TECHNOLOGY NEEDS ASSESSMENT FOR DOE ENVIRONMENTAL RESTORATION PROGRAMS

J. R. Duray, T. J. Carlson, C. E. Carpenter, L. E. Cummins and G. J. Daub
Chem-Nuclear Geotech, Inc.*
Grand Junction Projects Office
Grand Junction, Colorado

ABSTRACT

The "Technology Needs Assessment Final Report" describes current and planned environmental restoration activity, identifies technologies intended to be used or under consideration, and ranks technology deficiencies in the U.S. Department of Energy's environmental restoration program. Included in the ranking are treatment technologies, characterization technologies, and non-technology issues that affect environmental restoration. Data used for the assessment was gathered during interviews in the spring of 1991 with DOE site personnel responsible for the environmental restoration work.

INTRODUCTION

The U.S. Department of Energy (DOE) is depending on results from its technology development program to address DOE's environmental restoration problems. New, improved, and innovative technologies are needed if the DOE is to meet its environmental restoration goals within its 30-year schedule. The technologies employed must not only be safe for environmental restoration workers but also must produce results that protect the health of future generations. The magnitude of the DOE's environmental restoration problems is so vast and complex that choices must be made now – choices that are cost effective, maximize safety, give significant leverage to the program schedule, and speed up the environmental restoration activities.

To facilitate the determination of its priority needs, the DOE Office of Environmental Restoration sponsored the Technology Needs Assessment (TNA). The objective of the TNA is to identify and rank technology deficiencies within the environmental restoration program. Any substantive issue or concern inhibiting the implementation of an environmental restoration (i.e., a technology deficiency) is a candidate for technology development. An important goal for the TNA was to complete the study quickly. The study began in January 1991 and concluded with delivery of the final report during the first week in August 1991.

Information on environmental restoration and decontamination and decommissioning topics was gathered primarily through personal interviews with the DOE and contractor personnel directly responsible for the environmental restorations. Environmental restoration problems, candidate technologies considered for restoration action, and technology deficiencies associated with the candidate technologies were obtained from site personnel and are listed in the "TNA Final Report." Thus, the Technology Needs Assessment is a needs-driven assessment.

Assembly, organization, and analyses of information obtained from the entire DOE complex was, as expected, formidable and complicated. Specific environmental restoration problems were identified at the sites. However, many of the sites' characterization activities were not started or were incomplete. Where characterization was complete or at an advanced stage, the environmental restoration problem was, in many cases, found to be complex and involved a combination of needs with unique constraints, such as agreements with State and Federal regulatory agencies. The challenge is to determine which technologies require immediate attention and which can be deferred. Adding to this complexity are non-technical issues that influence, often predominately, an environmental restoration. These issues, concerns, circumstances, etc., are grouped under the category "other factors." This category includes non-technical issues that inhibit successful implementation of a restoration technology. Typical examples are such issues as public acceptance, conflicting or ambiguous regulatory requirements, Federal procurement constraints, etc.

TECHNICAL APPROACH

Many previous ranking methods have used numerical "score and weight" factors. Decisions made on the basis of these methods often are contentious because they do not adequately account for all the information that must be considered to reach a decision.

In response to this criticism, the Council on Environmental Quality and the U.S. Environmental Protection Agency restructured the National Environmental Policy Act (NEPA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) evaluation of alternatives with a qualitative discussion of all factors except cost and risk assessment. Accordingly, a qualitative approach was selected for this TNA because it is more flexible at matching solutions to needs. Although our subjective approach may appear less rigorous, it is more defensible because it does not rely on a rigid algorithm that acts as an opaque barrier between the results and the input data.

Major steps of the TNA that describe the approach are briefly described in the following paragraphs.

Site visits were made to seven of eight DOE Field Offices and Rocky Flats and Fernald sites. Guidance about the type of environmental restoration information to be sought by the TNA team was provided to site personnel in advance. The site personnel interviewed were those directly responsible for the environmental restoration work. These interviews provided

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the TNA team with an efficient means to quickly gather data and to clarify details about a site's environmental restoration activities.

Organize data from site visits. Organization of site data was facilitated by use of a computer data base (PARADOX, Version 3.5). For each problem unit at a site, a contaminant classification (e.g., high-level waste, mixed, organic, etc.) is assigned. The data base includes contaminant(s), concentration and volume (if known), media, and unique circumstances (if any). Each problem- unit description lists social/political issues, human and environmental risk, and the schedule for the restoration action as well as relevant technologies under consideration to complete the restoration. Site personnel were also asked if a technology deficiency existed that prevented intended use of the technology under consideration.

