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Assessment of Technologies for the Remediation of Radioactively Contaminated Superfund Sites

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Office of Radiation Programs
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Executive Summary

This report is a screening evaluation of information needs for the development of generic treatability studies for the remediation of Superfund Radiation Sites on the National Priorities List (NPL). It presents a categorization of the 25 radiation sites currently proposed or listed on the NPL, and provides a rating system for evaluating technologies that may be used to remediate these sites. It also identifies gaps in site assessment and technology data and provides information about and recommendations for technology development. The approach used in this evaluation was to:

- Divide the 25 radiation sites into 9 categories based on combinations of 3 matrix groups (i.e., soils, water, and structures) and 3 contaminant groups (i.e., radium (Ra), thorium (Th), and/or uranium (U); other radionuclides; and mixed chemical and radioactive waste).

- Develop criteria to rate technologies numerically on their performance; i.e., potential to remediate the contaminant/matrix problems at the NPL radiation sites, and on their stage of development.

- Identify information gaps, summarize findings, and state recommendations.

The major findings in this report are:

- As of December 1988 a total of 25 radiation sites have either been listed (16) on the NPL or proposed for listing (9). Remedial Investigation/Feasibility Studies (RI/FS) are underway at 15 of the 25 sites; however, no site has been completely remediated.

- The majority (23/25) of the radiation sites fall into the contaminant/matrix category, "Soils Contaminated with Radium, Thorium, and/or Uranium." The second largest category is "Water Contaminated with Radium, Thorium, and/or Uranium."

- Additional radiological site assessment data would make it possible to perform a more comprehensive evaluation of potential remediation technologies.

- Radioactive contaminants are neither altered nor destroyed by any of the technologies evaluated.

- Every site remediation plan involving radioactive materials must select a final, environmentally safe disposal method and site for the radioactive waste.

- Technologies were rated numerically using "Performance" and "Development" criteria. Performance criteria were developed based on the mandates and preferences in the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). These criteria were "long term effectiveness" of remediation and the reduction of "toxicity, mobility, or volume" of the radioactive waste. Development criteria were selected to indicate the degree of information available on each technology and the stage of its development. Due to the short time frame allotted for this project, it was not possible to develop extensive criteria for technology assessment.

- Of the 29 technologies evaluated, 10 technologies (not currently in use for site remediation) show high scores for remediation performance and low scores for development. These technologies are:

  Soil Washing with Water
  Chemical Extraction with Salts
  Chemical Extraction with Acids
  Chemical Extraction with Complexing Agents
  Physical Screening
  Classification
  Gravity Concentration
  Flotation
  Vitrification
  Solidification

- Four additional technologies have a high potential for success and are already in use at several nonradiation NPL sites. These are ion exchange, carbon treatment (including precipitation and flocculation), and land encapsulation.

Definitions of the contaminants and matrices found at the 25 NPL radiation sites are provided in Table S-1. The number of sites in each contaminant/matrix group, and the number of promising technologies are shown in Tables S-2 and S-3, respectively.

The major recommendations in this report are:

- **Soils:**
  - Continue work on soil washing and chemical extraction studies, including treatability studies on soils from other sites with Ra, Th, and U contamination and on soils from sites contaminated with mixed waste.
  - Review information and begin field testing of physical separation, chemical extraction, vitrification, land encapsulation, solidification, and mine disposal.
  - Continue to encourage development and demonstration of remediation techniques.

- **Water:**
  - Conduct feasibility and treatability studies for removal of Ra, Th, and U and for removal of mixed waste.
  - For mixed waste, conduct bench- and pilot-scale tests of carbon treatment, chemical treatment, membrane separation, and ion exchange.

- **Structures:**
  - Design and conduct treatability studies of chemical extraction and decontamination.
  - Design and conduct bench-scale tests of shredding.

- **Additional Information:**
  - More fully characterize the current 25 radiation sites.
  - Two technologies that are currently in practice that are not included in this report are incineration and melting. Incineration is especially promising

for the treatment of mixed waste (i.e., incineration of radioactive and organic waste in soil). Follow up studies of this type should include analyses of these two technologies.

- **Technology Transfer:**
  - Support collection and transfer of information on remediation technologies.
- **Protocols:**
  - Develop protocols for treatability studies.
- **Input From Regions:**
  - Regions are encouraged to identify their needs for treatability studies at radiation sites.

Table S-1 Definitions of Contaminants and Matrices Found at the 25 NPL Radiation Sites.

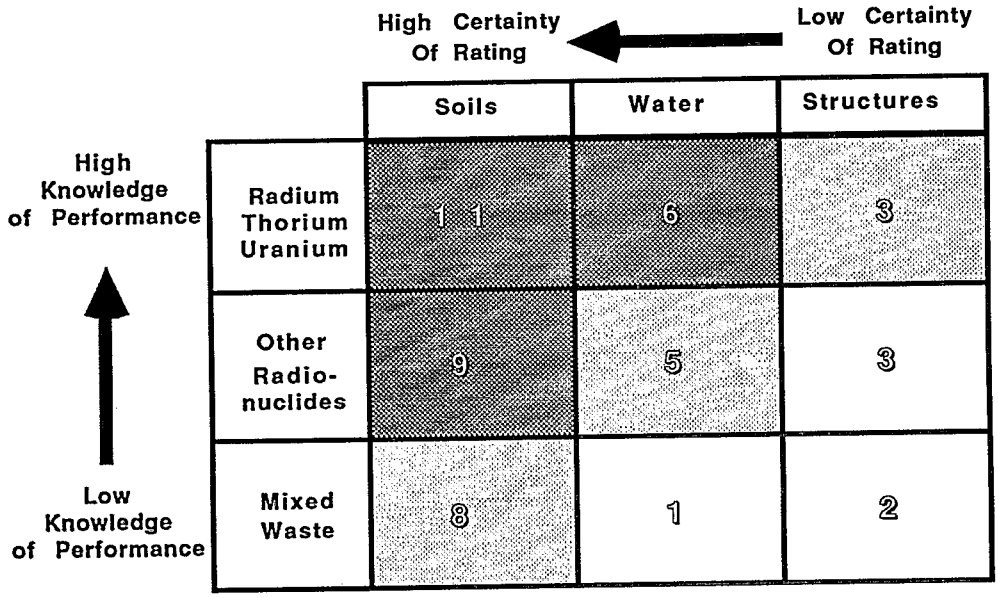
SITES	DEFINITIONS
Ra, Th, U	Sites that contain radium (Ra), thorium (Th), uranium (U) - either individually or in combination. No other radioactive materials are present, although nonradioactive metals may be present.
Other Radionuclides	Sites that contain other radioactive materials (e.g., plutonium). Ra, Th, and/or U and nonradioactive metals may also be present.
Mixed Waste	Radioactive waste (e.g., Ra, Th, U) that also contains RCRA* hazardous chemical waste. Nonradioactive metals may be present.
Soil	May contain soil tailings, silt, sand, gravel, sludges, sediments, clay, fill, or ash.
Water	Any body of fluid at a site, including ground water and surface water (i.e., lakes, streams, ponds, lagoons, rivers, and pools).
Structures	Physical structures on a site, such as buildings of any kind, equipment, and any constructed devices or building materials.

* Resource Conservation and Recovery Act (RCRA) waste listed in 40 CFR Part 261.

Table S- 2 Number of Sites in Each Contaminant / Matrix Group (Total NPL Sites = 25)

	SOILS	WATER	STRUCTURES
Radium Thorium Uranium	23	20	8
Other Radio-nuclides	6	5	2
Mixed Waste	11	12	3

Table S-3 Number of Promising* Technologies



* Promising = Performance Score of 7-10 (See Tables 6, 7 and 8).

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1. INTRODUCTION

1.1 PURPOSE

An Environmental Protection Agency (EPA) task group was formed at the request of the Director of the Office of Emergency and Remedial Response to assess the need for development of technologies for cleanup of radioactively contaminated Superfund sites. This assessment was necessary to ensure an adequate range of alternatives from which to select a remedy for these sites. This report provides an overview of existing remediation technologies as a starting point for further discussions on the need for developing these and other technologies. Inter- and intra-agency discussions will ensure that demonstration and research efforts will be coordinated and efficient.

1.2 SUPERFUND NEEDS FOR REMEDIAL EVALUATION

Under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), remedial action at Superfund sites must protect human health and the environment and meet applicable or relevant and appropriate requirements (ARARs) as established by Federal and State standards. CERCLA also requires the selection of cost-effective remedies that use permanent solutions and treatment technologies or resource recovery technologies to the maximum extent practicable. Preference is given for the selection of remedies that use treatment methods which permanently and significantly reduce the mobility, toxicity, or volume of hazardous substances.

EPA has developed an approach for selecting remedies at Superfund sites that is based on the balancing of specific criteria. Protective alternatives that achieve ARARs are evaluated on their relative long-and short-term effectiveness; implementability; reduction of toxicity, mobility, and volume of contaminants; and cost. In implementing this approach, EPA encourages a bias for initiating response actions necessary or appropriate to eliminate, reduce, or control hazards posed by a site as early as possible. Unfortunately, many remediation alternatives may be rejected, either because of the high implementation cost or because of the lack of development. There is, therefore, an increasing need to develop efficient data collection strategies and a broader range of technological alternatives.

1.3 EPA RESPONSIBILITY FOR RADIATION SITES

EPA has the authority to require cleanup of most releases of radioactive materials from private and federal sites. However, several categories of sites with radioactive releases are excluded by statute or as a matter of policy from cleanup under CERCLA:

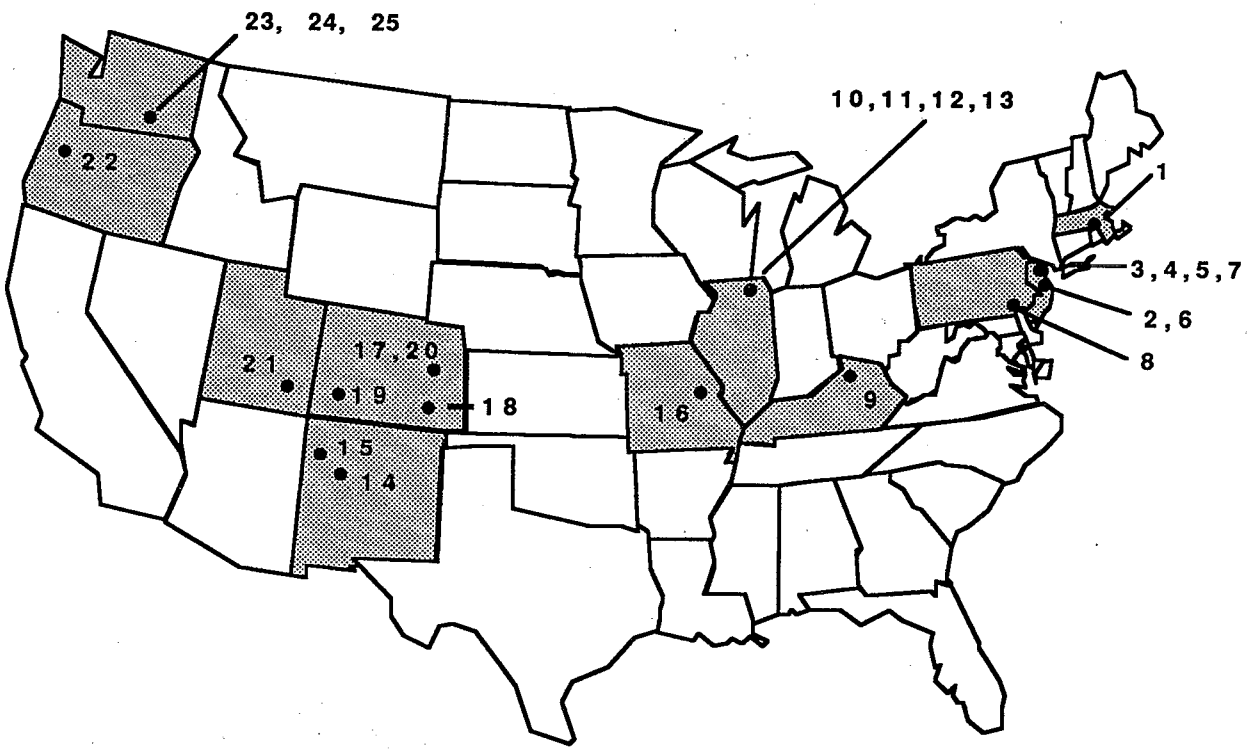
* Sites designated under the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA), and sites subject to Nuclear Regulatory Commission (NRC) financial protection requirements where there has been a "nuclear incident" are excluded from the National Priorities List (NPL) by statute.

* As a matter of policy, EPA has chosen not to list on the NPL releases from any facility with a current license issued by the NRC. However, this policy does not apply to formerly licensed NRC facilities or facilities with a license issued by a State pursuant to a delegation of authority from the NRC.

In some cases, the Federal agencies responsible for remediation of these sites may choose to follow certain parts of the CERCLA process, even though they are not required to do so.

There are 25 sites with radioactive substances currently listed or proposed for listing on the NPL (Figure 1 and Appendix B). Additional radiation sites may be proposed in future updates. As of December 1988, remedial investigations and feasibility studies (RI/FS) are underway at approximately 15 of the 25 sites. However, none of these sites has been completely remediated. In general, the majority of NPL radiation sites contain only low-level radioactive wastes (LLW), consisting primarily of soils contaminated with uranium (U), thorium (Th), and/or radium (Ra). However, a few sites (e.g., Hanford 100, 200, and 300-Areas) are known to contain high-level radioactive wastes (HLW). Twelve of the 25 NPL sites also contain mixed wastes--i.e., radioactive wastes commingled with Resource Conservation and Recovery Act (RCRA) hazardous chemical wastes.

Figure 1. Locations of the 25 radioactively contaminated Superfund sites



	Site Name	Site Location	
1	Schpack Landfill	Norton/Attleboro	MA
2	Maywood Chemical Co.	Maywood/Roch. Pk	NJ
3	U.S. Radium Corporation	Orange	NJ
4	W.R. Grace & Co. Inc. (USDOE)	Wayne Township	NJ
5	Glen Ridge Radium Site	Glen Ridge	NJ
6	Lodi Municipal Well	Lodi	NJ*
7	Montclair Radium Site	Montclair/W. Orge.	NJ
8	Lansdowne Radiation Site	Lansdowne	PA
9	Maxey Flats Nuclear Dispos.	Hillsboro	KY
10	Kerr-McGee (Kress Creek)	DuPage County	IL*
11	Kerr-McGee (Reed Keppler)	West Chicago	IL*
12	Kerr-McGee (Residential)	W. Chicago/DuPage	IL*
13	Kerr-McGee (Sewage)	West Chicago	IL*
14	Homestake Mining Company	Milan	NM
15	United Nuclear Corporation	Church Rock	NM
16	Weldon Spring Quarry (USDOE)	St. Charl. Co.	MO
17	Denver Radium Site	Denver	CO
18	Lincoln Park	Canon City	CO
19	Uravan Uranium	Uravan	CO
20	Rocky Flats Plant (USDOE)	Golden	CO*
21	Monticello Rad. Con. Props.	Monticello	UT
22	Teledyne Wah Chang	Albany	OR
23	Hanford 200-Area (USDOE)	Benton Co.	WA*
24	Hanford 300-Area (USDOE)	Benton Co.	WA*
25	Hanford 100-Area (USDOE)	Benton Co.	WA*

* Proposed: not final as of June 1988

1.4 APPROACH

Three tasks were developed in order to assess technology needs: (1) categorize the Superfund radiation sites; (2) match and evaluate technologies; and (3) identify technology gaps. Figure 2 shows a schematic of the basic methodology established to complete these objectives. Specific considerations are addressed in the following subgroups.

