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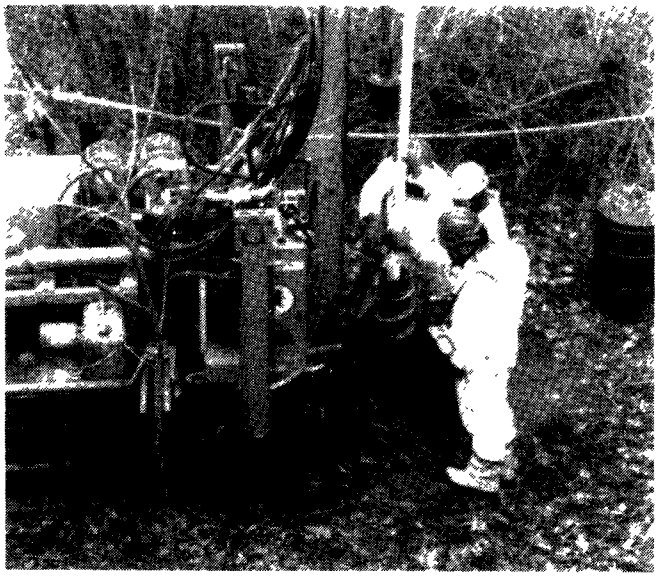
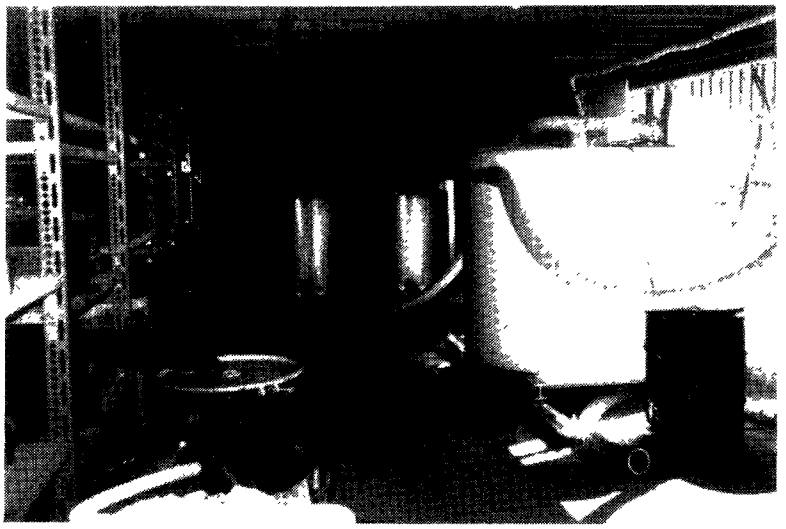
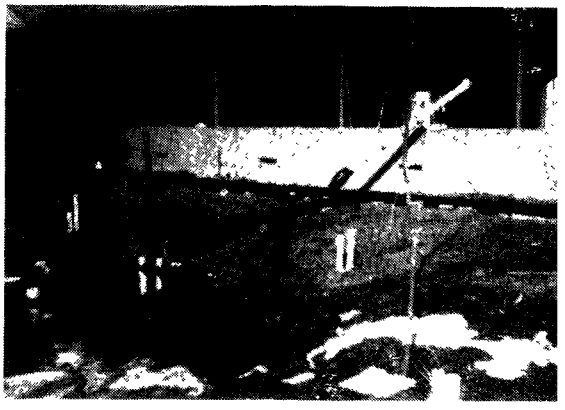
Superfund Research Plan

1989 - 1990







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Superfund Research Plan
1989 — 1990

Superfund Research Subcommittee
Hazardous Waste/Superfund Research Committee
Office of Research and Development
United States Environmental Protection Agency
Washington, DC 20460

December 1989

This research plan was prepared under the direction of the Superfund Research Subcommittee from materials provided by the Office of Research and Development and the Office of Solid Waste and Emergency Response. Comments or questions regarding this research plan should be directed to:

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This document was revised and updated in December 1989, to incorporate FY90 resources and changes.

PREFACE

EPA's Superfund research is a complex program, drawing together scientists and engineers from thirteen EPA laboratories, several dozen university research centers, other federal agencies, and hundreds of individual research grants. EPA's Office of Research and Development (ORD) prepared this *Superfund Research Plan* as an overview of this complex program, born from our recognition that the broad spectrum of Superfund research activities is almost impossible to comprehend from individual research plans, budget documents, or specialized reports.

Superfund research is changing, reflecting new impetus from the Regions and client offices, as well as in response to a recent management review of the Superfund program. This review provided a number of recommendations for a more effective, more efficient Superfund program. Two of the major recommendations in that review are directly relevant to the Agency's Superfund research program: (1) the need for extensive technical assistance, expert advice, and information transfer; and (2) additional emphasis on demonstration and evaluation of new treatment technologies for Superfund sites.

ORD has moved aggressively to augment its technical support programs to the Regions. In addition to its on-going program of fundamental research, development and evaluation, and field procedures and guidance, ORD has initiated a variety of new programs. These include:

- Establishment (together with the Office of Solid Waste and Emergency Response) of technical support centers to respond quickly to field requests.
- Increased number of staff devoted to providing technical assistance among laboratories and Regions.
- Restructured health and risk assessment research to better correspond with the specific requirements of the Superfund program offices.
- Establishment of a special technology assistance team to work at highly complex Superfund sites along with the Regional program managers.
- Establishment of a joint position in each EPA Region to serve as technical liaison to ORD laboratories.
- Increased funding and EPA facilities for evaluating remedial treatment technologies to better assist Regional managers in evaluating options.