Quality assurance of site information obtained was done by personnel from each site who verified the data that the TNA team recorded. A trip report, consisting of the information gathered by the TNA team from the site interviews, was sent to site personnel for review. An appendix to the Final Report contains all the trip reports, each revised according to the site's review comments.

Data evaluation consisted of a methodical process to classify information. Three categories of need were considered: environmental restoration, characterization, and "other factors." Environmental restoration problem-unit information and the technologies considered for application, characterization needs, and "other factors" were grouped to facilitate ranking.

A peer review panel, composed of academic and industrial environmental restoration experts, reviewed the technologies considered or planned by site personnel for characterization and restoration. The goals of the panel were to (1) evaluate the technology appropriateness, (2) identify deficiencies, (3) suggest additional technologies, and (4) offer comments relative to the ranking of technology deficiencies. The panel's independent perspective is contained in an appendix to the Final Report.

Prioritization of environmental restoration deficiencies is outlined in Table I. The ranking of technology deficiencies consisted of a two-step process. First, environmental restoration problems were classified, grouped, and sorted. Sorting into high, medium, and low categories was done according to responses to five problem criteria (Table I). The

TABLE I

Process Outline for Ranking Environmental Restoration Technology Deficiencies

Process	Criteria
1. Classify environmental restoration technologies considered by sites.	Five major technology group plus two additional groups. 1) Removal/recovery 2) Ex situ treatment 3) In situ treatment 4) In situ isolation/containment 5) Disposal 6) No action 7) Treatment unspecified
2. Classify each sites' problem units (total of 26 categories).	Ten primary problem group categories; 22 subgroup categories. 1) Basins/Ponds--Soils 2) High-Use Areas--Soils 3) Soils--General 4) Burial Grounds 5) Containerized Waste 6) Ground Water 7) Radioactive Biota 8) Underground Detonation Sites 9) Surface Water 10) D&D
3. Rank environmental restoration problem groups	Five problem criteria. 1) Unique DOE qualifications required? 2) Solve deficiency and solve significant problems? 3) Is problem significant health or environmental risk? 4) Is problem widespread in DOE complex? 5) Does technology exist that was successful on similar problems?
4. Rank deficiencies associated with high-ranked problem groups.	Three deficiency criteria. 1) Is deficiency significant to restoration? 2) Does deficiency apply to multiple problems? 3) Does deficiency help resolve other deficiencies?

grouping process preserved the relationship between environmental restoration problems and technology deficiencies by the intermediate-stage ranking of environmental restoration problem groups. Second, the technology deficiencies associated with problem units were ranked high, medium, and low by responses to three deficiency criteria (Table I). A two-step process was also used to rank characterization needs and "other factors" that influence environmental restorations.

ENVIRONMENTAL RESTORATION NEEDS

Nearly 300 environmental restoration problems, 100 candidate technologies, and 640 technology deficiencies were recorded during interviews and through correspondence with site personnel.

Environmental restoration activities throughout the DOE complex are at various phases of project activity. However, many activities are only in the initial stages of characterization, although some sites had some remedial activity underway. Generalizations of the problem categories had to be made to accommodate this diversity and also for those situations where the problem descriptions were not well defined.

Site personnel described environmental restoration problems according to each site's convention and convenience. The resulting specific problem descriptions (called problem units) varied from site to site. A problem unit is defined as (1) a single operable unit, (2) all problems existing in a given geographical area at a site, or (3) all problems at a site that are similar.

Problem-unit diversity required a sufficiently general means to group similar problems but be meaningful enough to retain problem uniqueness. Because most deficiencies identified by site personnel were associated with physical or chemical attributes, these attributes were used to group problem units and to link the associated deficiencies to general technology groups. The group categories were chosen to distinguish the relevant (known) aspects of the environmental restoration problems.

Candidate technologies were classified into seven categories. Five of the groups were treatment technology specific: removal/recovery, ex situ treatment, in situ isolation/containment, disposal, and in situ treatment. The other two categories were no action (non-treatment/non-removal) and treatment "not specified."

Problem units were grouped into 10 primary categories, including decontamination and decommissioning (D&D), and 22 subcategories for a total of 26 categories. The primary categories (Fig. 1) are generally based on physical properties while the subcategories (not shown) are based on chemical properties. If multiple problems exist within a problem unit, the unit is classified in all relevant categories.