1.4.1 Study Objectives and Data Quality

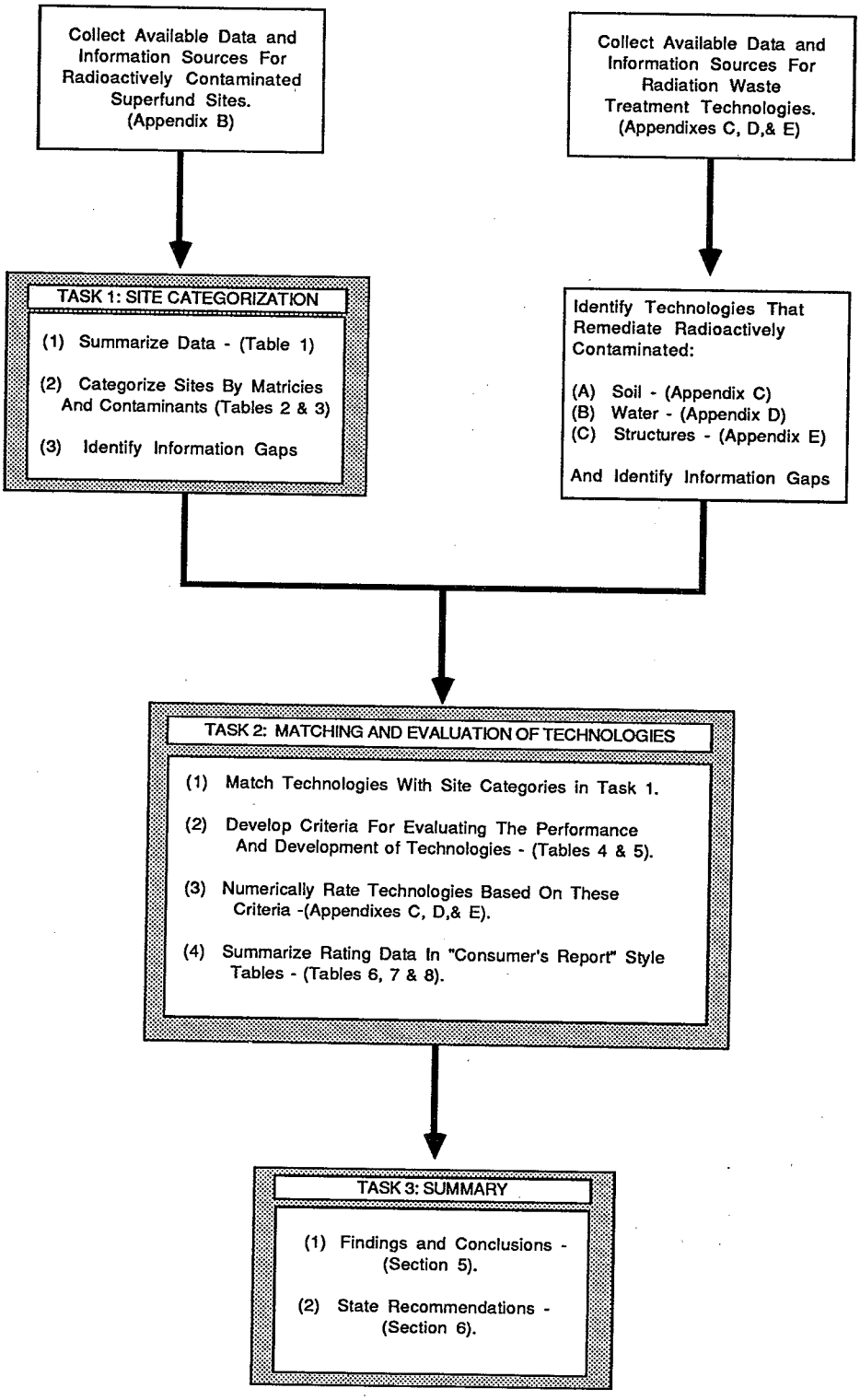
This study was undertaken to compile and assess readily available information that could aid the cleanup of contamination at Superfund sites and the prioritization of potential technological projects in support of the Superfund program.

The mutually agreed upon objective was a timely report reflecting general consensus within the Agency on available technologies and prioritization of technology needs rather than a comprehensive and detailed analysis that would require a lengthy production time. This report has been designed as a first step. It is a screening study that will be used to determine the degree and direction of additional analyses designed to guide and support the prioritization of technological needs.

Technologies were evaluated for capability in treating the identified site problems based on criteria developed for this project. The prioritization employed performance and development criteria intended as general screening factors. The performance of technologies was evaluated by a scoring system using criteria developed for reliability and effectiveness. The development of technologies was evaluated by a scoring system based on stage of development and available information.

Following the publication of an "Interim Final Draft" of this report in December 1988, a search was conducted of relevant reference material from EPA program offices and support contractors including the Office of Radiation Programs (ORP), Risk Reduction Engineering Laboratory (RREL), Eastern Environmental Radiation Facility (EERF), and

Figure 2. Methodology used to assess technologies for the remediation of radioactively contaminated Superfund sites.



Office of Research and Development (ORD). In addition, reference material was obtained from Brookhaven National Laboratory, Oak Ridge National Laboratory, the EPA Library, and from various technical data searches.

The references that were found are included in this final draft of the report. Based on these references, each technology, as applied to each contaminant/matrix combination, was re-scored. Re-scoring was based on criteria shown in Tables 4 and 5, using engineering judgement. Few scores changed even one point from the scores in the interim final draft. The highest rating in each category was used for the results presented in this final draft.

The scoring process developed and used in this project serves well its intended use as a screening device, identifying gaps in information necessary for full evaluation and resulting in recommendations for research, development, and treatability studies.

1.4.2 Use of Treament Trains for Soil Remediation

It has become apparent during the remediation of most Superfund sites that more than one treatment or technology is needed to achieve the cleanup goals. This is also true for radiation sites, whether dealing with contaminated soils, water, or structures. For example, in the case of soil remediation, the technologies are quite varied; some concentrate the contaminants, others isolate them, and still others dilute or immobilize them. Technologies that clean some fraction of a contaminated soil, and in the process concentrate contaminants within the remaining fraction, can be used in series with other technologies to produce a large amount of cleaned soil and an immobilized small fraction of contaminated soil.

Chemical extraction, physical separation, and soil washing may require treatment of effluent streams to fully address the contamination. The other technologies can be used as a sole remediation approach.

Chemical extraction, physical separation, and soil washing can all be used as the primary or secondary technologies. Other technologies can be used as secondary technologies if only two stages of treatment are employed - or as tertiary technologies, if three stages of treatment are employed.

An example of a tertiary treatment concept is:

Primary Technology ...	Physical Separation
Secondary Technology ...	Chemical Extraction
Tertiary Technology ...	Vitrification.

Radon control is generally a single-stage technology, and not part of a treatment train.

2. CATEGORIZATION OF SUPERFUND RADIATION SITES (TASK 1)

2.1 PURPOSE

Categorization of the 25 radiation sites was accomplished as the first task in order to identify common factors, which might assist in the subsequent evaluation and matching of remediation technologies in Task 2.

2.2 METHODS

Information obtained from the site-specific data in Appendix B and summarized in Table 1 was used to categorize the sites. Several parameters and methodologies were considered in order to place sites into groups. The parameters selected for site categorization were:

- Contaminants detected at the site.
- Matrices in which the contaminants are found.

Each of the two broad categories were divided individually into three categories based on information about the radiation sites. Contaminants were divided into the categories: (1) Radium, Thorium, and Uranium; (2) Other Radionuclides; and (3) Mixed Wastes. The matrices were divided into; (1) Soil; (2) Water; and (3) Structures. Air was not selected because it is very rarely a problem at radiation sites. Even though Radon is not a category, radon control technologies are evaluated in the soil and structures categories.

Other parameters that were considered and rejected included the concentrations, exposure pathways, and quantities of radioactive wastes. These were rejected because they did not directly affect the feasibility of using a particular treatment method.

TABLE 1 Summary of data on radioactively contaminated Superfund sites
(Refer to site data sheets in appendix B)

	SITE NUMBER*																									Total No.	Percent of Total Sites
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25		
Radium	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X				21	84
Thorium	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X		X		X	X				19	76
Uranium	X	X	X	X	X	X	X		X	X	X			X	X	X	X	X	X		X	X	X	X	X	21	84
Other Rad.								X	X											X			X	X	X	6	24
Heavy Metal	X	X		X						X	X	X	X	X	X	X		X	X		X	X	X	X	X	17	68
Chemical Waste	X	X				X			X						X	X			X	X		X	X	X	X	12	48
Soil	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	24	96
Water	X	X	X	X		X			X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	21	84
Structures			X	X				X	X						X	X	X				X					8	32
High > 100 pCi/g	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X				X	X				17	68
Low < 100 pCi/g				X		X																				2	8
Surface Water			X	X					X	X		X	X	X	X	X		X	X	X		X	X	X	X	16	64
Ground Water	X	X	X	X		X			X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	21	84
Air - Radon		X	X	X	X		X	X	X		X	X	X	X	X	X	X		X		X	X				17	68
External Gamma		X	X	X	X		X	X	X	X	X	X	X		X	X	X									14	56
Large >10^5 cu.yd.		X		X	X		X		X	X				X	X	X	X	X	X	X	X		X	X	X	17	68
Small <10^5 cu.yd.	X		X					X			X	X	X									X				7	28
NPL Final	X	X	X	X	X		X	X	X					X	X	X	X	X	X		X	X				16	64
NPL Proposed						X				X	X	X	X							X			X	X	X	9	36
Pre-RI/FS	X			X												X							X	X	X	6	24
RI/FS		X	X		X	X	X		X	X	X	X	X	X	X					X	X	X				15	60
RD/RA								X									X	X	X							4	16
Enforcement		X							X					X				X	X	X	X	X	X	X	X	11	44

	Site Name	Location	St
1	Schpack Landfill	Norton/Attleboro	MA
2	Maywood Chemical Co.	Maywood/Roch. Pk	NJ
3	U.S. Radium Corporation	Orange	NJ
4	W.R. Grace & Co. Inc. (USDOE)	Wayne Township	NJ
5	Glen Ridge Radium Site	Glen Ridge	NJ
6	Lodi Municipal Well	Lodi	NJ
7	Montclair Radium Site	Montclair/W. Orge.	NJ
8	Lansdowne Radiation Site	Lansdowne	PA
9	Maxey Flats Nuclear Dispos.	Hillsboro	KY
10	Kerr-McGee (Kress Creek)	DuPage County	IL
11	Kerr-McGee (Reed Keppler)	West Chicago	IL
12	Kerr-McGee (Residential)	W. Chicago/DuPage	IL
13	Kerr-McGee (Sewage)	West Chicago	IL
14	Homestake Mining Company	Milan	NM
15	United Nuclear Corporation	Church Rock	NM
16	Weldon Spring Quarry (USDOE)	St. Charl. Co.	MO
17	Denver Radium Site	Denver	CO
18	Lincoln Park	Canon City	CO
19	Uravan Uranium	Uravan	CO
20	Rocky Flats Plant (USDOE)	Golden	CO
21	Monticello Rad. Con. Props.	Monticello	UT
22	Teledyne Wah Chang	Albany	OR
23	Hanford 200-Area (USDOE)	Benton Co.	WA
24	Hanford 300-Area (USDOE)	Benton Co.	WA
25	Hanford 100-Area (USDOE)	Benton Co.	WA

2.3 RESULTS

The data presented in Table 1 were used to create the categorization schemes in Tables 2 and 3. In Table 2, sites are shown categorized by the matrices; i.e., soil, water, and structures, in which the radiation is associated. The sites are also broadly classified as to whether or not radioactive wastes are commingled with RCRA hazardous chemical waste (i.e., mixed waste). Waste categories may contain nonradioactive metals. Mutually exclusive categories of sites are presented in Table 3. These categories may change as additional site information is obtained or as additional sites are added to the NPL.

Table 2. Number of Sites in Each Contaminant / Matrix Group (Total NPL Sites = 25)

	SOILS		WATER		STRUCTURES	
	Site #s	No.	Site #s	No.	Site #s	No.
Radium Thorium Uranium	1,2,3,4,5,7, 8,9,10,11,12, 13,14,15,16, 17,18,19,21, 22,23,24,25	23	1,2,3,4,6,9, 10,11,12, 13,14,15,16, 17,18,19, 22 23,24,25	20	3,4,8,9,15, 16,17,21	8
Other Rad.	8,9,20,23, 24,25	6	9,20,23, 24,25	5	8,9	2
Mixed Waste	1,2,9,15, 16,19,20, 22,23,24, 25	11	1,2,6,9,15,16 19,20,22,23, 24,25	12	9,15,16	3

DEFINITIONS

Ra, Th, U Sites	Sites that contain Ra, Th, U - either individually or in combination. No other radioactive metals are present, although nonradioactive metals may be present.
Other Rad. Sites	Sites that contain other radioactive waste (e.g., plutonium). Ra, Th, and/or U may be present. Nonradioactive metals may be present.
Mixed Waste	Radioactive waste (e.g., Ra, Th, U) that also contains RCRA* hazardous chemical waste. Nonradioactive metals may be present.
Soil	May contain soil tailings, silt, sand, gravel, sludges, sediments, clay, fill or ash.
Water	Any body of fluid at a site, including lakes, streams, ponds, lagoons, rivers, and pools.
Structures	Physical structures on a site, such as buildings of any kind, equipment, and any constructed devices or building materials

* Resource Conservation and Recovery Act (RCRA) waste listed in 40 CFR Part 261.

TABLE 3. Mutually exclusive categories of the 25 NPL radiation sites

Site Categories	Definitions	Matrix 1 Soil	Matrix 2 Water	Matrix 3 Struct.	Contaminant 1 Ra, Th, U	Contaminant 2 Other Rad	Contaminant 3 Mixed	Site Numbers	Total No.
1	Sites with Radium (Ra), Thorium (Th), Uranium (U) Soil Contamination Only	X			X			5, 7	2
2	Sites with Ra, Th, U Soil and Water Contamination Only	X	X		X			10, 11, 12, 13, 14,18	6
3	Sites with Ra, Th, U Soil and Structure Contamination Only	X		X	X			8, 21	2
4	Sites with Ra, Th, U Soil, Water, and Structure Contamination	X	X	X	X			3, 4, 17	3
5	Mixed Waste with Ra, Th, U Water Contamination Only		X				X	6	1
6	Mixed Waste with Ra, Th, U Soil and Water Contamination Only	X	X				X	1, 2, 19, 22	4
7	Mixed Waste with Ra, Th, U Soil Water, and Structure Contamination Only	X	X	X			X	15, 16	2
8	Mixed Waste with Other Rad. Waste Soil + Water Contamination Only	X	X			X	X	20, 23, 24, 25	4
9	Mixed Waste With Ra, Th, U + Other Rad. Soil, Water, and Structure Contamination	X	X	X		X	X	9	1
								Total	25

Definitions

1. Mixed waste.... Radiological waste that also contains organic contaminants. Non-radiological metals also may be present.

2. Ra, Th, U Sites ... Sites that contain Ra, Th, U -- either individually or in combination. No other radiological metals are present. Nonradiological metals may be present.

3. Other Rad. Sites... Sites that contain other radiological waste (e.g. plutonium). Ra, Th, and/or U may be present. Nonradiological metals also may be present.

4. Soil... May contain soil tailings,silt,sand,fill gravel, sludges, sediments, clay, or ash.

5. Water... Any body of fluid at a site--including lakes, streams, ponds, lagoons, rivers, and pools.

6. Struct... Physical structures on a site, such as buildings of any kind, equipment, and any constructed devices or building materials.

3. EVALUATION OF REMEDIATION TECHNOLOGIES (Task 2)

3.1 PURPOSE

A primary objective of this project was to identify information and development needs for technologies, which might be used at the radiation sites categorized in Task 1. To accomplish this objective, the Task Group assembled three lists of current potential remediation technologies - one each for soil, water, and structures - and evaluated them based on performance and development rating criteria.

3.2 METHODS

Remediation technologies were evaluated numerically using two performance (Table 4) and two development (Table 5) criteria. These criteria were selected in order to be consistent with the mandates and preferences established under CERCLA. Two parameters define the performance rating: reliability and effectiveness. Reliability, defined in terms of the degree of certainty associated with the permanence of the remedy, is closely associated with the CERCLA requirement for permanent solutions. The proposed National Contingency Plan (NCP) breaks out effectiveness into long-term effectiveness and short-term effectiveness. Long-term effectiveness, reliability over time, and permanence are closely related. Effectiveness, for the purpose of this effort, focuses on the effectiveness of the technology to reduce the mobility, toxicity of the waste, and has been defined in terms of the degree to which the technology achieves this goal.

Rating numbers from one to five were assigned to each criterion, where one represented the lowest and five the highest rating. Technologies listed in Tables C-5, D-5, and E-5 were scored based on the criteria in Tables 4 and 5. All four criteria were weighted equally.

TABLE 4 PERFORMANCE CRITERIA

(1) Reliability

Reliability of the treatment process over the long term was evaluated. A rating of 5 was considered to reflect high reliability for permanence of the remedy. The specific criteria are as follows:

Rating	Criteria
5	Highly certain to be reliable for > 1000 years.
4	Highly certain to be reliable for 100 - 1000 years.
3	Highly certain to be reliable for 30 - 100 years.
2	Highly certain to be reliable for approx. 30 years.
1	Likely to be reliable for < 30 years.

(2) Effectiveness

How well the technology reduces the toxicity, mobility, or volume of the waste. A rating of 5 indicates the technology fully achieves its design objectives. The criteria are as follows:

Rating	Criteria
5	Essentially eliminates toxicity, mobility or volume.
4	Significantly reduces toxicity, mobility or volume.
3	Moderately reduces toxicity, mobility or volume.
2	Minimum reduction of toxicity, mobility or volume.
1	No reduction of toxicity, mobility or volume.

TABLE 5 DEVELOPMENT CRITERIA

(1) Stage of Research and Development (R&D): Defines the status of the technology by the degree of testing. Technologies that have been used at a Superfund site for cleanup were given the highest ranking (5). The specific criteria are as follows.

Rating	Criteria
5	Remediation of one or more radioactively contaminated waste sites have been documented.
4	One or more demonstrations with radiation waste have been documented.
3	One or more pilot plant tests with radiation waste have been documented.
2	One or more bench-scale tests with radiation waste have been documented.
1	The technology has not been tested on radioactively contaminated waste.

(2) Available Information: Defines the degree of information that is available. If well-documented information is available, the technology was rated 5.

