based), and in-situ solidification options. A general approach for the conduct of bench and pilot scale studies and the function of these studies in the overall RI/FS process may be outlined as follows:

- Identify preliminary data requirements for bench- and pilot-scale studies to be satisfied during the Phase I Remedial Investigation/Conduct Phase I FS (preliminary screening as contained in this document and the RI/FS Work Plan).
- Collect the preliminary site data and re-assess the status of proposed bench- and pilot-scale studies.
- Evaluate solidification data provided as a result of the Hazcon, Inc., field study to be conducted at the Douglassville Disposal Site under the SITE Program.
- Complete technology screening and the preliminary identification of alternatives (Phase II FS). Update this comparative evaluation document in response to USEPA comments and new developments. Update costs to a more detailed level (i.e., beyond unit costing).
- Generate subcontractor specifications for each remedial technology to be studied. Provide this information to USEPA and the U.S. Army Corps of Engineers for review and approval.
- Issue solicitations for bids (SFB) to those vendors capable of providing support in areas where bench/pilot-scale studies are required. Provide vendors with all chemical-analytical, hydrogeologic, hydrologic, meteorologic, and other pertinent site data.
- Conduct technical review of bids and solicit USEPA approval regarding vendor selection.
- Have vendors initiate treatability studies (bench scale) during Phase II RI. Vendors will be asked to provide results of bench-scale studies, and all interested parties will review data. Recommendations regarding the relative merits of conducting field demonstrations will

be supplied to USEPA and COE. Field demonstrations to be completed during Phase II RI.

- Utilize data collected during Phase I and Phase II RIs to conduct Phase III FS (detailed evaluation of alternatives).

The approach outlined above is consistent with recent guidance provided by USEPA with regard to the RI/FS process. The preliminary technology screening presented in this document provides a good deal of the background necessary to complete the Phase I FS. As a result of this screening process, a number of preliminary treatability-study-based data requirements have been identified. Although the majority of these data requirements will only be satisfied upon completion of bench- and pilot-scale studies, several data requirements have been identified. These have been included in the RI/FS Work Plan for the Douglassville Disposal Site.

Preliminary data to be obtained during the Phase I RI include such information as microbial activity assessments (ATP tests) for soils, wastes, and groundwater, macronutrient availability (nitrogen and phosphorus), total organic carbon content, soil reaction and groundwater pH, dissolved oxygen content of groundwater, soil percent moisture, and BTU content of contaminated soils and wastes. Additional information relative to bench- and pilot-scale studies will be collected as a matter of course during the Phase I RI (i.e., nature and extent of contamination, permeability, etc.).

Field applications of in-situ biodegradation technologies have shown a great deal of promise for aquifer restoration. Such an approach may be particularly suited for treatment of contaminated groundwater and the solid aquifer matrix. However, in-situ treatment of the backfilled lagoons and other such sources through water-table elevation or through the use of infiltration galleries is considered impractical. Therefore, it is recommended that more emphasis be placed on source control measures (through excavation followed by land application or liquid solids contact) with regard to biodegradation treatability studies.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Five general categories of treatment-based source control technologies have been discussed in this document:

- Thermal treatment methods
- Extraction-based treatment methods
- Biological treatment methods
- Solidification/Fixation treatment methods
- Physical treatment methods

Information collected during the Phase I RI and other site data will be provided to vendors of thermal treatment technologies. The information gathered during initial field investigations and vendor responses will aid in the selection of an appropriate thermal treatment technology.

Plate and frame or belt filter presses may be suited for sludge dewatering operations. Areas that may be subjected to such pretreatment include the facility drainage channel and the unlined surface impoundment in the filter cake disposal area.

Of the extraction-based technologies reviewed, it has been concluded that post-excavation liquid solid contacting approaches will be more effective in dealing with the highly contaminated sources (i.e., the backfilled lagoons, etc.) than in-situ approaches effected through infiltration galleries or water-table elevation. In-situ applications are better suited for aquifer cleanup and for post-excavation remediation of unsaturated zone residuals.

A biodegradation approach (through landfarming) is considered worthy of additional investigation, at least at the bench scale. If this method can achieve the desired action levels, it will be particularly attractive because of the comparatively simple logistical and operation-and-maintenance requirements. Previous applications of such an approach (although on simpler waste materials) have shown it to be very cost-effective. This method will not generate residual solid, liquid, or gaseous waste streams that require treatment or disposal.

In-situ solidification approaches are also considered worthy of additional study. In addition, study of an in-situ vitrification approach may also be warranted, although this process has not been demonstrated for the treatment of oily wastes. Useful general information with regard to the applicability of a solidification option will be obtained as a result of the Hazcon field demonstration. In-situ approaches are considered favorable because costs are expected to be substantially lower than post-excavation solidification or extraction-based techniques.

Preliminary data requirements have been identified and, where possible, have been incorporated into the RI/FS Work Plan. Because of the complexity of site problems, solicitations will be submitted to subcontractors experienced in each of the various technologies. Vendors will be selected to conduct bench-scale studies based on bids and qualifications. The applicability of particular treatment methods will be re-assessed upon completion of bench-scale studies. Promising technologies will be carried to a field-demonstration stage.

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