The problem groups were then ranked according to five problem criteria:

1. Is the contaminant one that the DOE is uniquely qualified to address?
2. Does the deficiency solve a significant contamination problem in terms of source, volume, or toxicity?
3. Does the contamination represent a significant current or near-term potential risk to workers, the public, and/or the environment?
4. Is the environmental restoration need widely identified across the DOE complex?
5. Have other similar environmental restoration needs been successfully addressed with existing technologies?

Of the 26 total categories, 12 are ranked high, 9 are ranked medium, and 5 are ranked low. In general, the high-ranked problems are those with radioactive- or mixed-waste contamination, constitute a current or potential source of groundwater contamination, and are common throughout the DOE complex.

The 12 high-ranked problem groups are

- Soils--Basins/Ponds
  - Low-level waste with or without metals
  - Mixed low-level and hazardous waste

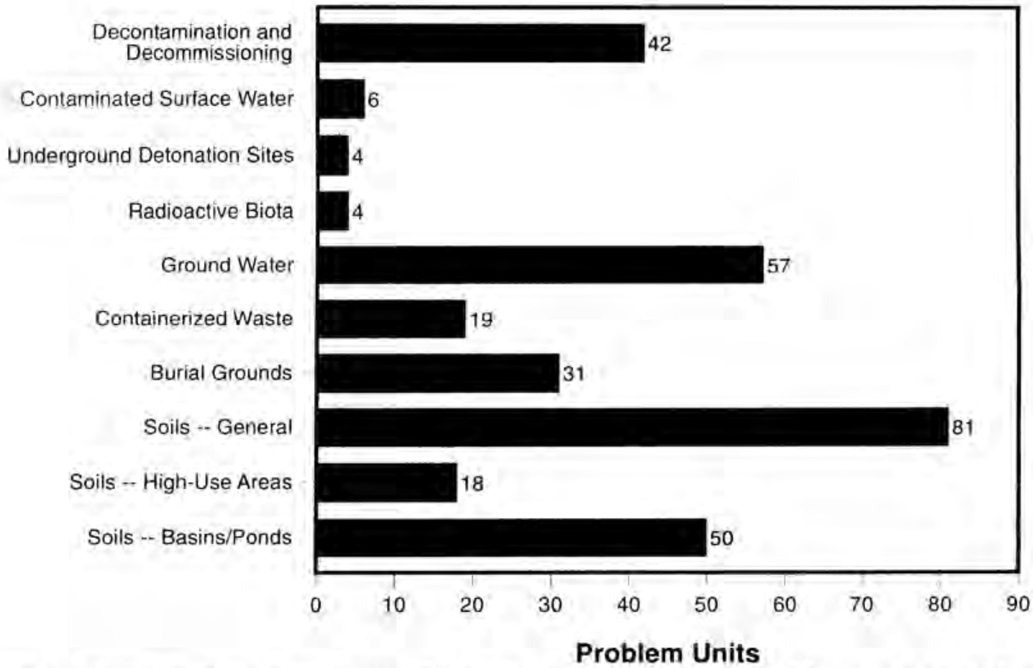

Fig. 1. Primary problem group categories used to sort problem units and frequency of citation.

- Soils--High-Use Areas
  - Radioactive (all types) and hazardous waste
  - Soils with low-level waste that surrounds piping, tanks, and buildings
- Burial Grounds
  - Low-level or non-hazardous waste
  - Mixed low-level waste and hazardous organic waste
- Containerized Waste
  - Sludges in tanks with radioactive (all types) and hazardous waste
- Ground Water
  - Radioactive (no tritium) and hazardous waste
  - Tritium and hazardous waste
  - Tritium
- Decontamination and Decommissioning

Deficiencies associated with the high-ranked problem groups were then ranked according to three deficiency criteria:

1. Does the deficiency significantly hinder the selection and implementation of a given technology?
2. Does the deficiency apply to multiple environmental restoration needs by virtue of contaminants or media addressed?
3. Does solving the deficiency aid in the resolution of other deficiencies associated with the same or other technologies?

A technology deficiency is the reason a technology fails to successfully meet the environmental restoration need. Clearly, a deficiency is related to the associated technology (or technology group) and also to the environmental restoration need (problem group). The resulting high-ranked technology deficiencies, listed according to technology group, are given in Table II. Specific technologies cited by site personnel for the high-ranked technology deficiencies are listed in Table III.