Rating	Criteria
5	Information based on a well-coordinated research program. Peer-reviewed field demonstration reports. Peer-reviewed research reports containing quantitative performance data. Investigation of radioactively contaminated waste.
4	No coordinated research program in place. Peer-reviewed field demonstration reports. Peer-reviewed research reports containing quantitative performance data. Investigation of radioactively contaminated waste.
3	No coordinated research program in place. No peer-reviewed field demonstration reports. Peer-reviewed reports. Investigation of radioactively contaminated waste.
2	No coordinated research program in place. No field demonstration reports. No peer-reviewed reports. Investigation of radioactively contaminated waste.
1	No coordinated research program in place. No field demonstration reports. No peer-reviewed research reports. Investigation of nonradioactively contaminated waste.

3.3 RESULTS

Totaled numerical rating data on performance and development along with references for all the applicable technology options are shown in Tables C-2 to C-4 (Appendix C) for contaminated soils, in Tables D-2 to D-4 (Appendix D) for contaminated water, and in Tables E-2 to E-4 (Appendix E) for contaminated structures.

4. IDENTIFICATION OF INFORMATION GAPS (Task 3)

4.1 PURPOSE

The third phase of this project was to identify information gaps and needs for the assessment of technologies that may be evaluated as feasible alternatives for Superfund radiation site remediation.

4.2 AVAILABILITY OF INFORMATION

The primary source of site information was pre-remedial investigation studies undertaken to determine NPL qualification. Site information is therefore incomplete, and characterizations derived from it are not sufficiently detailed for making site-specific decisions on the applicability of the technologies discussed in this report.

The sources of technology information varied greatly by matrix category. EPA reports and other published documents provided information on soil, water, and structural remediation technologies. The references are listed at the end of Appendixes C, D, and E, and serve as a basis for rating technologies applicable to soil, water, and structures, respectively.

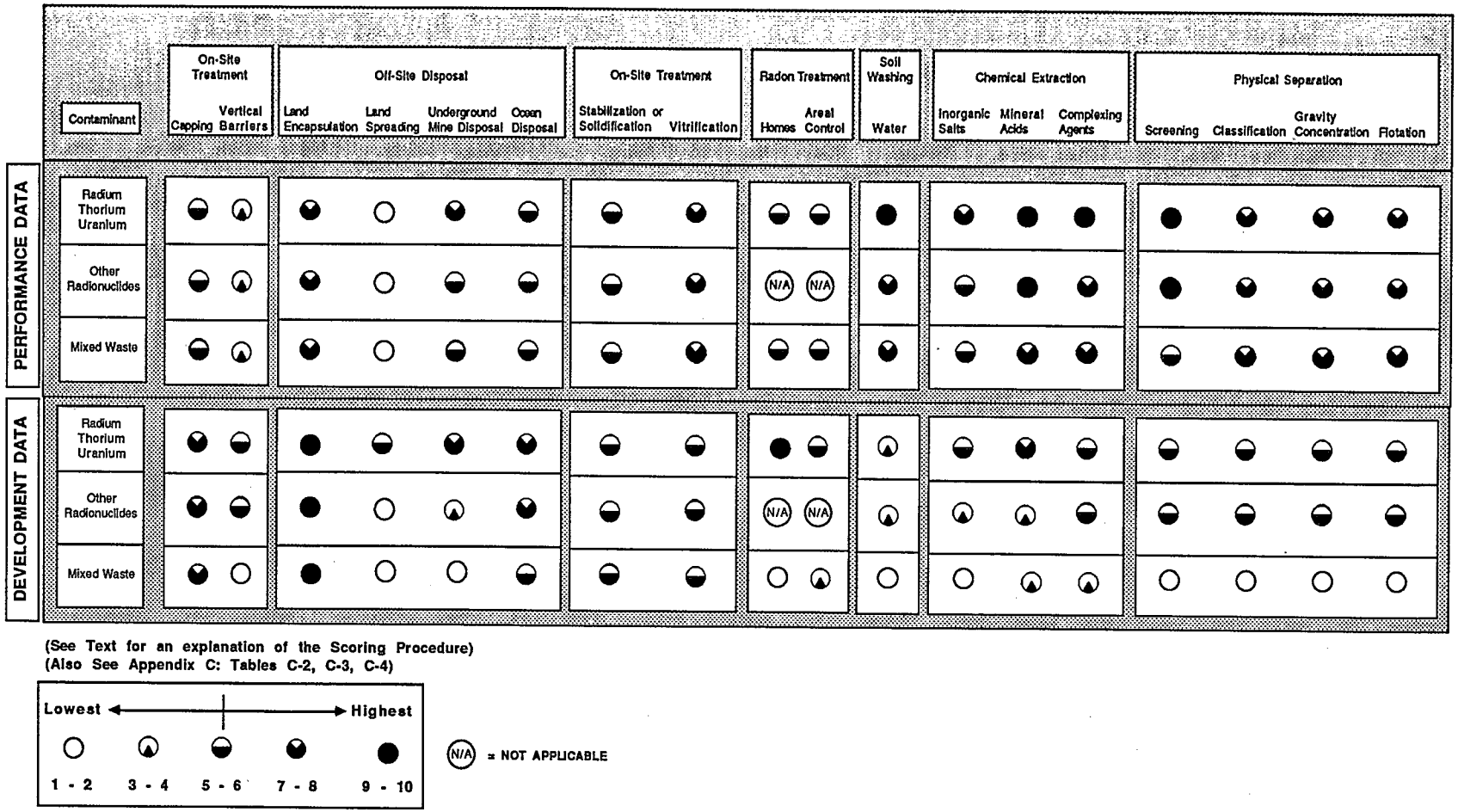
4.3 REMEDIATION TECHNOLOGIES

The nine sets of scoring data (Tables C-2, C-3, C-4, D-2, D-3, D-4, E-2, E-3, E-4) were used to construct the summary data in Tables 6 to 8. A high score on Performance indicates a high potential for use in remediation, and a high score for Development indicates that a technology has been well tested and documented on radiation applications. Conversely, low scores for Performance and Development indicate that a technology is either not applicable for remediation or that further information based on testing is necessary before a final decision on its applicability can be made.

TABLE 6. Potential for use of treatment technologies at NPL radiation sites

for

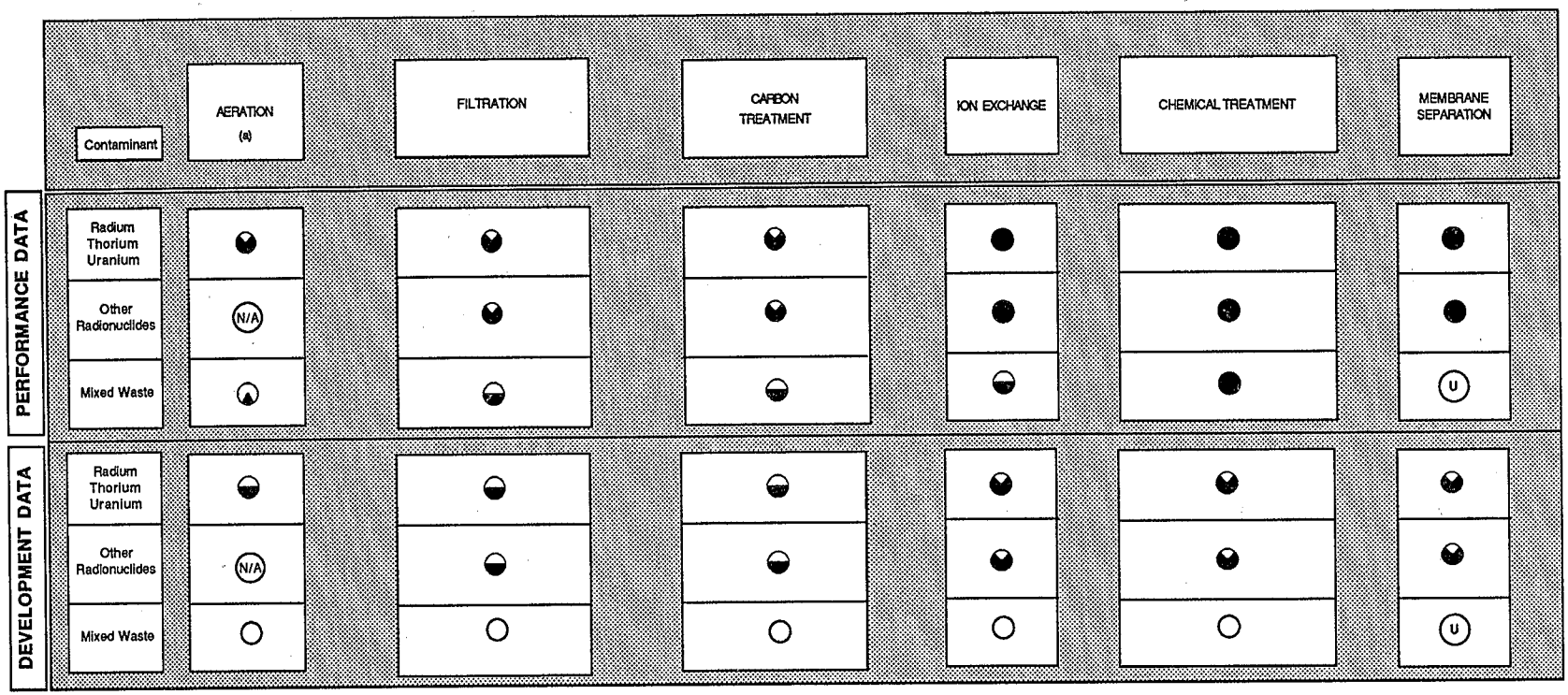
CONTAMINATED SOILS



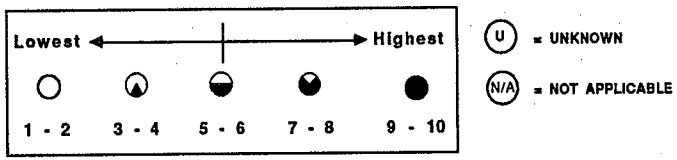
(See Text for an explanation of the Scoring Procedure)
(Also See Appendix C: Tables C-2, C-3, C-4)

N/A = NOT APPLICABLE

TABLE 7. Potential for use of treatment technologies at NPL radiation sites for CONTAMINATED WATER

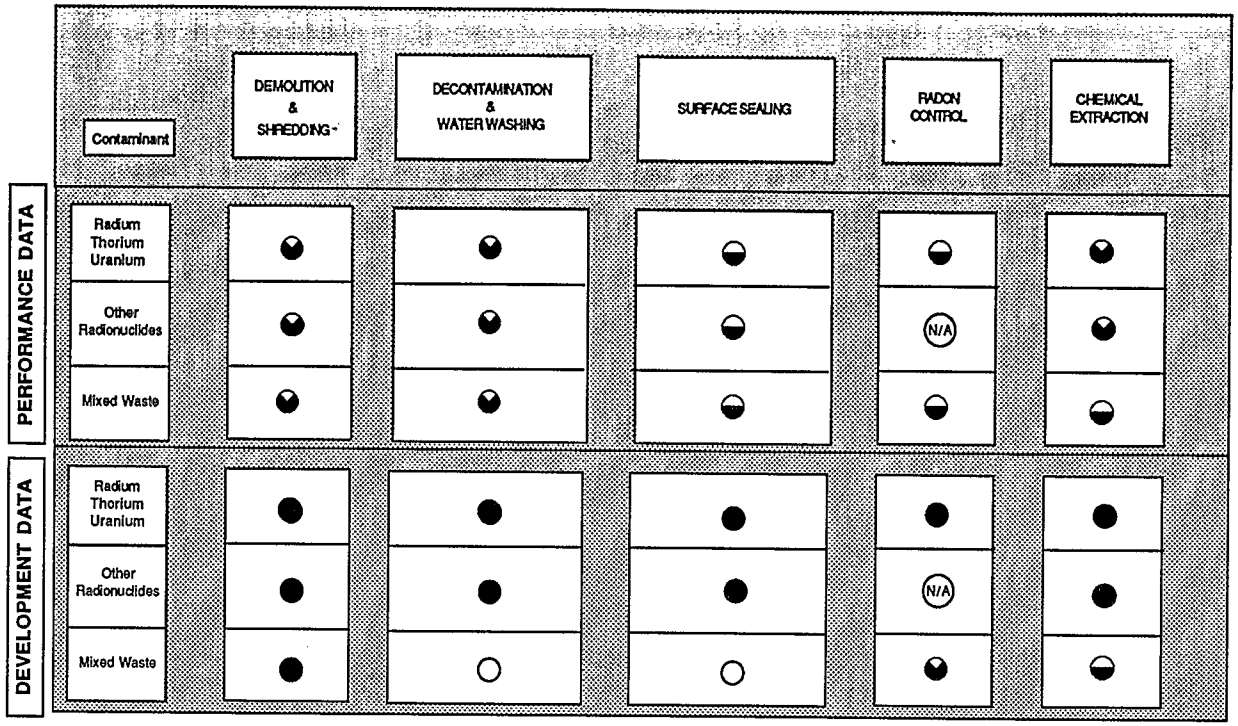


(See Text for an explanation of the Scoring Procedure)
(Also See Appendix D: Tables D-2, D-3, D-4)

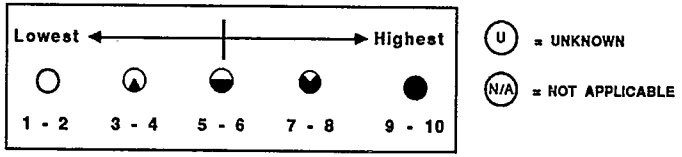


(a) Applicable only for radon remediation

TABLE 8 . Potential for use of technologies at NPL radiation sites for CONTAMINATED STRUCTURES



(See Text for an explanation of the Scoring Procedure)
(Also See Appendix E: Tables E-2, E-3, E-4)



5. FINDINGS AND CONCLUSIONS

The major findings and conclusions of this report are as follows:

5.1 SITE CHARACTERIZATION

- There are currently 25 sites with radioactive contamination listed (16) on the NPL or proposed for listing (9).

- 15 of the 25 NPL sites have RI/FS studies underway; to date, no site has been remediated completely (Tables 1, 2 and 9).

- There is a lack of contaminant/matrix information on the 25 NPL radiation sites. This is probably due to the early stage of remedial development for these sites; i.e. either no remedial actions have been started or RI/FS studies have not been completed.

- In evaluating technology development needs, it was necessary to assess technologies based on their use on individual site problems. These problems were characterized as contaminant/matrix categories. The category with the largest number of NPL sites is "Soil Contaminated with Radium, Thorium, and Uranium."

- In the time frame allotted for this project it was not possible to develop criteria that reflect all possible considerations necessary for assessing technology for site remediation.

Table 9 Number of Sites in Each Contaminant / Matrix Group (Total NPL Sites = 25)

	SOILS	WATER	STRUCTURES
Radium Thorium Uranium	23	20	8
Other Rad.	6	5	2
Mixed Waste	11	12	3

DEFINITIONS

Ra, Th, U Sites	Sites that contain Ra, Th, U - either individually or in combination. No other radioactive metals are present, although nonradioactive metals may be present.
Other Rad. SItes	Sites that contain other radioactive waste (e.g., plutonium). Ra, Th, and/or U may be present. Nonradioactive metals may be present.
Mixed Waste	Radioactive waste (e.g., Ra, Th, U) that also contains RCRA* hazardous chemical waste. Nonradioactive metals may be present.
Soil	May contain soil tailings, silt, sand, gravel, sludges, sediments, clay, fill or ash.
Water	Any body of fluid at a site, including lakes, streams, ponds, lagoons, rivers, and pools.
Structures	Physical structures on a site, such as buildings of any kind, equipment, and any constructed devices or building materials

* Resource Conservation and Recovery Act (RCRA) waste listed in 40 CFR Part 261.

5.2 TECHNOLOGY ASSESSMENT AND INFORMATION GAPS

- In order to assess technologies for use at NPL radiation sites, it was necessary to develop concise, reproducible performance criteria. Several criteria were considered. Those which reflected CERCLA requirements; i.e., (1) "long term effectiveness", and (2) the capability to reduce or eliminate, as nearly as possible, the "toxicity, mobility, or volume" of waste, were chosen.

- Twenty-nine technologies were evaluated (Tables 6, 7, 8, and 10*). Ten technologies have not been used thus far, nor developed in spite of their potential for success in reducing site problems. Those technologies are vitrification, soil washing, salt extraction, acid extraction, complexation, physical screening, classification, gravity concentration, solidification, and flotation.

- Four technologies have high performance scores and are already in use at nonradiation NPL sites. Those technologies are ion exchange, carbon treatment, chemical treatment (includes precipitation and flocculation) and land encapsulation.