The "no action" or "non-treatment/non-removal" technology group does not require any treatment technology development. Yet, the deficiency is the methodology to establish if restoration action is needed. Some specific deficiencies mentioned by site personnel regarding the "no action" alternative are the inability to establish short-term and long-term risk because of "no action" and inadequate monitoring methods.

CHARACTERIZATION NEEDS

Characterization needs comprise any activity or system that supports the identification and understanding of a site's physical and chemical properties. Site personnel identified approximately 250 characterization needs.

Ranking the characterization needs consisted of (1) classify the needs and (2) determine answers to five criteria for each classification. The characterization needs were then sorted into high, medium, and low categories on the basis of answers to the five criteria and the professional judgment of the TNA team.

Eleven primary characterization need categories are shown in Fig. 2; the 24 separate subcategories are not shown.

The five criteria used for ranking characterization needs are

1. What can be gained by focusing research and development resources on this characterization need?
2. How many environmental restoration problems require this characterization need and are they significant problems?
3. If characterization needs are not resolved, can existing characterization technologies allow remedial action decisions with a reasonable level of uncertainty?
4. If characterization needs are not resolved, can existing characterization technologies provide an acceptable level of worker safety?

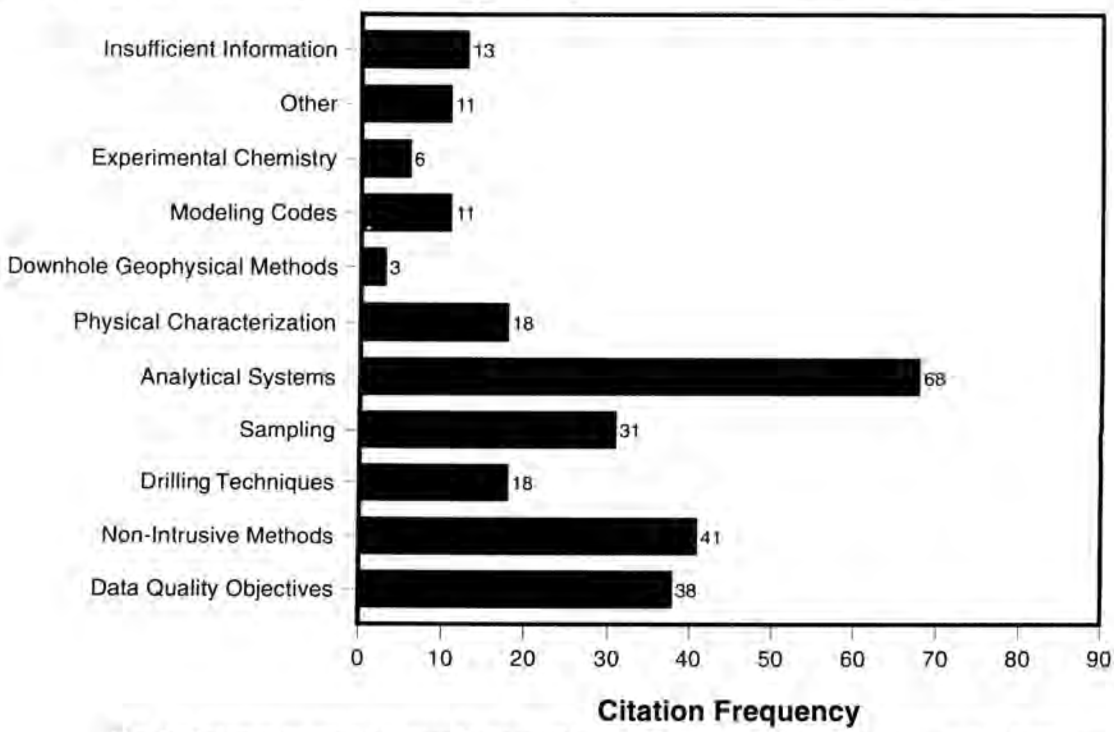

Fig. 2. Categories used to classify sites' characterization needs and frequency of citation.

TABLE II

Summary of Actions Needed To Address High-Ranked Technology Deficiencies and Associated Technology Groups

Technology Deficiency	Technology Group
Improve worker safety and protect public health during removal of wastes, particularly for high-level or high-activity wastes.	Removal/recovery
Develop better waste minimization methods during removal or subsequent decontamination for all waste types.	Removal/recovery and disposal
Develop better methods to minimize secondary waste during ex situ treatment of all waste types and to stabilize and evaluate secondary waste forms.	Ex situ treatment
Develop more efficient and effective methods for ex situ treatment, particularly for D&D.	Ex situ treatment
Develop better separation and partitioning methods.	Ex situ treatment
Establish performance criteria; develop methods for verifying and monitoring that criteria are met for in situ treatment and isolation for all waste types.	In situ treatment, in situ isolation, or containment
Remove uncertainty regarding long-term effectiveness of in situ isolation methods.	In situ isolation or containment
Develop criteria for disposal of mixed wastes and establish policy for siting of disposal facilities.	Disposal
Develop better methods to evaluate the remediation need and the setting of remediation goals.	No action

5. Would resolution of characterization needs significantly reduce costs and/or time compared with existing characterization technologies?

Ranking put 10 characterization needs in the high category, 11 in the medium category, and 7 in the low category. Information was insufficient to rank one category. The 10 characterization needs ranked high are

- Data Quality Objectives
  - Development of a uniform approach for data quality objectives.
- Non-Intrusive Methods
  - Non-intrusive methods to determine the location of buried waste areas, waste forms, and utilities.
  - Non-intrusive methods to locate and/or identify buried contaminants.
  - Better methods to characterize the subsurface geology.
- Sampling
  - Improved remote-sampling techniques for tank sludges and other media that may contain high-level wastes.
- Analytical Methods
  - Field analysis equipment to provide real-time analytical capabilities.
  - Fixed-base laboratories to provide faster sample turnaround time.
  - Remote systems for analysis in isolated or hazardous areas.
- Physical Characterization
  - Improved methods to evaluate tank integrity and to identify leaks in tanks.
  - Equipment for in situ measurement of physical properties of tank wastes.

Generally, the 10 high-ranked characterization needs are complex-wide problems and, if successfully addressed, would improve worker safety, contribute to meeting schedule commitments, and result in cost savings when compared with available baseline technologies.

OTHER ENVIRONMENTAL RESTORATION FACTORS

Non-technology issues were consistently mentioned as obstacles to environmental restoration by site personnel. These issues are called "other factors." The "other factors" were grouped into 10 primary categories (Fig. 3) and 8 subcategories for a total of 16 categories; more than 215 issues were grouped and then ranked.

The three criteria used for ranking are

1. How many environmental restoration problems were identified with "other factors"?
2. How will the successful resolution of the "other factors" benefit the environmental program?

TABLE III

Technologies Under Consideration By Site Personnel That Correspond to High-priority Technology Deficiencies

Technology Group	Technology	Deficiency
Removal/recovery	Excavation Mechanical removal Remote retrieval Pumping (water)	Worker safety; public protection
Removal/recovery	Excavation Pumping (sludge)	Waste minimization during removal; decontamination
Ex situ treatment	D&D technologies Reverse osmosis (water) Incineration Soil washing	Minimize secondary waste; stabilization
Ex situ treatment	D&D technologies Ion exchange (water) Liquid membrane (water) Electrodialysis Ultrafiltration Precipitation (water) Activated carbon (water)	Improve efficiency and effectiveness
Ex situ treatment	Bioremediation Complexant destruction Solidification Vitrification Molecular recognition Polyethylene encapsulation Soil washing	Separation and partitioning
In situ treatment	Barriers	Performance verification and monitoring criteria
In situ isolation, containment	Grouting Flushing Solidification Bioremediation	
In situ isolation, containment	Capping Grout curtain Barriers Grouting Vitrification	Long-term effectiveness
Disposal		Mixed-waste disposal criteria
No action		Determine remediation need

3. What are the consequences to the environmental program if these "other factors" are not resolved?

Eight "other factors" are ranked high, five are ranked medium, and three are ranked low. The non-technology issues or "other factors," which include two educational issues, ranked high are

- Lack of waste disposal options and a mixed-waste policy.
- Issues related to cleanup goals, risk assessment, and or/future land use.
- Issues related to regulatory acceptance.
- Issues related to public acceptance.
- Data evaluation and management.