- Several technologies were found to have high performance scores and low development scores. Soil washing, chemical extraction (with inorganic salts, mineral acids, and

---

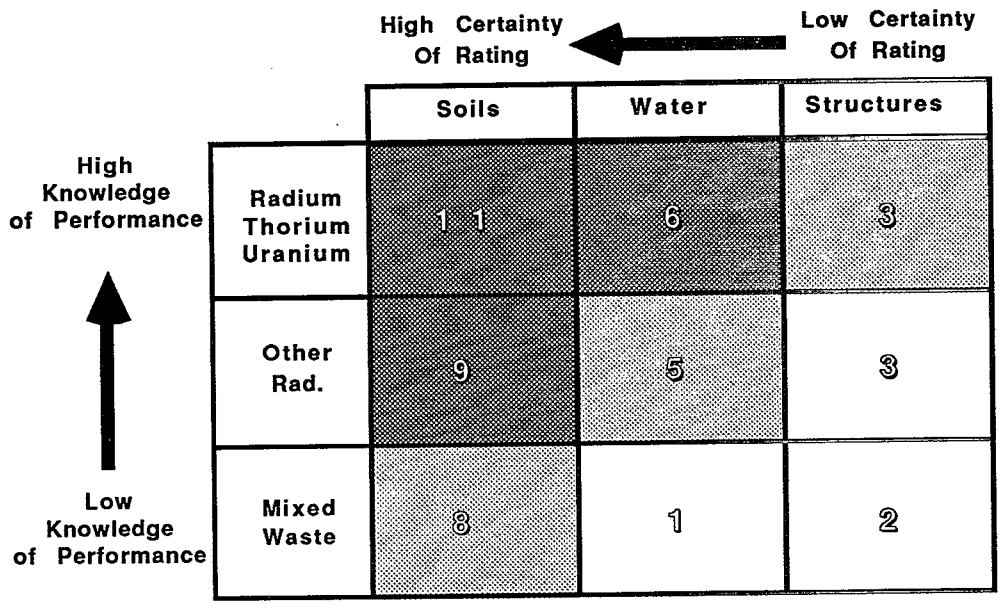
* Table 10 summarizes the data developed in this report on rating the performance remediation technologies. Promissing technologies are defined as those which scored 7 to 10 on the performance criteria (Tables 4, 6, 7 and 8). The arrow on the left indicates the relative amount of knowledge about the performance of a technology: As indicated, there is little knowledge about the performance of technologies which address mixed wastes, and the most amount of knowledge concerning the performance of technologies which treat Ra, Th, and U. The arrow at the top indicates the level of certainty about the ratings (based on the collective judgement of the Task Group): The least amount of certainty is associated with the ratings for contaminated structure remediation technologies, and the highest certainty is associated with the ratings for technologies which cleanup radioactively contaminated soils.

complexing agents), physical separation (including screening, classification, gravity concentration, flotation), solidification and vitrification all fell into this category. Also included was shredding, as a pretreatment technology.

- Some technologies had low or medium performance scores and high development scores. An example is capping of U, Th, and Ra contaminated soils.

- There are few technologies available for evaluation or assessment for use on mixed waste sites.

Table 10 Number of Promising* Technologies



* Promising = Performance Score of 7-10 (See Tables 6, 7 and 8).

DEFINITIONS

Ra, Th, U Sites	Sites that contain Ra, Th, U - either individually or in combination. No other radioactive metals are present, although nonradioactive metals may be present.
Other Rad. SItes	Sites that contain other radioactive waste (e.g., plutonium). Ra, Th, and/or U may be present. Nonradioactive metals may be present.
Mixed Waste	Radioactive waste (e.g., Ra, Th, U) that also contains RCRA* hazardous chemical waste. Nonradioactive metals may be present.
Soil	May contain soil tailings, silt, sand, gravel, sludges, sediments, clay, fill or ash.
Water	Any body of fluid at a site, including lakes, streams, ponds, lagoons, rivers, and pools.
Structures	Physical structures on a site, such as buildings of any kind, equipment, and any constructed devices or building materials

* Resource Conservation and Recovery Act (RCRA) waste listed in 40 CFR Part 261.

6. RECOMMENDATIONS

Based on the findings and conclusions in this report, the following research, development, and treatability activities are recommended.

Soils: Because of the prevalence of contaminated soils and the lack of technologies suitable for their cleanup, the following approach is recommended:

1. Since current soil washing and chemical extraction studies are providing data that indicate a strong potential for field implementation, work on these techniques should continue. High priority should be given to:

   a. Design and performance of treatability studies on soils from other sites that have Ra, Th, and U contamination. This is the most common type of contamination and several sites can readily be selected.

   b. Design and performance of treatability studies on mixed waste. There are substantial quantities of mixed waste soils that will require treatment, however the information base to support such work is limited.

2. Following a review of the literature and other valuable information sources (e.g., DOE, private sector, and international), begin treatability/field testing (pilot and, when appropriate, demonstration) of the following technologies:

   a. physical separation
   b. chemical extraction
   c. vitrification
   d. land encapsulation
   e. solidification
   f. mine disposal

3. Continue to encourage the development and offering of technologies for demonstration in remediation of these sites.

Water: Development of water treatment technologies is important because more than 80 per cent (See Tables 1 and 9) of the current NPL radioactive sites have water contamination, and because promising technologies (i.e., soil washing, physical separation, and chemical extraction) for remediation of contaminated soils will have treatment trains containing contaminated water. The following recommended tasks are listed in order of priority:

1. Conduct technology feasibility and treatability work on removing Ra, Th, and U from water. This work should include:

    a. Field testing of high performance technologies for remediation of Ra and U from contaminated water sites.

    b. Treatability studies at a site that has thorium contaminated water, since information on thorium is limited.

2. Conduct treatability studies on water contaminated with mixed waste. This is one of the most difficult and least studied problem areas. The following technologies are expected to require both bench and pilot scale testing:

    a. carbon treatment
    b. chemical treatment
    c. membrane separation
    d. ion exchange

Structures: Very little information is available on the remediation of structures contaminated with low-level radioactive wastes. The following technical approaches are promising:

1. Design and conduct treatability studies on chemical extraction and decontamination.

2. Design and conduct bench-scale tests of shredding.

Utility of additional information: Technology application is dependent upon the ability to characterize the technology and document its performance. Additional

information from literature evaluation, discussions with other agencies and other sources would increase our confidence in the technologies described in this report. Additional information should also include more detailed radiological assessments of the existing 25 radiation sites. Given that much of the work represented in this report is based on professional judgement and currently available data, adjustments in the prioritization may be appropriate as new information becomes available.

Technology transfer: Many of the information requirements of parties facing low-level radioactive waste cleanup actions are expected to be generic. Therefore, it is recommended that the appropriation and transfer of information on technologies used for the cleanup of low-level radioactive wastes be supported among different groups.

Protocols: Given that treatability studies are essential steps for developing and testing technologies for remediation of soil, water, and structures, protocols for their conduct should be developed. These protocols will aid in comparing results across different studies and constructing more efficient approaches to testing methods.

Input from regions: Regions are encouraged to identify their needs for treatability studies at radioactive sites.

Appendix A

Members of the OSWER, ORP AND ORD Technology Task Group

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Larry Zaragoza	OSWER / OPMT	245-3529
Jennifer Haley	OERR/ HSCD / SPGB	475-6705
Robert Dyer	ORP/ ASD /ESSB	475-9630
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APPENDIX B

*RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTIONS**

* Number of sites and information are current as of December 1988.

Source of information definitions:
Fact Sheet - Prepared by region
EPA NPL Site Status Sheet - Issued by Superfund office based on region fact sheet
Site Status Report From EPA Region - Radioactive Superfund site questionnaire sent to regions

B - 1 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

Shpack Landfill
Norton/Attleboro, Massachusetts

EPA Contact Region I:

David Lederer, FTS 573-9662

Summary of Site Use

Private landfill since 1940s shows radium and uranium as well as other contaminants.

Other Manufacturing/Industrial; Landfill, Chemical Process/Manuf.; Landfill Municipal

Status:

NPL	Rank	Score	Lead	Status
Final	672	29.45	Fund	Pre-RI/FS

Final site response assessment report, 11/21/85, prepared by NUS Corp. for performance of remedial activities. Monitoring program included water samples from 10 observation wells and soil samples analyzed for priority pollutants and gross alpha, beta, and gamma radioactivity.

No Remedial Investigation/Feasibility Study (RI/FS) available yet.

Radiation Data:

Ra-226, U-238, U-238, U-234 above natural background levels but uneven distribution in surface and subsurface soil. K-40, Th-228, Th-230 present.

Rn-222 240 pCi/L ground water.

Measured values in soil (pCi/g):

Ra-226	1,571
U-238	16,460
U-235	200
U-234	4,200

Matrix Characteristics:

Wetland or swamp area; sand, gravel, silt, and clay, organic deposits. Nonradioactive contaminants: 1,2-dichloroethylene, trichloroethylene, tetrachloroethylene, chromium, cadmium, nickel.

Source:

Unknown, possibly manufacture of luminescent dials and former operation of nuclear submarine contractor.

Approximate Area and Volume:

Shpack about 8 acres; Attleboro about 2.5 acres; 100 tons.

Environmental Impact:

About 35 private wells within 3-mile radius of the site serve approximately 130 people. The nearest well, located 150 feet away, is shallow. EPA is currently conducting additional monitoring on- and off-site to further characterize the site. ORNL 1982 survey revealed no migration of radionuclides into ground water; no hydraulic gradient (vertical or horizontal) in underlying aquifers. However, U.S. DOE survey found radium and uranium in soil (1984) with radioactive and organic contaminants extending to ground water in many cases. Rn-222 at 328 pCi/L in ground water in 1980 study by private consultant considered suspect. Airborne radionuclide contamination no apparent threat to public. Based on existing data as of 11/85, no indication of immediate public health threat.

Source of Information:

Final Site Response Assessment Report D583-1-5-22, Revision 2; prepared by NUS Corp., 11/21/85

B-2 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

Maywood Chemical Company
(Sears Property)
Maywood, Rochelle Park, New Jersey

EPA Contact Region II:

Pat Evangelista, FTS 264-6311

Summary of Site Use

Thorium wastes from production of mantles for gas lamps in the 1920s in 3 fill areas in residential/ commercial area.

Other Manufacturing/ Industrial Surface Impoundment Landfill, Comm./Indus.

Status:

NPL	Rank	Score	Lead	Status
Final	157	51.19	Enforcement	RI/FS

Site was identified under FUSRAP, and DOE was designated to perform remedial action related to radioactive residues. Residential properties in Maywood, Rochelle Park, and parts of Lodi, NJ were remediated. Soil from old disposal areas was removed. Temporary storage facility called the Maywood Interim Storage Site (MISS) developed. DOE conducting continuous monitoring at MISS and detailed characterizations of properties related to the Maywood site.

Radiation Data:

Elevated gamma radiation;

Ground water:
gross alpha 18.4 pCi/L.
Rn-222 0.9-300 pCi/L

Surface soil:
Th-232 70 pCi/g
Ra-226 10 pCi/g
U-238 77 pCi/g

Subsurface soil
Th-232 180 pCi/g
Ra-226 37 pCi/g
U-238 <232 pCi/g

Stream sediment
Th-232 93 pCi/g
Ra-226 9 pCi/g
U-238 <57 pCi/g

Matrix Characteristics:

Tailings, soil, clay-like tailings; used as fill material in several residential and commercial properties; stream sediment; water; air. Nonradioactive contaminants in soil and tailings: arsenic, chromium, nickel, lead, cadmium, beryllium, pesticides, methyl chloride, xylene, toluene, ethyl benzene, acetone, MEK.

Source:

Maywood Chemical Works; extraction of thorium.

Approximate Area and Volume:

42 acres (entire location), area of contamination not known; 270,000 cu yd.

Environmental Impact:

36,000 residents within 4-mi radius. Radon gas found by NRC at levels higher than background in one residence. Elevated gamma radiation levels on adjacent properties.

Source of Information:

"Characterization Report for Sears Property, Maywood, New Jersey," DOE/OR/20722.140, oak Ridge National Laboratory, 5/87. "Engineering Evaluation of Disposal Alternatives for Radioactive Waste from Remedial Actions in and around Maywood, New Jersey, DOE/OR/20722-79, Oak Ridge National Laboratory, 3/86.

EPA NPL Site Status Sheet

B - 3 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

U.S. Radium Corporation
Orange, New Jersey

EPA Contact Region II:

Raimo Liias, FTS 264-8099

Summary of Site Use:

Radium ore was processed from 1915 to 1926 and wastes were disposed of on site.

Ore Process/Refining/Smelter, Waste Piles

Status:

NPL	Rank	Score	Lead	Status
Final	423	37.79	Fund	RI/FS

Limited site characterization done at U.S. Radium and satellite properties by EPA and NJDEP. Final work plan for RI/FS prepared in 7/87. RI/FS to begin in Fall 1989.

Radiation Data:

New Jersey Department of Environmental Protection (NJDEP) has found radon and decay products in air in elevated concentrations and gamma radiation levels around property significantly above background levels. U-238, U-234, Th-230 and Ra-226 present in soil and concrete and Rn-222 in air.

Surface Soil:

Ra-226 3.2-670 pCi/g: U-238 minor

Subsurface Soil (2-4.5 ft):

Ra -226 2,090-3,290 pCi/g
U - 238 90-12000 pCi/g

Matrix Characteristics:

Building materials, grounds, soil, surface, and ground water.

Source:

Former radium ore processing plant, lab and manufacturing facility, and radium cottage industry.

Approximate Area and Volume:

One acre; estimated 10,000 cu yd (~1,600 tons of processed ore waste was dumped on site).

Environmental Impact:

32,000 residents within 1/2-mi radius. NJDEP has found radon and decay products in air in excessive concentrations; gamma radiation levels around property greater than normal. Satellite properties where radium dial painting and lab work done may also be contaminated.

Source of Information:

EPA NPL Site status sheet. EPA Office of Radiation Programs. "Final Work Plan for Remedial Investigation and Feasibility Study, U.S. Radium Corporation-site, City of Orange, Essex County, New Jersey," Camp Dresser & McKee Inc., for U.S. EPA April 1987.

B - 4 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

W. R. Grace/Wayne Interim (U.S. DOE)
Storage Site (WISS)
Wayne, New Jersey

EPA Contact Region II:

Kay Stone, FTS 264-4595

Summary of Site Use:

Extracted thorium and rare earth elements from 1948 to 1971. Released for unrestricted use by the NRC in 1975. Now runoff of contaminated soil is the concern.

Ore Process/Refining/Smelter, Landfill, Com./Indus.

Status:

NPL	Rank	Score	Lead	Status
Final	214	47.14	Fund	Pre-RI/FS

Site was partially remediated in 1986 by DOE/FUSRAP. Various vicinity properties, including Sheffield Brook, have been remediated since 1986, with radioactively contaminated soils removed from the properties and placed in a secured storage pile at the WISS. Temporary storage of thorium tailings, the source of the contamination, will be at the WISS, awaiting a permanent disposal site in New Jersey. RI/FS scheduled to begin in FY 1990.

Radiation Data:

Gamma Exposure Levels: 45 mR/hr (max) above background: Background Avg=61 mR/yr.

Soil Concentrations:

Total U	2.7 pCi/g
Th-232	3.8 pCi/g
Ra-226	5.1 pCi/g
Ra-228	6.9 pCi/g

Ground-water Concentrations:
(Highest Annual Avg. for 1987)

Ra-226	0.4 pCi/L
Ra-228	3.3 pCi/L
Total U	4.6 pCi/L
Th-232	0.3 pCi/L

Surface water Concentrations:
(Highest Annual Avg. for 1987)

Ra-226	0.2 pCi/L
Ra-228	2.0 pCi/L
Total U	3.4 pCi/L
Th-232	<0.2 pCi/L

Sediment Concentrations:
(Highest Annual Avg. for 1987)

Ra-226	0.8 pCi/g
Ra-228	3.2 pCi/g
Total U	1.5 pCi/g
Th-232	0.9 pCi/g

Radon Concentrations:
(Highest Annual Avg. for 1987)

Ra-222	1.3 pCi/L
Ra-220	0.7 pCi/L

Matrix Characteristics:

Sand and gravel; tailings from processing monazite ores; tailings buried on site; surface and ground water; air. Storage pile is covered and secured. Consists of thorium tailings and demolished radioactively contaminated buildings remediated from vicinity properties. Underlying ground is known to be contaminated by processing wastes.

Source:

Thorium ore (monazite) extraction plant on site.

Approximate Area and Volume:

6.5 acres; 49,000 cubic yards in storage pile; 70,000 cubic yards buried on site.

Environmental Impact:

51,000 residents within 3-mi radius. Surrounded by commercial properties to the southeast and southwest: residences to north and northeast. Large truck garden farm about 300 feet northwest of site. Railroad siding in Pequannock Township contains about 400 cubic yards of contaminated soil. This is awaiting establishment of a permanent disposal site. The potential for further contamination by runoff has been abated somewhat by work done to date at site.

Source of Information:

"Wayne Interim Storage Site Annual Site Environmental Report, Calendar Year 1985," DOE/OR/20722-103, Oak Ridge Operations Office. 8/86.

"Wayne Interim Storage Site Annual Site Environmental Report, Calendar Year 1987," published 4/88.

Site Status Report from EPA Region II; 10/88.

B - 5 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

Glen Ridge Radium Site
Essex County, New Jersey

(Also see Montclair/West Orange Radium Site #7)

EPA Contact Region II:

Raimo Liias, FTS 264-8099

Summary of Site Use:

Radium processing wastes from the 1920s was used for fill in residential areas.

Landfill, Comm./Indus.