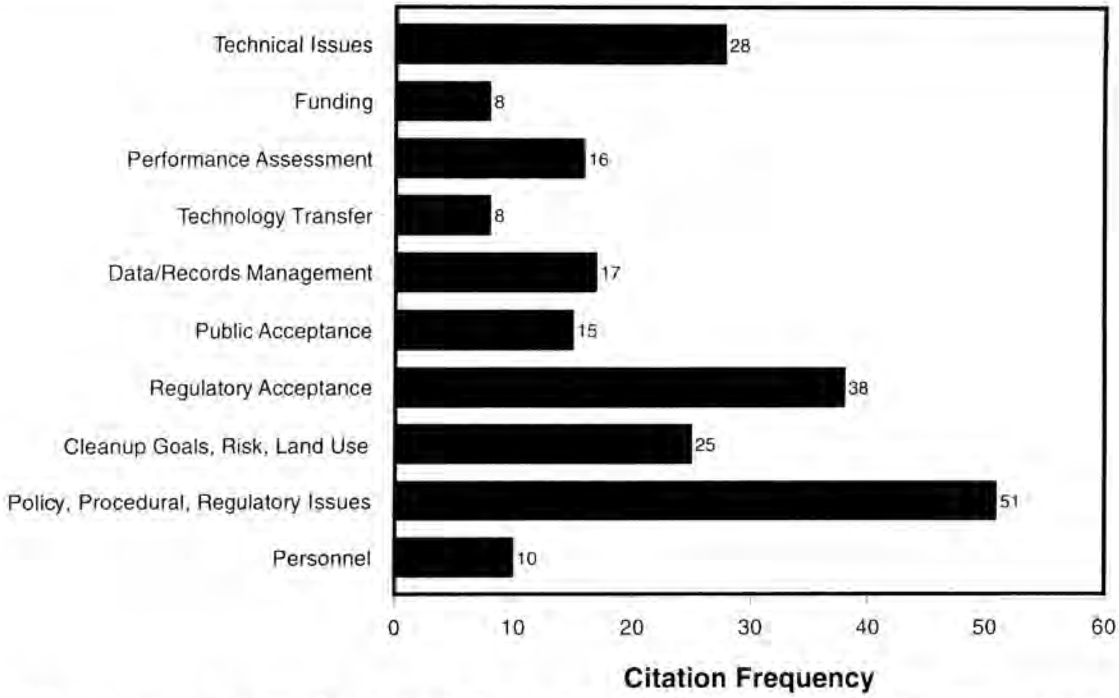

Fig. 3. Categories used to classify non-technical issues of "other factors" and frequency of citation.

- Performance assessment of environmental restoration options.
- Personnel-related issues.
- Issues related to technology transfer.

DISCUSSION

The complexity of the environmental restoration program is staggering. At the beginning of the TNA project, the expectation was to learn 80 to 90 percent of the problem picture, the technology needs, and the technology deficiencies. Even with this expectation, the challenge to set priorities was and is formidable. What are foremost among the identified high-priority problems to address first?

More than 70 percent of the problems recorded in the TNA Final Report involved radioactive- or mixed-waste contamination. Contaminated soil, buried materials, and sludge in buried and possibly leaking tanks are the major sources of ground-water contamination. However, the major volume of contamination will consist of debris from decontamination and decommissioning activities unless significant and waste-minimizing decontamination technologies are developed. Clearly, waste minimization methods, including improved separation and partitioning methods, are needed for D&D (and mixed-waste) as well as an increase in waste storage capacity.

Perhaps the most significant obstacles to the cleanup of radioactive and mixed waste result from the absence of a mixed-waste policy (other waste disposal options), risk assessment criteria, well-defined cleanup goals, and realistic land-use scenarios.

The high-priority characterization needs clearly address the major sources of the DOE's contamination and also have significant application to hazardous waste. New and improved non-intrusive characterization techniques and remote systems will protect workers and help maintain public confidence about environmental restoration activities. The improvements in these characterization needs are directly applicable to the major sources of ground-water contamination. Improved sampling methods are needed not only for characterization purposes but also to protect workers in hazardous areas. New and improved analytic field equipment also contributes to worker safety and provides real-time data for screening and action decisions. The establishment of data quality objectives is of special significance because it addresses the most frequently asked question about the quality and, indirectly, the quantity of data necessary to support environmental restoration decisions. More qualified laboratories are needed to provide decision-quality data.

In situ isolation and treatment actions are hindered by lack of criteria that specify acceptable performance as well as methods to verify and monitor the performance. Unless performance criteria, acceptable verification and monitoring methods, and long-term effectiveness criteria are developed, in situ environmental restoration actions cannot be considered effective. Therefore, technology development emphasis must be given to removal and ex situ treatment technologies.

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