Status:

NPL	Rank	Score	Lead	Status
Final	178	49.14	Fund	RI/FS

EPA released a draft Remedial Investigation and Feasibility Study (RI/FS) report in 9/85. Supplemental FS of interim and final alternatives was released 4/89. Record of decision (ROD) signed for portion of the site June 30, 1989. Supplemental ROD will be issued for the remainder of the site at a later date. New Jersey Department of Environmental Protection (NJDEP) began remediation of nine residential properties by excavating contaminated soil 6/85. EPA RI/FS report considered remedial cleanup and disposal alternatives. Due to the extent of radium contamination, EPA has been conducting additional field studies.

Radiation Data:

Rn-222 gas in homes, 0.5-440 pCi/L before remediation; radium in soil above background 40% of properties; Ra-226, U-234 present)

Gamma radiation levels: 1,000 μR/hr (max).

Soil Concentrations:

Ra	4,545	pCi/g	(max)
Th	4,545	pCi/g	(max)
U	310	pCi/g	(max)

Matrix Characteristics:

Ash and cinders in discrete pockets; also apparently mixed with soil (silt, sand, and gravel, or used alone as fill).

Source:

Alleged to be former radium-processing facility nearby.

Approximate Area and Volume:

127 acres; 350,000 cu yd total in 3 separate areas; over 750 properties involved.

Environmental Impact:

Approximately 750 properties in 3 areas. 76,000 residents within 3-mi radius. EPA, Centers for Disease Control (CDC), Agency for Toxic Substances and Disease Registry (ATSDR) have determined the long-term impact on health of residents.

Source of Information:

"Radon Contamination in Montclair and Glen Ridge New Jersey Investigation and Emergency Response," by J.V. Czapor and K. Gigliello, and J. Eng.

"Feasibility study for Montclair/West Orange, Glen Ridge, New Jersey Radium Sites," Draft Final Report, U.S. EPA, 1985.

Site Status Report from EPA Region II; 10/88.

B - 6 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

Lodi Municipal Well
Lodi, New Jersey

EPA Contact Region II:

Ron Rusin, FTS 264-1873

Summary of Site Use:

Municipal well near a thorium processing facility is contaminated with U-238 decay series elements.

Ground-water Plume.

Status:

NPL	Rank	Score	Lead	Status
Proposed	- - -	33.39	Fund	RI/FS

Well closed 12/83.

Draft RI report completed 7/89 and under review. RI/FS will determine whether the source of contamination may be attributed to either a man-made contaminant or a naturally occurring source.

Radiation Data:

One well out of nine contaminated with gross alpha radiation from U-238 decay.

Matrix Characteristics:

Ground water; VOCs present in most of nine wells.

Source:

Possibly nearby thorium processing facility, or may be a natural source.

Approximate Area and Volume:

One well radioactively contaminated; 2.35 sq mi.

Environmental Impact:

One well closed due to radioactive contamination. Other eight are shut down due to volatile organic contamination. Lodi using alternate water supply.

Source of Information:

EPA NPL site status sheet.

B - 7 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

Montclair/West Orange Radium Site
Essex County, New Jersey

(Also see Glen Ridge Radium Site#5)

EPA Contact Region II:

Raimo Liias, FTS 264-8099

Summary of Site Use:

Radium processing wastes from the 1920s was used for fill in residential areas.

Landfarm, Treatment, Spreading.

Status:

NPL	Rank	Score	Lead	Status
Final	178	49.14	Fund	RI/FS

EPA released a draft Remedial Investigation and Feasibility Study (RI/FS) report in 9/85. Supplemental FS of interim and final alternatives was released 4/89. Record of decision was signed for a portion of the site on June 30, 1989. Supplemental ROD will be issued for the remainder of the site at a later date. New Jersey Department of Environmental Protection (NJDEP) began remediation of nine residential properties by excavating contaminated soil 6/85. EPA RI/FS report considered remedial cleanup and disposal alternatives. Due to the extent of radium contamination, EPA has been conducting additional field studies. As of 3/87, EPA has been unable to solve the soil disposal problem and is developing a supplemental RI/FS to focus continuing protective action while final remedy developed.

Radiation Data:

Rn-222 gas in homes, 0.5-440 pCi/L before remediation; radium in soil above background 40% of properties; Ra-226, U-234 present)

Gamma radiation levels as high as 1300 μR/hr.

Subsurface concentration:

Ra	1 - 5386	pCi/g (max)
Th	1 - 4620	pCi/g (max)
U	1 - 248	pCi/g (max)

Matrix Characteristics:

Ash and cinders in discrete pockets; also apparently mixed with soil (silt, sand, and gravel, or used alone as fill).

Source:

Alleged to be former radium-processing facility nearby.

Approximate Area and Volume:

Montclair/West Orange: approx. 50,000 cu yd of contaminated material throughout the neighborhood of approx. 1 square mile. Total contaminated soil is approx. 300,000 cu yd in 3 separate areas; over 750 properties involved.

Environmental Impact:

Approximately 750 properties in 3 areas. 76,000 residents within 3-mi radius. EPA, Centers for Disease Control (CDC), Agency for Toxic Substances and Disease Registry (ATSDR) have determined the long-term impact on health of residents.

Source of Information:

EPA NPL site status sheet 5/86; update 11/86 and 3/87.

"Radon Contamination in Montclair and Glen Ridge New Jersey Investigation and Emergency Response," by J.V. Czapor and K. Gigliello, and J. Eng.

"Feasibility study for Montclair/West Orange, Glen Ridge, New Jersey Radium Sites," Draft Final Report, U.S. EPA, 1985.

Site Status Report from EPA Region II; 10/88.

B-8 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

Lansdowne Radiation Site
105-107 E. Stratford Av.
Lansdowne, Pennsylvania

EPA Contact Region III:

Vic Janosik, FTS 597-8996

Summary of Site Use:

Basement laboratory (1924-1944) left residence contaminated with radium. Made radium sources for therapy.

Other Manufacturing/Industrial, Waste Piles.

Status:

NPL	Rank	Score	Lead	Status
Final	703	20.32	Fund	RA

Site is undergoing Remedial Action (RA), which began 8/88 and will continue for 8 mos. to 1 year. Based on a radiological assessment of the property and a remedial action plan prepared by Argonne National Laboratory in 1985, EPA has decided to dismantle the duplex residence and dispose of contaminated materials at a licensed burial site (Utah).

Radiation Data:

Beta-gamma levels = 900,000 dpm/sq cm
Alpha levels = 200,000 dpm/sq cm.

Soil Concentration (max.):

Ra-226	2,800± 300	pCi/g
Th-230	1,310 ±100	pCi/g
Ac-227	32 ± 3	pCi/g

Radon Concentrations:

Rn-222	31	pCi/L
Rn-220	37	pCi/L

Soil, sewer lines, building materials contaminated with Ra-226, Th-230, Ac-227, and Pa-231. Rn at 0.021 - 0.309 working level (WL).

Matrix Characteristics:

Soil, concrete, other building materials, sewer line waste.

Source:

Basement operation for radium purification and packaging by former occupant.

Approximate Area and Volume:

52,000 sq ft of land; 30,000 cu ft of contaminated articles/structures; 800-2,000 cu yd of contaminated soil, extending to 8 ft depth.

Environmental Impact:

Severe contamination of building and surrounding grounds. ATSDR issued (3/85) health advisory warning that radiation levels in the structure were unsafe. Heavily populated residential area with neighboring properties contaminated with radium. However, none of the surrounding homes have greater than background contamination.

Source of Information:

"Radiological Assessment Report For The Lansdowne Property" (ANL, Sept. 1985) and the Remedial Action Plan prepared by Argonne National Laboratory.

Site Status Report from EPA Region III; 10/88.

B - 9 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

Maxey Flats Nuclear Disposal Site
Hillsboro, Kentucky

EPA Contact Region IV:

Harold Taylor, FTS 257-7791

Summary of Site Use:

Radioactive wastes deposited at privately operated burial facility on state-owned land. State licensed.

Landfill, Comm./Indus.

Status:

NPL	Rank	Score	Lead	Status
Final	612	31.71	Enforcement	RI/FS

RI/FS work plan completed 6/30/86 with focus on risk assessment and evaluation of alternative remediation, based on containment of waste. Consent order entered into 3/87 by EPA and site steering committee to perform RI/FS per work plan. RI was finalized 6/1/89 and FS is due 9/1/89. Goal is to issue ROD at end of 1st quarter of FY 1990.

Radiation Data:

Transuranic nuclides in the environment; elevated concentrations of tritium, cobalt, and strontium. Site contains approx. 4.75 million cubic feet of low-level radioactive waste equaling approx. 2.4 million Ci of by-product material, about 533,000 pounds of source material, about 950 pounds of special nuclear material, and more than 140 pounds of plutonium.

Gamma radiation 10-32 mR/hr; 30,000 pCi/cubic meter activity level.

Soil Concentrations:

Ra	9	pCi/g	(max)
U	14	pCi/g	(max)
Th	2	pCi/g	(max)
H-3	560,000	pCi/g	(max)
Cs-137	1	pCi/g	
Co-60	<1	pCi/g	

(plus organic contaminants)

Gound-water Concentrations:

Ra-226	300	pCi/L	(max)
U	105	pCi/L	(max)
H-3	2,000,000	pCi/mL	(max)
Sr-90	13,000	pCi/L	(max)
Pu-239	2	pCi/L	(max)

(plus organic contaminants)

Surface water Concentrations:

Ra-226	290	pCi/L	(max)
Gross Alpha	2	pCi/L	(max)
Gross Beta	1	pCi/L	(max)
H-3	68,800	pCi/L	(max)

(plus organic contaminants)

Sediment Concentrations:

Ra-226	4	pCi/g	(max)
Sr-90	5	pCi/g	(max)
Pu-239	1	pCi/g	(max)
Cs-137	<1	pCi/g	(max)
H-3	70	pCi/g	(max)

(plus organic contaminants)

Air Concentrations:

H-3	3,000	pCi/cu meter	(max)

Matrix Characteristics:

Low-level radioactive waste burial facility; leachate, soil, air; flora, fauna. Nonradioactive contaminants: benzene, naphthalene, d-n-oxylphthalate, 1,4-dioxane, dichlorodifluoromethane, 1,1-dichloroethene, pentanol, ethylenediaminetetraacetic acid,2-methylpropionic acid, 2-methylbutanoic acid, 3-methylbutanoic acid, valeric acid, isobutyric acid, 2-methylbutyric acid, 3-methylbutyric acid, pentanoic acid, 2-methylpentanoic acid, 3-methylpentanoic acid, Ca-branched acids, phenol, hexanoic acid, 2-methylhexanoic acid,

cresol (isomers), 2-ethylhexanoic acid, Ce-branched acid, benzoic acid, octanoic acid, phenylacetic acid, phenylpropionic acid, phenylhexanoic acid, toluic acid, p-dioxane, methyl isobutyl ketone, toluene, xylene (isomers), cyclohexanol, dibutyl ketone, fenchone, triethyl phosphate, naphthalejie, tributyl phosphate, a-terpineol.

Source:

Disposal site for various low-level radioactive waste sources. Liquid storage buildings (200,000 gallons of leachate stored above ground) and a building enclosing the old evaporator. Residuals on building. Tritium in leachate.

Approximate Area and Volume:

280 acres (total site), 25 acres (contaminated), 178,000 cu yd., 200,000 gallons; 10 steel tanks, evaporator, soil in buildings.

Environmental Impact:

152 residents live within 1-mi radius. Leachate escaping through bedrock fractures into underlying sandstone and trenches. Leachate from a number of trenches contains soluble plutonium. Evidence of migration of tritium from trench water to wells has been established but not in high enough levels to pose a public health hazard. Local residents are on public water supply system, however.

Source of Information:

RI/FS Work Plan (6/86).
Draft RI sent to OWPE (10/88)
Site Status Report from EPA Region IV; 10/88.

B-10. RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

Kerr-McGee (Kress Creek)
and the West Branch of the DuPage River
West Chicago, Illinois

EPA Contact Region V:

Mary Logan, FTS 886-9288.

Summary of Site Use:

Thorium processing wastes discharged to creek from 1931 to 1973.

Ore Process/Refining/Smelter, Surface Impoundment, Outfall, Surface water.

Status:

NPL	Rank	Score	Lead	Status
Proposed	- - -	39.05	Fund	RI/FS

The Nuclear Regulatory Commission (NRC) issued an order to Kerr-McGee to prepare a cleanup plan for Kress Creek and affected portions of the West Branch of the DuPage River. The NRC's Atomic Safety Licensing Board upheld Kerr-McGee's challenge. The NRC staff has appealed this decision. Should the appeal fail, EPA must consider using Superfund to remedy the creek and river contamination.

Radiation Data:

About 1.5 mi of creek and river are contaminated in the streams and along the banks. Peak total thorium concentrations are 555 pCi/g at a depth of 60 cm (2 ft). Thorium has been identified as deep as 170 cm (6 ft). Peak gamma levels are 250 μR/hr along the bank.

Matrix Characteristics:

Sediment, soil, tailings.

Approximate Area and Volume:

Undetermined but substantial. Affected area is about 1.5 miles of creek and river bed and the adjacent banks.

Source:

The Rare Earths Facility, an ore processing facility that had been used to process thorium and rare earth ores containing radioactive thorium, uranium, and radium.

Environmental Impact:

There are several routes for potential risks to the environment and public health, including direct external radiation exposure; inhalation exposure and ingestion of contaminated soils, ground water, and surface water. The contaminated media at the site consists of wastes from the Rare Earths Facility. The primary radionuclide present is Th-232.

Source of Information:

Comprehensive Radiological Survey of Kress Creek, West Chicago Area, Illinois, 2/84, Oak Ridge Associated Universities.

Site Status Report from EPA Region V; 10/88.

B-11 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

Kerr-McGee (Reed Keppler)
Reed-Keppler Park,
West Chicago, Illinois

EPA Contact Region V:

Mary Logan, FTS 886-9288

Summary of Site Use:

Thorium processing wastes landfilled in gravel quarry next to public park.

Waste Piles, Landfill, Comm./Indus.

Status:

NPL	Rank	Score	Lead	Status
Proposed	- - -	29.45	Fund	RI/FS

The Remedial Investigation Report has been completed. Samples were analyzed for 23 metals, Th-232, U-238, Ra-228, and Ra-226 in the soil; and gross alpha, Th-232, and Ra-226 in the ground water.

Radiation Data:

Gamma exposure levels up to 16,000 μR/hr.

Ground-water concentration:
Th-232 23 pCi/L
Ra-226 8 pCi/L

Soil concentration (max)
Th-232 11,000 pCi/g.

Matrix Characteristics:

Till, gravel, ground water, and air.

Approximate Area and Volume:

It is estimated that 20,000 cu yd of thorium contaminated material is located within the Park in a 11,000-sq yd area.

Source:

The Rare Earths Facility, an ore processing facility that had been used to process thorium and rare earth ores containing radioactive thorium, uranium, and radium.

Environmental Impact:

There are several routes of potential risks to the environment and public health including direct external radiation exposure; inhalation exposure; and ingestion of contaminated soils, ground water, and surface water. The contaminated media at the site are wastes from the Rare Earths Facility. The primary radionuclide present is thorium-232

Source of Information:

Remedial Investigation Report, Kerr-McGee Radiation-sites, West Chicago, 9/86, CH2M Hill.

Site Status Report from EPA Region V; 10/88.

B-12 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

Kerr-McGee (Residential)
Off-Site Properties
West Chicago, Illinois

EPA Contact Region V:

Mary Logan, FTS 886-9288

Summary of Site Use:

Thorium processing wastes used as fill in at least 87 areas within the city.

Waste Piles.

Status:

NPL	Rank	Score	Lead	Status
Proposed	- - -	29.45	Fund	RI/FS

The Remedial Investigation Report has been completed. Mitigation procedures were carried out at 116 locations.

Radiation Data:

Contamination in excess of 2,000-3,000 μR/hr was noted prior to the mitigative measures. Th-232 up to 16,000 pCi/g in soil was measured.

Matrix Characteristics:

Till, gravel, fill, tailings.

Approximate Area and Volume:

The area consists of 117 residential lots of various sizes. Approximately 61,000 cu yd.

Source:

The Rare Earths Facility, an ore-processing facility that had been used to process thorium and rare earth ores containing radioactive thorium, uranium, and radium.

Environmental Impact:

There are several routes of potential risks to the environment and public health including direct external radiation exposure; inhalation exposure; and ingestion of contaminated soils, ground water, and surface water. The contaminated media at the site consists of wastes from the Rare Earths Facility. The primary radionuclide present is thorium-232.

Source of Information:

Remedial Investigation Report, Kerr-McGee Radiation-sites, West Chicago, Illinois, 9/86, CH2M Hill.

Site Status Report from EPA Region V; 10/88.

B-13 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

Kerr-McGee (Sewage Treatment Plant)
West Chicago Sewage Treatment Plant
West Chicago, Illinois

EPA Contact Region V:

Mary Logan, FTS 886-9288

Summary of Site Use:

Thorium processing wastes used as fill at the sewage treatment plant.

Landfill,Comm./Indus., Waste Piles, Tank, below ground.

Status:

NPL	Rank	Score	Lead	Status
Proposed	- - -	29.45	Fund	RI/FS

The Remedial Investigation Report has been completed. Samples were analyzed for metals, radon, thoron and thorium. Values were presented for As, Ba, Cd, Cr, Fe, Pb, Hg, and Se.

Radiation Data:

Gamma radiation = 2,000-3,000 μR/hr.

Soil Concentration (nominal)
Th-232 4,900 pCi/g

Groundwater Concentration
Th-232 30 fCi/L
Th-230 <1 pCi/L
Ra-226 <1 pCi/L

Matrix Characteristics:

Soil; till; gravel; ground water; monazite ore.

Approximate Area and Volume:

25 acres (includes plant site and Reed-Keppler Park and not just contaminated area): 40,000 cu yd.

Source:

The Rare Earths Facility, an ore processing facility that had been used to process thorium and rare earth ores containing radioactive thorium, uranium, and radium.

Environmental Impact:

There are several routes of potential risks to the environment and public health, including direct external radiation exposure; inhalation exposure; and ingestion of contaminated soils, ground water, and surface water. The contaminated media at the site are wastes from the Rare Earths Facility. The primary radionuclide present is thorium-232.

Source of Information:

Remedial Investigation Report, Kerr-McGee Radiation-sites, West Chicago, Illinois, 9/86, CH2M Hill.

Site Status Report from EPA Region V; 10/88.

B-14 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

The Homestake Mining Company
Uranium Mill
Cibola County, New Mexico

(about 5.5 miles north of Man)

EPA Contact Region VI:

William Rowe, FTS 255-6730

Summary of Site Use:

Uranium mill since 1958 with heavy metal contamination from two large tailings ponds.

Surface Impoundment, Mining site, Surface.

Status:

NPL	Rank	Score	Lead	Status
Final	528	34.21	Enforcement	RI/FS

Homestake and EPA signed an Administrative Order in 6/87 for implementation of a workplan for a radon RI/FS developed by New Mexico's contractor, Geomet. A 15-month RI testing program was completed, and the ROD is expected to be signed in 9/89. Naturally occurring dispersed tailings, ground-water contamination, and tailings piles may be considered as to how they act as sources.

Radiation Data:

Rn-222 in the air, 0.03 WL; radium in the mill tailings, 60-100 pCi/g; uranium in the water, 720 ppb. One-year monitoring study of indoor and outdoor radon concentrations. Outdoor radon concentrations ranged from 0.05 pCi/L (background) to 2.6 pCi/L.

Matrix Characteristics:

Soil, tailings, ground water, and air.

Approximate Area and Volume:

245 acres at 6,600-foot elevation; 16,500,000 cu yd.

Source:

Potential sources are:

Homestake Mining Company uranium mill tailings, Anaconda mill tailings, Ambrosia Lake mining area, and areas of near-surface uranium mineralization.

Environmental Impact:

About 200 people depend upon the shallow aquifer as a water supply. An alternate water supply is in place, and aquifer restoration by Homestake has been somewhat successful. Radon levels indoors and outdoors in several subdivisions near the mill may be above background.

Source of Information:

Geomet Report Number 18-1739, 3/87. "WORK PLAN FOR HOMESTAKE MINING COMPANY STUDY AREA NEAR MILAN, NEW MEXICO," RI/FS for EAI.D., R.P.B., State of New Mexico.

B-15 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

United Nuclear Corporation
Church Rock, New Mexico

(17 miles northeast of Gallup)

EPA Contact Region VI:

William Rowe, FTS 255-6730

Summary of Site Use:

Uranium mill since 1977. Tailings impoundment failed in 1979 to the Rio Puerco River.

Surface impoundment, Mining site, Surface.

Status:

NPL	Rank	Score	Lead	Status
Final	651	30.36	Fund	RI/FS

EPA completed an RI/FS ground-water operable unit FS in August 1988, and signed a ROD in September 1988. EPA and the U.S. Nuclear Regulatory Commission (NRC) signed a memorandum of understanding (MOU) in 8/88 to coordinate and ensure full site remediation. UNC has submitted a Reclamation Plan under conditions of its source materials license. NRC, with EPA's review, gave partial approval to the Reclamation Plan. Mill complex will be decommissioned and associated areas will be decontaminated/surveyed under NRC license conditions/directives.

Radiation Data:

Gamma Exposure: some areas > 150 μR/hr.

Soil: EPA did not sample soils during RI/FS. On the basis of the MOU, NRC is responsible for comprehensive surveying of soils affected by windblown tailings. The primary contaminant is radium.

Groundwater Concentrations:

Ra-226	47	mg/L
Ra-228	36	mg/L
Th-230	3,760	mg/L (max)
Gross alpha	350	pCi/L (max: not Rn)
Gross beta	77	pCi/L (max)

(plus ammonia, nitrates, As, Cd, Co, Ni, Se)

Surface water Concentrations:

Ra-226/8	24	pCi/L (max: w/Rn)
Th-230	277,733	pCi/L (max)
U	Not	Analyzed

(plus ammonia, nitrates, sulfates, Al, Mn, Se)

Radioactive Contaminants	Tailings Pile (pCi/g)	Pond (pCi/L)
U-238	29	3,900
Th-230	290	93,000
Ra-226	290	130
Rn-222	no data	no data

Matrix Characteristics:

Tailings, ground-water. Mill complex: includes mill, office buildings, foundation and concrete structures, storage tanks. Also, mine shafts and work areas. Includes retention-sediment ponds, evaporation pads. Mill effluent: stored solids and spilled or windblown materials. Mainly tailings and extracted product. Nonradioactive contaminants:

Pond	(mg/L)
arsenic	1.22
barium	0.29
cadmium	0.11
lead	1.56
mercury	0.0005
molybdenum	2.30
selenium	0.53
vanadium	46.94
zinc	7.22

Approximate Area and Volume:

The mill tailings pond covers 170 acres and is 15-20 ft thick; 4,700,000 cu yd.

Source:

The source of the radiation is a uranium mill site, largely from the tailings ponds.

Environmental Impact:

Several people use the shallow alluvial aquifers in the area. A break in the tailings dam in 1979 sent 93 million gallons of tailings fluid into the Rio Puerco. The upper Gallup aquifer is contaminated in the vicinity of the tailings pond. The alluvial aquifer is also contaminated.

Source of Information:

Site Status Summary, 5/87 and Technical Memorandum, Phase I Field Study, RI/FS, United Nuclear, Church Rock, N. Mexico, October 4, 1985, CH2M Hill.

PRP Reports, State of New Mexico Site Inspections, UNC and EPA Sampling Data.

Site Status Report from EPA Region VI; 10/88.

B-16 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

Weldon Spring Quarry and
Chemical/Raffinate Plant (USDOE/Army)
St. Charles City, Missouri

EPA Contact Region VII:

Dan Wall, FTS 757-2856

Summary of Site Use:

Quarry used by Army for disposal of TNT wastes and by AEC/NRC for disposal of thorium residues and radium-contaminated equipment.

Sand and gravel pit; Surface impoundment; Chemical Process/Manuf.; Milit. Ord. Prod./Stor./Disp.; Ore Process/Refining/ Smelter.

Status:

NPL	Rank	Score	Lead	Status
Final	672	55.60	Fund	Pre-RI/FS

Quarry: Under an agreement with EPA (4/87), DOE is developing an operable unit RI/FS. A ROD is expected by the third quarter of 1990. Chemical Plant: A ROD is expected by 4/91.

Radiation Data:

According to results of monitoring by DOE and the U.S. Geological Survey (USGS), radioactive materials have been released to surface water, ground water, and air. Thorium, uranium, and radium residues have been placed in quarry.

Quarry:

Gamma Exposure Rates: 1.5 - 625 μR/hr.

Soil Concentrations:

Ra	1,200	pCi/g
U	2,400	pCi/g
Th	6,800	pCi/g

(plus, nitroaromatics, PCBs, and PAHs)

Groundwater Concentrations:

U	8,800	pCi/L	on-site
	4,692	pCi/L	off-site

(plus, 2,4,6 TNT)

Surface Water Concentrations:

U	2,100	pCi/L	on-site
	116	pCi/L	off-site

Radon Concentrations:

Rn	3	pCi/L	perimeter (avg)
	18	pCi/L	on-site (max)

Chemical Plant/Raffinate Pits (4):

Gamma Exposure Rates: 9 - 807 μR/hr.

Soil Concentrations:

Ra	22	pCi/g	(max)
U	50,000	pCi/g	
Th	25	pCi/g	

(plus, organics and heavy metals: Pb;Ba;Zn)

Sediment Concentrations:

Ra-226/8	850	pCi/g	(dry:max)
U-238	710	pCi/g	
U-234	810	pCi/g	
U-235	40	pCi/g	
Th-230	2,400	pCi/g	
Th-232	120	pCi/g	

(plus, organics and heavy metals: Pb;Ba;Zn)

Ground-water Concentrations:

U	58	pCi/L

(plus, organics, nitrate, sulfates, and heavy metals: Li;Sr)

Surface water Concentrations:

U	2,380	pCi/L
Ra	290	pCi/L

(plus, Pb, Sr, and Li)

Storm Water: U = 3,500 pCi/L

Radon Concentrations:
Rn 1 pCi/L

Structural Contamination: Uranium is the principal contaminant in 43 buildings, the interior of 8 of these process buildings are heavily contaminated.

Matrix Characteristics:

Drums, process equipment, building rubble, debris, raffinate sludges and soils which range from gravely to clay-like and organically rich. Soils and sludges are variably contaminated with TNT, DNT, and other organics.

Source:

Uranium and thorium ore processing. Previously US Army Ordnance works.

Approximate Area and Volume:

220 acre complex; quarry is 9 acres; 95,000 cu yd radioactive material; Pits contain 550,000 cu yd radioactive residues along with other wastes.

Environmental Impact:

Potential contamination of alluvial aquifer 0.5 mi from quarry, serving 58,000 people. Uranium and radium have been detected in off-site monitoring wells, with radium concentrations exceeding drinking water standards.

Source of Information:

Draft EIS (2/87)
Radiologic Characterization Report (2/87)
Annual Environ. Monitoring Report (8/87)

Site status report from EPA Region VII (10/88)

B-17 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

Denver Radium Superfund Sites
Denver, Colorado

EPA Contact Region VIII:

Sonya Pennock, FTS 564-7505

Summary of Site Use:

31 properties in Denver where radium was processed, refined or fabricated before 1915.

Ore Process/Refining/Smelter.

Status:

NPL	Rank	Score	Lead	Status
Final	269	44.11	Fund	RD/RA

Feasibility Studies have been completed for 10 fund-lead operable units and for 4 fund-lead operable unit. ROD's are pending. Remedial Design is underway at four operable units. Negotiations with Potentially Responsible Parties are underway at the enforcement-lead operable unit.

Radiation Data:

U-234, -238, Th-230, Ra-226, Rn-222 present.

Gamma radiation concentrations:
57-2,547 μR/hr (max)

Soil concentrations
Ra 79 - 5093 pCi/g (max)

Rn/progeny 0.30 WL (grab)

Matrix Characteristics:

Asphalt, soil, pond bottom sediment, building debris and contents, ground water, and airborne particulates

Source:

Former Denver National Radium Institute and other processors involved in radium processing through World War I and early 1920s, generating large quantities of radioactive residues.

Approximate Area and Volume:

Approximate volume 106,000 cu yd, covering a total of about 40 acres in 44 locations within a 4-mi radius of downtown Denver.

Environmental Impact:

Potential risk to human health, including direct exposure, inhalation of radon, ingestion of radionuclides and contaminated media.

Source of Information:

Final Feasibility Study, Denver Radium site, Operable Unit X, 6/87; Final Feasibility Study & Responsiveness, Denver Radium Site, Operable Units IVN, Vols. I and II, 9/86; Remedial Alternative Selection and Community Relations Responsiveness Summary, Operable Unit VII, 3/86. Remedial Investigation Report 4/86.

B-18 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

Lincoln Park
Canon City, Colorado

EPA Contact Region VIII:

Gene Taylor, FTS 564-1640

Summary of Site Use:

Drinking water wells probably affected by wastes from Cotter Corp. uranium mill.

Mining site, Subsurface.

Status:

NPL	Rank	Score	Lead	Status
Final	621	31.31	Enforcement	RD/RA

RI/FS submitted to EPA by the State for review 3/86. Memorandum of Agreement between State and EPA 4/86. The State of Colorado has lead responsibility for negotiations, development, and implementation of remedy.

Radiation Data:

Ground-water quality studies per 1987 USGS report included Ra-226 between 0.05 and 1.6 pCi/L, and U-234 and -238 between 0.4 and 5, 700 µg/L.

Matrix Characteristics:

Contaminated ground water derived from unlined tailings ponds. Nonradioactive contaminants: molybdenum and selenium.

Source:

Uranium mill (Cotter Corporation).

Approximate Area and Volume:

900 acres; 1,900,000 tons.

Environmental Impact:

386 residents within 3-mi radius. Contaminated ground water in the vicinity and down gradient. No permitted drinking water wells in the area. Company's monitoring data indicate a plume of contaminants, including molybdenum. uranium, and selenium extending from mill and affecting private wells that were serving 200 people.

Source of Information:

4/87 Fact Sheet. "Ground-water Flow and Quality Near Canon City, Colorado." US Geological Survey, WRI Report 87-4014, 1987. EPA Office of Radiation Programs.

B-19 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

Uravan Uranium Project
Montrose City, Uravan, Colorado.

EPA Contact Region VIII:

Gene Taylor, FTS 564-1640

Summary of Site Use:

Mill began in 1915 for radium recovery, then vanadium and most recently, uranium

Surface impoundment; Waste Piles; Mining Site, Surface.

Status:

NPL	Rank	Score	Lead	Status
Final	275	43.53	Enforcement	RD/RA

State of Colorado negotiating remedy with responsible parties. EPA and State have entered into MOA 4/86, designating State to pursue effective remedy. The State of Colorado has negotiated an agreement with Responsible Parties, and the agreement has been approved by U.S. District Court. EPA submitted comments to State on remedial action plan 12/86.

Radiation Data:

Radionuclides and Rn-222, U-234, U-238; Th-230; Ra-226.

Th	16,000 - 165,000	pCi/L
U	1,500 - 16, 000	pCi/L
Ra	66 - 676	pCi/L.

Matrix Characteristics:

Ground-water and air, raffinate, tailings, surface water. Selenium, nickel, ammonia, sulfates.

Source:

Uranium and vanadium recovery plant; milling operations; little activity at present; owned and operated by Union Carbide Corporation.

Approximate Area and Volume:

900 acres; 2,000,000 tons removed: 10,000,000 tons stabilized.

Environmental Impact:

Town in remote area. 125 residents within 3-mi radius. All residents moved 12/86; no permanent residents. Ground water and air contaminated with process waste, including uranium. Discharge and disposal of large volume of process wastes releasing radiation.

Source of Information:

4/87 Fact Sheet
Department of Energy Remediation Programs

B-20 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

Rocky Flats Plant (USDOE)
Golden, Colorado

EPA Contact Region VIII:

Nat Miullo, FTS 564-1668

Summary of Site Use:

DOE GOCO with releases to ground-water and surface water that may or may not be above federally permitted levels.

Surface Impoundment; Milit. Ord. Prod. /Stor./Disp. Spill

Status:

NPL	Rank	Score	Lead	Status
Proposed	- - -	64.32	Enforcement	RI/FS

Compliance agreement entered into by DOE, EPA, and Colorado Dept. of Health 7/86, defining respective roles and responsibilities. DOE is responsible for remedial actions. RI/FS work plans completed 2/87; As a result of EPA review and negotiation, DOE submitted a technical proposal for interim response action for high priority areas in 3/89. CERCLA interagency agreement was entered into by DOE, EPA and Colorodo Department of Health 5/85.. DOE has done some remedial work such as capping and removing plutonium contaminated soil.

Radiation Data:

Plutonium and tritium releases.

Matrix Characteristics:

Soil and sediment; wastewater impoundments.

Source:

Production of nuclear weapons triggers; plutonium recovery; americium research.

Approximate Area and Volume:

6,550 acres total area; 91 sites; over 1,000 waste streams.

Environmental Impact:

Plutonium and tritium have contaminated soils and sediments in surface water. Ground water has been contaminated with nitrate. Approximately 80,000 people live within 3 mi of the facility.

Source of Information:

4/87 Fact Sheet
7/85 NPL Fact Sheet.

B-21 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

Monticello Radioactivity Contaminated Properties
Monticello, Utah

EPA Contact Region VIII:

Lam Nguyen, FTS 564-1793

Summary of Site Use:

Tailings from vanadium and uranium ore used for fill and aggregate for mortar and concrete.

Waste Piles; Ore Process/Refining/Smelter

Status:

NPL	Rank	Score	Lead	Status
Final	502	35.03	Enforcement	RI/FS

DOE has assumed responsibility for most of the remedial action. EPA is negotiating Memorandum of Agreement (MOA) with DOE to better define respective roles in cleanup activities. DOE has authorized cleanup of 15 properties and is studying several more for inclusion in program. EPA conducted planned removal action of two of the most contaminated structures in Monticello during 1983-1984.

Radiation Data:

Widely dispersed radioactive tailings; U-238, 234, -226, Th-230, Rn-222, Ra-226.

Concentrations:

Ra-226	23,000	pCi/g
U-238	24,000	pCi/g
U	18,000	pCi/g

Matrix Characteristics:

Tailings from vanadium and uranium ore processing; radioactive tailings widely dispersed throughout town as fill material and as aggregate for mortar and concrete. Vanadium 1-16,532 ppm.

Source:

Uranium and Vanadium ore processing in Monticello plant from 1942 to 1960. Some tailings may have been brought in from another mill in Dry Valley.

Approximate Area and Volume:

152 potentially contaminated properties; 182,000 cu yd.

Environmental Impact:

1500 residents within 1/2-mi radius. 152 potentially contaminated properties. Widely dispersed contamination, apparently mostly in near-surface soils.

Source of Information:

4/87 Fact Sheet. EPA Office of Radiation Programs

B-22 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

Teledyne Wah Chang
Albany, Oregon

EPA Contact Region X:

Neil Thompson, FTS 399-7177

Summary of Site Use:

Wastes from production of zirconium and rare earth elements, with heavy metals and low levels of radioactive materials.

Ore Process/Refining/Smelter; Surface Impoundment.

Status:

NPL	Rank	Score	Lead	Status
Final	- - -	54.27	Enforcement	RI/FS

EPA recently completed a remedial plan outlining the investigations needed to determine the full extent of cleanup required at the site. Wah Chang had requested permission from the State to cover the old storage ponds to minimize percolation that could contribute to possible leachate into the Williamette. In 1/83, the State drafted a permit indicating its preference for moving the sludges to another location on company property farther from the river. This action has been appealed. RI/FS started in 10/88 and is continuing. Work plan negotiated for full RI/FS.

Radiation Data:

Wastes from production of zirconium and rare earths, with heavy metals (Ba, Cd) and U, Ra, and Th wastes from ore process/refining/smelter operations. Radiation off site is generally below established limits. Contaminated radioactive waste has been removed from the site to a low-level radioactive waste repository (Hanford).

Sludge Concentrations (stored on site):

Ra-226	120	pCi/g (max)
Th	619	pCi/g (max)
Total U	10,000	mg/kg (max)

(plus zirconium, halfnium, titanium, and other rare earth metals)

Groundwater Concentrations:

Ra-228	11	pCi/L

(plus SO4, NaCl, and CaCl2)

Surface water: Not measured.
Sediment: Not measured.
Air: Measured, but data not available.
Gross alpha: Measured, but data not available.
No contaminated articles/structures.

Matrix Characteristics:

On-site process wastes consisting of a large volume of solids containing Ra, U, Th, heavy metals (Ba, Cd, Cr, and Pb), and chlorinated solvents contaminating ground-water, surface water and air.

Source:

Zirconium and rare earth ore processing in Teledyne plant beginning in 1957.

Approximate Area and Volume:

10,000 cubic yards; 4 acres (Sludge)

Environmental Impact:

Industrial area with 3 houses nearby. Contaminated radioactive waste has been taken off site. Storage facility for sludges on site with radiation emission controls. Secondary alternative is to move sludge disposal area from flood plain and build a new facility.

Source of Information:

NPL Fact Sheet
Data collected in 1982 included in a Report by CH2M Hill (1988).
Status report from EPA Region X (10/88).

B-23 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

Hanford 200-Area (USDOE)
Benton County, Washington

EPA Contact Region X:

Paul Day, FTS 444-6623

Summary of Site Use:

DOE GOCO with releases to ground-water that include organics as well as radioactive substances.

Landfill, Comm./Indus.; Open Burning; Surface Impoundment; Milit. Ord. Prod. /Stor./Disp.

Status:

NPL	Rank	Score	Lead	Status
Proposed	-	- -	69.05	Enforce Pre-RI/FS

EPA, USDOE, and Washington Department of Ecology are jointly developing an action plan that will include the work needed to address this area under the Superfund program, as well as other work needed to meet permitting, corrective action, and compliance requirements of Subtitle C of CERCLA.

Radiation Data:

U, Pu-239/40, Cs-137, Sr-90, Co-60, I-129, and tritium. Hazardous solvents, organics, mineral acids, and inorganic salts.

Matrix Characteristics:

Solid and dilute liquid wastes comprised of radioactive, mixed and hazardous constituents in trenches, ditches, and landfills. Tritium, I-129, U, cyanide, and carbon tetrachloride have been detected at levels significantly above background in ground-water beneath the area. Plumes of contaminated ground-water cover approx. 215 square miles. Tritium has been detected in Richland's surface water intakes (20 miles South) at levels above background.

Source:

USDOE nuclear activities, primarily production of nuclear materials for national defense, at Hanford since 1943.

Approximate Area and Volume:

Approximately one billion cubic yards of mixed radioactive and chemical wastes in trenches, ditches, and landfills at 230 disposal locations in the middle of the 570-square-mile Hanford Site.

Environmental Impact:

Surface water within 3 miles of the 200-Area provides drinking water to 70,000 people and irrigates over 1,000 acres. Surface and ground waters form site are contaminated with significant levels of U, Pu, I-129 and tritium, and hazardous chemicals.

Source of Information:

NPL Fact Sheet.

B-24 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

Hanford 300-Area
Benton County, Washington

EPA Contact Region X:

Paul Day, FTS 444-6623

Summary of Site Use:

DOE GOCO with releases of uranium to ground water that include organics as well as radioactive materials.

Containers/Drums; Landfill, Comm./Indus.; Surface impoundment; Other Manufacturing/Indust.

Status:

NPL	Rank	Score	Lead	Status
Proposed	---	65.23	Enforce	Pre-RI/FS

EPA, USDOE, and Washington Department of Ecology are jointly developing an action plan that will include the work needed to address this area under the Superfund program, as well as other work needed to meet permitting, corrective action, and compliance requirements of Subtitle C of CERCLA.

Radiation Data:

U, Pu-238, 239/40, Cs-137, Sr-90, Co-60, and Pr-147. Hazardous solvents, organics, mineral acids, inorganic salts, Hg, Cr,Pb,Ni, Zn, Co, and Be

Matrix Characteristics:

Solid and dilute liquid wastes comprised of radioactive, mixed and hazardous constituents in trenches, ditches, and landfills. Uranium detected at levels significantly above background in area springs, wells, and the Columbia River. Disposal locations and plumes of contaminated groundwater cover approx. 5 square miles.

Source:

USDOE nuclear activities, primarily production of nuclear materials for national defense, at Hanford since 1943. Fabrication of nuclear fuels.

Approximate Area and Volume:

Approximately 27 million cubic yards of mixed radioactive and chemical wastes in trenches, ponds, and landfills at 14 disposal locations in the southern section of the 570-square-mile-Hanford Site. Disposal locations and plumes of contaminated ground-water cover approx. 5 square miles.

Environmental Impact:

Surface water within 3 miles of the 300-Area provides drinking water to 70,000 people. Surface and ground waters from site are contaminated with significant levels of U, Pu, Cr, Hg and hazardous chemicals.

Source of Information:

4/87 Fact Sheet. EPA Office of Radiation Programs

B-25 RADIOACTIVE WASTE SUPERFUND SITE DESCRIPTION

Name and Location:

Hanford 100-Area
Benton County, Washington

EPA Contact Region X:

Paul Day, FTS 444-6623

Summary of Site Use:

DOE GOCO with releases of chromium and stronium-90 to ground water and Sr-90 to surface water. Organics are released as well as radioactive materials.

Landfill, Comm./Indus.; Open Burning; Surface Impoundment; Milit. Ord. Prod. / Stor. Dispos.

Status:

NPL	Rank	Score	Lead	Status
Proposed	---	46.38	Enforce	Pre-RI/FS

EPA, U.S. DOE, and Washington Department of Ecology are jointly developing an action plan that will include the work needed to address this area under the Superfund program, as well as other work needed to meet permitting, corrective action, and compliance requirements of Subtitle C of CERCLA.

Radiation Data:

U, Pu-238, 239/40, Cs-137, Sr-90, Co-60, Ni-63, Eu-152/4/5, and tritium. Hazardous solvents, organics, mineral acids, inorganic salts, Hg, Cr,Pb,Ni,Co.

Matrix Characteristics:

Solid and dilute liquid wastes comprised of radioactive, mixed and hazardous constituents in trenches, ditches, and landfills. Chromium and Sr-90 detected at levels significantly above background in ground-water and the Columbia River. Disposal locations and plumes of contaminated groundwater cover approx. 11 square miles.

Source:

U.S. DOE nuclear activities, primarily production of nuclear materials for national defense, at Hanford since 1943. Location of nine nuclear reactors: eight were in use during the 1940s and 1950s; the ninth, the N-Reactor, has been used since the early 1960s to produce plutonium and electricity.

Approximate Area and Volume:

Approximately 4.3 billion cubic yards of mixed radioactive and chemical wastes in cribs, trenches, and burial grounds at 110 disposal locations in the northern section of the 570-square-mile-Hanford Site. Disposal locations and plumes of contaminated groundwater cover approx. 11 square miles.

Environmental Impact:

Surface water within 3 miles of the 100-Area provides drinking water to 3,000 workers in the 100- and 200-Areas. Surface and ground waters from site are contaminated with significant levels of U, Pu, Sr-90, Cr, Hg and hazardous chemicals.

Source of Information:

4/87 Fact Sheet. EPA Office of Radiation Programs

APPENDIX C

RADIOACTIVE SOIL REMEDIATION TECHNOLOGIES

TABLE C-1
DESCRIPTION OF RADIOACTIVE SOIL REMEDIATION TECHNOLOGIES

Capping .... involves covering the contaminated site with a barrier sufficiently thick and impermeable to minimize the diffusion of radon gas and attenuate the gamma radiation associated with the radionuclides.

Vertical Barriers .... are walls installed around the contaminated zone to help confine the material and any contaminated ground-water that might otherwise flow from the site.

Land Encapsulation .... addresses excavated contaminated soil which is redeposited at a site that has been provided with complete barrier protection (plastic liners and impermeable materials).

Land Spreading .... involves low-level contaminated waste that is excavated, transported to a suitable site, and spread on unused land, ensuring that radioactivity levels approach the natural background level.

Underground Mine Disposal .... uses underground mines to provide secure and remote containment for contaminated wastes.

Ocean Disposal .... is an alternative to land-based disposal options for low levels of contaminated soil. The contaminated soil is disposed of in selected locations in the ocean. Any migration of contaminants should be slow, well dispersed, and diluted.

Stabilization/Solidification .... immobilizes radionuclides (and could attenuate radon emanation) by trapping them in an impervious matrix. The solidification agent (Portland cement, silica grout, etc.) is injected in situ or mixed with excavated soil.

TABLE C-1 (Continued)

Vitrification .... is a process that can immobilize radioactive contaminants by heating the contaminated material to its melting temperature and then cooling to a solid glassy mass.

Radon Control .... involves ventilation of buildings and areas to dilute the radon gas to acceptable levels.

Soil Washing .... involves water (with or without additives) to wash contaminated waste. Some contaminants are soluble in water while others are washed free of the soil particles. Physical separation techniques are then used to separate the soil into clean and contaminated fractions.

Chemical Extraction .... removes contaminants by mixing soil with chemicals. The product is separated into cleaned and contaminated soil fractions and a liquid extract containing radionuclides. The soluble radionuclides are separated from the extractant by ion exchange, co-precipitation, or membrane filtration.

Physical Separation .... uses screening, classification, flotation, and gravity concentration to separate fine soil particles which may contain radioactive contaminants. Screening is mechanical separation based on particle size differences. Classification involves the separation of particles based on their settling rate in fluids, normally water.

TABLE C-2. Assessment of remediation technology for soils - U, Th, Ra.

Remediation Technologies		Evaluation of Technology: Performance: Reliability	Performance: Effectiveness	Performance: Total	Development: Stage of R&D	Development: Info. Available	Development: Total
On Site Disposal	Capping	3	2	5	4	4	8
	Vertical Barriers	2	2	4	3	2	5
Off Site Disposal	Land Encapsulation	4	4	8	5	4	9
	Land Spreading	1	1	2	4	2	6
	Underground Mine	3	4	7	4	3	7
	Ocean Disposal	3	2	5	4	3	7
On Site Treatment	Solidification	4	2	6	3	3	6
	Vitrification	4	3	7	3	3	6
Radon Control	Homes	2	4	6	5	5	10
	Areal	2	4	6	3	2	5
Soil Washing	Water	5	4	9	2	2	4
Chemical Extraction	Inorganic Salts	5	3	8	3	3	6
	Mineral Acids	5	5	10	3	4	7
	Complexing Agents	5	4	9	3	3	6
Physical Separation	Screening	5	4	9	3	3	6
	Classification	4	4	8	3	3	6
	Gravity Concentration	4	4	8	3	3	6
	Flotation	4	4	8	3	3	6

References for Table C-2 (Soils - U, Th, Ra) (a)

ON SITE DISPOSAL	
CAPPING:	.5,21#,44,69,86,88,89,90#,104#,111,113,138
VERTICAL BARRIERS:	.1,18,38,85#,104#
OFF SITE DISPOSAL:	
LAND ENCAPSULATION:	.5,20,21,87,104#
LAND SPREADING:	.22,104#
UNDERGROUND MINE:	.22,24,27,28,104#,138
OCEAN DISPOSAL:	.5,21#,29,50
ON SITE TREATMENT:	
SOLIDIFICATION:	.11,32,76,93,94,98,99#,104#,119,133,138
VITRIFICATION:	.33,41,42,81,84#,104#,105
RADON CONTROL:	
HOMES:	.2,7,8,9,10,35#,36#,70,83,103,104#,107,109,112#,138,139,141, .142,143,144,145,146
AREAL:	.37,39,40,43,45,104,113,138,139
SOIL WASHING:	
WATER:	.6,25,26,48,71,73,75,82#,100,101,104#,118,130
CHEMICAL EXTRACTION:	
INORGANIC SALTS:	.3,14,30,31,49,51,57,63,67,72,73,82,100,104#,106,115,116, .120,122,123,124,126,130#,140
MINERAL ACIDS:	.3,14,16,23,30,31,45,51,52,54,55,56,57,63,67,71,72,74,100, .101,102,104#,106,108,110,114,116,120,121,122,123,124, .125,126,127,128,130#,131,138,140
COMPLEXING AGENTS:	.3,14,45,46,53,57,63,67,72,104#,106,116,117,120,121#,122, .126,130#,138,140
PHYSICAL SEPARATION:	
SCREENING:	.19,59,60,62,64,65,67,68,79,82,104#,130#,135
CLASSIFICATION:	.19#,58#,59,60,61,62,65,67,68,72,73,96,104#,129#
GRAVITY CONCENTRATION:	.19,58,59,60,62,65,66,96,104#
FLOTATION:	.19#,59,60,62#,65,67,72,79,95,104#,129#,135#

(a) For list of references corresponding to reference numbers, see the reference list at the end of this appendix.

This reference is more comprehensive on the subject technology.

TABLE C-3. Assessment of remediation technology for soils - other radionuclides.

Remediation Technologies		Evaluation of Technology					
		Performance			Development		
		Reliability	Effectiveness	Total	Stage of R&D	Info. Available	Total
On-Site Disposal	Capping	3	2	5	4	3	7
	Vertical Barriers	2	2	4	4	2	6
Off Site Disposal	Land Encapsulation	4	4	8	5	4	9
	Land Spreading	1	1	2	1	1	2
	Underground Mine	3	3	6	2	2	4
	Ocean Disposal	3	2	5	4	3	7
On Site Treatment	Solidification	4	2	6	3	3	6
	Vitrification	4	4	8	3	3	6
Radon Control	Homes	N/A	N/A	N/A	N/A	N/A	N/A
	Areal	N/A	N/A	N/A	N/A	N/A	N/A
Soil Washing	Water	4	4	8	2	2	4
Chemical Extraction	Inorganic Salts	3	3	6	2	2	4
	Mineral Acids	5	4	9	2	2	4
	Complexing Agents	3	4	7	3	3	6
Physical Separation	Screening	5	4	9	3	3	6
	Classification	4	4	8	3	3	6
	Gravity Concentration	4	4	8	3	3	6
	Flotation	4	4	8	3	3	6

Reference for Table C-3 (Soils-Other Radionuclides) (a)

ON SITE DISPOSAL

CAPPING:	21#,69,89,90#,104#,111
VERTICAL BARRIERS:	1,18,38,85#,104*

OFF SITE DISPOSAL:

LAND ENCAPSULATION:	20,21,87#,104#
LAND SPREADING:	22,104#
UNDERGROUND MINE:	22,24,27,28,104#
OCEAN DISPOSAL:	21#,29,47,50

ON-SITE TREATMENT:

SOLIDIFICATION:	76,93,94,98,99#,104#
VITRIFICATION:	33,81,84#,104#

RADON CONTROL:

HOMES:	NOT APPLICABLE
AREAL:	NOT APPLICABLE

SOIL WASHING:

WATER:	71,73,75,104#,132

CHEMICAL EXTRACTION:

INORGANIC SALTS:	30,67,72,73,120
MINERAL ACIDS:	16,30,45,67,71,72,120
COMPLEXING AGENTS:	45,67,72,120

PHYSICAL SEPARATION:

SCREENING:	59,60,62,64,65,67,104#,132
CLASSIFICATION:	58#,59,60,62,65,66,67,72,73,96,104#,132,136#,137#
GRAVITY CONCENTRATION:	58,59,60,62,65,66,96,104#
FLOTATION:	59,60,62#,65,72,95,104#

(a) For list of references corresponding to reference numbers, see the Reference list at the end of this Appendix.

This reference is more comprehensive on the subject technology.

TABLE C-4. Assessment of remediation technology for soils - mixed waste.

Remediation Technologies		Evaluation of Technology: Performance – Reliability	Performance – Effectiveness	Performance – Total	Development – Stage of R&D	Development – Info. Available	Development – Total
On Site Disposal	Capping	3	2	5	4	3	7
	Vertical Barriers	1	2	3	1	1	2
Off Site Disposal	Land Encapsulation	4	4	8	5	4	9
	Land Spreading	1	1	2	1	1	2
	Underground Mine	3	3	6	1	1	2
	Ocean Disposal	3	2	5	4	2	6
On Site Treatment	Solidification	4	2	6	3	3	6
	Vitrification	4	3	7	3	3	6
Radon Control	Homes	2	4	6	1	1	2
	Areal	2	4	6	2	2	4
Soil Washing	Water	4	3	7	1	1	2
Chemical Extraction	Inorganic Salts	3	2	5	1	1	2
	Mineral Acids	4	4	8	2	2	4
	Complexing Agents	4	4	8	2	2	4
Physical Separation	Screening	3	2	5	1	1	2
	Classification	4	4	8	1	1	2
	Gravity Concentration	4	4	8	1	1	2
	Flotation	4	4	8	1	1	2

References for Table C-4 (Soils-Mixed Waste) (a)

ON SITE DISPOSAL:	
CAPPING:	12,13,15,17,21#,69,85,89,90#,104#
VERTICAL BARRIERS:	18,38,85#,104#
OFF SITE DISPOSAL:	
LAND ENCAPSULATION:	20,21,88,91,92#,104#
LAND SPREADING:	22,104#
UNDERGROUND MINE:	22,24,27,28,104#
OCEAN DISPOSAL:	21#,29
ON SITE TREATMENT:	
SOLIDIFICATION:	34,93,97,104#,134
VITRIFICATION:	33,81
RADON CONTROL:	
HOMES:	104
AREAL:	37,39,40,43,104#
SOIL WASHING:	
WATER:	71,73,75,77,78,80,104#
CHEMICAL EXTRACTION:	
INORGANIC SALTS:	67,72,73
MINERAL ACIDS:	67,71,72
COMPLEXING AGENTS:	67,72,80
PHYSICAL SEPARATION:	
SCREENING:	59,64,65,67
CLASSIFICATION:	59,60,65,66,67,72,73,96,104#
GRAVITY CONCENTRATION:	58#,59,60,65,66,96,104#
FLOTATION:	59,60,65,67,72,95,104#

(a) For list of references corresponding to reference numbers, see the reference listat the end of this appendix.

This reference is more comprehensive for the subject technology.

TABLE C-5. **Considerations for the use of soil remediation technologies.**

	CONSIDERATIONS		
Technology	**Ra, Th, U**	**Other Radionuclides**	**Mixed Waste**
Capping	Protects surface water. Does not control horizontal ground-water migration. Degree of radiation attenuation is unknown. Does not remove source of radiation.	Similar to Ra, Th, U	Similar to Ra, Th, U
Vertical Barriers	Controls horizontal ground-water migration. Does not control vertical migration. May not attenuate radiation. Does not remove source of radiation.	Similar to Ra, Th, U	Similar to Ra, Th, U
Land Encapsulation	Effective control of all migration. Must find suitable site.	Similar to Ra, Th, U	Similar to Ra, Th, U
Land Spreading	Applicable to low-level, dry, granular, soil-like material not mixed with other contaminants. Must find suitable site.	Similar to Ra, Th, U	Reports not available. (See Note) Should not be applicable to most mixed waste.
Underground Mine Disposal	Not applicable to bulk storage. For low levels of waste. Must find a suitable site.	Similar to Ra, Th, U	Similar to Ra, Th, U
Ocean Disposal	Covered by stringent regulations. Long-term effects unknown.	Similar to Ra, Th, U	Similar to Ra, Th, U

(Continued)

TABLE C-5 (Continued)

	CONSIDERATIONS		
Technology	**Ra, Th, U**	**Other Radionuclides**	**Mixed Waste**
Stabilization/ Solidification	Degree of radiation attenuation is unknown. Long-term effects unknown. Type of waste may interfere with process.	Reports not available (See Note) Similar to Ra, Th, U	Reports not available (See Note) Chemicals may react with waste.
Vitrification	Degree of radiation attenuation unknown. Must address volatilization of contaminants.	Similar to Ra, Th, U	Similar to Ra, Th, U
Radon Control	Disperses gas, does not remediate the source of contamination or reduce radiation.	Not Applicable	Similar to Ra, Th, U
Soil Washing	Soil cleaned with water, with or without additives. Normally includes physical separation techniques to isolate clean soil fraction.	Similar to Ra, Th, U	Need development and testing
Chemical Extraction	May not clean soils that contain large quantities of refractory minerals.	Similar to Ra, Th, U	Need development and testing
Physical Separation	Not applicable if contaminants are distributed throughout all the soil fractions.	Similar to Ra, Th, U	Need development and testing

NOTE: When there was no specific information on the use of a particular technology on a category of contaminant, ratings were developed based on engineering judgement and extrapolation from other applications.

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APPENDIX D

RADIOACTIVE WATER TREATMENT TECHNOLOGIES

TABLE D-1
DESCRIPTION OF RADIOACTIVE WATER REMEDIATION TECHNOLOGIES

Aeration .... strips volatile gases (e.g. radon) from liquids. Aeration can be accomplished with forced air through a packed tower, water spray in air, or bubbling air through a water chamber.

Filtration .... removes suspended solids (which may be agglomerated by coagulants) by passing the fluid through a filtering medium (not granular activated carbon) on which the solids build up.

Carbon Treatment .... uses granular activated carbon (GAC) to adsorb many dissolved solids and gases. Very effective for radon removal.

Ion Exchange .... uses synthetic resins or natural zeolites to exchange radionuclide ions in the feedwater with ions on the resin/zeolite material.

Chemical Treatment .... includes precipitation and co-precipitation of radionuclides by the addition of chemical additives. The precipitates are removed by filtration.

Membrane Separation .... involves reverse osmosis, technology that uses a specially prepared membrane that permits water to flow through the membrane while selectively restricting some contaminants, such as radium and uranium, or electrolysis.

TABLE D-2. Assessment of remediation technology for water - U, Th, Ra.

Remediation Technologies	Evaluation of Technology					
	Performance			Development		
	Reliability	Effectiveness	Total	Stage of R&D	Info. Available	Total
Aeration	5	3	8	3	2	5
Filtration	5	3	8	3	2	5
Carbon Treatment	5	3	8	3	2	5
Ion Exchange	5	5	10	5	3	8
Chemical Treatment	5	4	9	5	3	8
Membrane Separation	5	4	9	4	3	7

REFERENCES: (a)

Aeration: (b) 5#,16,33,34,35,41,43#,49

Filtration: 1,3,4,5#,7,9,13#,33,35

Carbon Treatment: 1,3,5#,16,17#,33,35,40,41,43,48,51

Ion Exchange: 1,3,4,5#,6,8#,9,10,11,12,18,33,35,37,39,42,44,45,46,48,49,50

Chemical Treatment: 1,3,4,5#,6,7,9,10,15,33,35,38,39,42,45,46,48,50

Membrane Separation 1,2,3,4,5#,9,14,17#,33,35,36,44,47

(a) For list of references corresponding to reference numbers, see the reference list at the end of this appendix.
(b) Applicable only for radon remediation.

This reference is more comprehensive on the subject technology.

TABLE D-3. Assessment of remediation technology for water - other radionuclides.

Remediation Technologies	Evaluation of Technology					
	Performance			Development		
	Reliability	Effectiveness	Total	Stage of R&D	Info. Available	Total
Aeration	N/A	N/A	N/A	N/A	N/A	N/A
Filtration	5	3	8	3	2	5
Carbon Treatment	5	3	8	3	2	5
Ion Exchange	5	5	10	5	3	8
Chemical Treatment	5	4	9	5	3	8
Membrane Separation	5	4	9	4	3	7

References: (a)

Aeration: Not Applicable

Filtration: 3,5#,19,20,24,26,27,29,30,31,32

Carbon Treatment: 21,24,27,29

Ion Exchange: 3,5#,19,21,22,24,26,27,28#,29,30,31,32

Chemical Treatment: 3,5#,19,20,21#,23,24,26,27,29,30,31,32,38

Membrane Separation: 3,5#,25,26,32

(a) For list of references corresponding to reference numbers, see the reference list at the end of this appendix.

This reference is more comprehensive on the subject technology.

TABLE D-4. Assessment of remediation technology for water - mixed waste.

Remediation Technologies	Evaluation of Technology					
	Performance			Development		
	Reliability	Effectiveness	Total	Stage of R&D	Info. Available	Total
Aeration	2	2	4	1	1	2
Filtration	3	2	5	1	1	2
Carbon Treatment	3	3	6	1	1	2
Ion Exchange	3	2	5	1	1	2
Chemical Treatment	5	4	9	1	1	2
Membrane Separation	UNK.	UNK.	UNK.	UNK.	UNK.	UNK.

References: (a)

Aeration: (b) Only applicable to volatile organics and radon remediation
Does not attenuate radiation

Filtration: (b) Not available

Carbon Treatment: (b) Not available

Ion Exchange: (b) Not available

Chemical Treatment: (b) Not available

Membrane Saparation: Unknown

(a) For list of references corresponding to reference numbers, see the reference list at the end of this appendix.

(b) When there was no specific information on the use of a particular technology on a category of contaminant, ratings were developed based on engineering judgment and extrapolation from other applications.

TABLE D-5. Considerations for the use of water remediation technologies..

	CONSIDERATIONS		
Technology	**Ra, Th, U**	**Other Radionuclides**	**Mixed Waste**
Aeration	Not applicable except when radon is present. Disperses radon in the atmosphere, which can be a problem.	Not applicable.	Reports not available.(See Note) Only applicable to volatile organics and radon. Does not attenuate radiation.
Filtration	Coagulation/filtration removes only particulates (turbidity). Land encapsulation is required for final disposal of conc. waste. Not applicable to dissolved nuclides.	Similar to Ra, Th, U	Reports not available. (See Note) Only applicable to particulates.
Carbon Treatment	Applicable to dissolved solids and gases (radon). Requires another technology for final disposition of conc. wastes.	Reports not available. (See Note) Similar to Ra, Th, U	Reports not available. (See Note) Only applicable to dissolved solids/gases
Ion Exchange	Applicable to dissolved contaminants. Generally requires filtration as pretreatment. Requires another technology for final disposition of conc. waste.	Reports not available. (See Note) Similar to Ra, Th, U	Reports not available. (See Note) Only applicable to dissolved ionic contaminants.
Chemical Treatment	Some applicability for precipitation of Ra, Th, U, with lime; Ra with barium sulfate. Requires final disposition of waste.	Reports not available. (See Note)	Reports not available. (See Note)
Membrane Separation	Applicable for radium and uranium separation from ground water. Pretreatment is required to remove material that would foul the membrane.	Reports not available. (See Note)	Reports not available. (See Note)

NOTE: When there was no specific information on the use of a particular technology on a category of contaminant, ratings were developed based on engineering judgement and extrapolation from other applications.

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APPENDIX E

RADIOACTIVE STRUCTURE REMEDIATION TECHNOLOGIES

TABLE E-1
DESCRIPTION OF RADIOACTIVE STRUCTURE REMEDIATION TECHNOLOGIES

Demolition/Shredding .... involves blasting, wrecking, sawing, drilling, and crushing of buildings, structures, or equipment. This produces a sized material that can be treated by other remediation technologies.

Decontamination/Washing .... uses a high pressure water jet to remove contaminated debris from surfaces. The debris and water are then collected and physically or chemically decontaminated.

Surface Sealing .... involves the application of a material that penetrates a porous surface and immobilizes contaminants in place.

Radon Control .... involves ventilation of buildings and areas to dilute the radon gas to acceptable levels or prevent its entry.

Chemical Extraction .... chemical solvents are circulated across the surface of a structure to solubilize the contaminants. The debris and chemicals are then collected and decontaminated.

TABLE E-2. Assessment of remediation technology for structures - U, Th, Ra.

Remediation Technologies	Evaluation of Technology					
	Performance			Development		
	Reliability	Effectiveness	Total	Stage of R&D	Info. Available	Total
Demolition/Shredding Treatment	3	4	7	5	4	9
Decontamination/Water Washing	4	4	8	5	4	9
Surface Sealing	2	3	5	5	4	9
Radon Control (b)	2	4	6	5	5	10
Chemical Extraction	4	4	8	5	4	9

References: (a)

Demolition/Shredding Treatment:	1,3#,4,6,8,9,10,11,14,18,25,26,27,30,31#,32,37,40,41
Decontamination/Water Washing:	1,3#,4,6,9,10,14,18,25,26,27,31#,32,35,37,40,41
Surface Sealing:	1,3#,9,10,14,27,31#,40,41
Radon Control:	7,13,14,15,16,19,20,21,22,23,24#,28,29,33,34,42,43, 44,45,46
Chemical Extraction:	1,3#,9,10,12,14,17,18,27,31#,39,40,41

(a) For list of references corresponding to reference numbers, see the reference list at the end of this appendix.

(b) Radon remediation techniques have been used with success at Superfund sites. However, they are not intended as permanent measures.

This reference is more comprehensive on the subject technology.

TABLE E-3. Assessment of remediation technology for structures - other radionuclides.

	Evaluation of Technology					
	Performance			Development		
Remediation Technologies	Reliability	Effectiveness	Total	Stage of R&D	Info. Available	Total
Demolition/Shredding	3	4	7	5	4	9
Decontam./Water Washing	4	4	8	5	4	9
Surface Sealing	2	3	5	5	4	9
Radon Control	N/A	N/A	N/A	N/A	N/A	N/A
Chemical Extraction	4	4	8	5	4	9

(U = UNKNOWN)
(N/A = Not Applicable)

References: (a)

Demolition/Shredding Treatment: 1,3#,4,5,6,8,10,11,14,18,25,26,30,31#,32,36,37,38

Decontamination/Water Washing: 1,3#,4,5,6,8,10,11,14,18,25,26,30,31#,32,36,37,38

Surface Sealing: 1,3#,10,14,31#,36,38

Radon Control: Not Applicable

Chemical Extraction: 1,2,3#,10,12,14,17,18,31#,38,39

(a) For list of references corresponding to reference numbers, see the reference list at the end of this appendix.

This reference is more comprehensive on the subject technology.

TABLE E-4. Assessment of remediation technology for structures - mixed waste.

Remediation Technologies	Evaluation of Technology					
	Performance			Development		
	Reliability	Effectiveness	Total	Stage of R&D	Info. Available	Total
Demolition/Shredding Treatment	3	4	7	5	4	9
Decontamination/Water Washing	4	4	8	1	1	2
Surface Sealing	2	3	5	1	1	2
Radon Control (b)	2	4	6	5	3	8
Chemical Extraction	3	2	5	2	3	5

References: (a)

Demolition/Shredding Treatment: 3#,9,14,27,40,41

Decontamination/Water Washing: 3#,9,14,27,40,41

Surface Sealing: 3#,9,14,27,40,41

Radon Control: (c) Not Available

Chemical Extraction: 3#,9,14,17,27,40,41

(a) For list of references corresponding to reference numbers, see the reference list at the end of this appendix.

(b) Radon remediation techniques have been used with success at superfund sites However, they are not intended as permanent measures.

(c) When there was no specific information on the use of a particular technology on a category of contaminant, ratings were developed based on engineering judgment.

This reference is more comprehensive on the subject technology.

TABLE E-5. Considerations for the use of structure remediation technologies

	CONSIDERATIONS		
Technology	**Ra, Th, U**	**Other Radionuclides**	**Mixed Waste**
Demolition/ Shredding/ Treatment	Demolition & shredding produces a sized material that can be treated by soil remediation technologies.	Similar to Ra, Th, U	Reports not available. (See Note) Must address volatilization of contaminants.
Decontamination Water Washing	Washing with water can remove contaminants. Requires water remediation technology for final disposition of waste.	Similar to Ra, Th, U	Reports not available. (See Note)
Surface Sealing	Reduces mobility. Does not remediate source of contamination or reduce radiation.	Similar to Ra, Th, U	Reports not available. (See Note)
Radon Control	Disperses gas; does not remediate source of contamination or reduce radiation.	Not Applicable	Similar to Ra, Th, U
Chemical Extraction	Washing with acids can remove contaminants. Requires remediation technology for final disposition of waste.	Similar to Ra, Th, U	Reports not available. (See Note)

NOTE: When there was no specific information on the use of a particular technology on a category of contaminant, ratings were developed based on engineering judgement and extrapolation from other applications.

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