This *Superfund Research Plan* outlines the overall research framework, from fundamental research to direct technical assistance. It describes the research activities that are underway or planned, how the program is changing in response to emerging needs, and the basis for research priorities. Superfund research focuses on an exciting array of technical questions: biological degradation of hazardous waste and other innovative treatment technologies; advances in subsurface monitoring techniques and portable field-monitoring equipment; understanding ecological impacts and non-cancer human health risks posed by Superfund sites; and many others. The goal of our research is to provide a better technical understanding of the health and ecological risks at Superfund sites and remediation technologies, and to provide the information and tools needed to assess and clean up specific sites.

Erich W. Bretthauer
Acting Assistant Administrator
Office of Research and Development

EXECUTIVE SUMMARY

This Superfund Research Plan describes the Environmental Protection Agency's (EPA's) research program to reduce or eliminate risks posed by uncontrolled releases of hazardous substances into the environment. It presents the Office of Research and Development's (ORD's) coordinated approach for delivering technical information to Superfund-related personnel and is intended to help Agency, Office of Management and Budget, and Congressional reviewers better understand the details of the Superfund research program for fiscal years 1989 and 1990. The plan encompasses all research, development, demonstration, and technical assistance undertaken by ORD offices and laboratories in support of the Superfund program, and discusses the coordination of similar research by other agencies.

The original Superfund law, the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), was envisioned as a cleanup effort that would use existing knowledge to assess and clean up the nation's abandoned hazardous waste sites. It was soon recognized, however, that better tools and information would be needed to assess risks at sites, to understand potential effects on human health and the environment, and to provide reliable, cost-effective cleanup solutions.

The Superfund Amendments and Reauthorization Act of 1986 (SARA), signed on October 17, 1986, made major changes to the original Superfund law. The amendments mandated strict cleanup standards strongly favoring permanent remedies at waste sites; stronger EPA control in settlement with parties potentially responsible for waste sites; a mandatory schedule for initiation of cleanup work and studies; assessment of the potential threats to human health posed by each waste site; and increased state and public involvement in the cleanup decision-making process. SARA also explicitly authorized the Environmental Protection Agency, in concert with several other agencies, to conduct hazardous waste research, development, and demonstrations and to aggressively pursue a program of technology transfer and training.

To meet the technical and scientific needs of the EPA, state, local, and private sector personnel involved in cleaning up Superfund sites, ORD's research, development, and demonstration program has been designed to improve the accuracy and timeliness of human health and environmental risk assessments, improve information on the performance and availability of treatment technologies that offer permanent protection of human health and the environment, and provide direct technical assistance to personnel in the field involved in the remedial process. The target audiences of Superfund research are EPA Emergency and Remedial Response, Waste Programs Enforcement, and Regional, state, and local Superfund site assessment and cleanup personnel, including on-scene coordinators, remedial project managers, supporting independent contractors, emergency response teams, treatment technology firms, and potentially responsible parties.

ORD's research program is divided into *fundamental research, development and evaluation, field procedures and guidance*, and *technical support*. This organization reflects ORD's objective of improving risk assessment and risk reduction technologies available for use in the field. *Fundamental research* expands the knowledge base from which innovative methods may spring. *Development and evaluation* utilizes new concepts to increase the number and effectiveness of risk assessment techniques and treatment technologies available for use at contaminated sites. The development of *field procedures and guidance* packages information from development and evaluation to improve their use in the field. *Technical support* supplies direct expert assistance to field personnel.

Within this overall research structure, ORD's research program is arranged into eight broad technical areas to assign responsibilities and to provide the framework for planning, budgeting, and justifying the research program. These issues represent the greatest scientific and engineering needs of the Superfund program.

- *Technical Assistance at Specific Sites.* Reviews remedial action design and implementation plans, and provides technical expertise and review to OERR, the Office of Waste Programs Enforcement (OWPE), and the Regions.

- *Quality Assurance for Field Sampling and Laboratory Analysis.* Ensures comparable, legally defensible environmental measurements by providing support to the national Contract Laboratory Program, developing laboratory and field analytical methods for chemical measurements and characterization, and reviewing quality assurance and quality control plans.

- *Field Methods for Superfund Site Assessment and Cleanup.* Provides techniques and procedures to allow on-scene coordinators and remedial program managers to quickly and effectively assess the degree of hazard posed at specific sites. This includes the evaluation of technologies needed to ensure personnel health and safety during removal and cleanup operations and the development of information on carcinogenicity and chronic health effects needed by the Office of Emergency and Remedial Response (OERR) to adjust reportable quantities for specific chemicals.

- *Manuals and Training Seminars.* Disseminates information and conducts training seminars for OERR, Regions, States, and local authorities to assist them in Superfund site cleanup.

- *Performance of Treatment Technologies.* Develops and evaluates technologies, techniques, and construction materials that may provide cost-effective control of hazardous waste releases but require additional laboratory development to be ready for field application.

- *Superfund Innovative Technology Evaluations (SITE) Program.* Conducts research, development, and demonstrations that promote commercialization of alternative treatment and monitoring technologies.

- *Health Effects, Risk Assessment, and Detection Techniques.* Conducts research and development to enhance the scientific capabilities to quickly detect potentially hazardous environmental contaminants, evaluate human health effects, and assess risks to human health from hazardous substances.

- *University-Based Fundamental Research.* Provides long- and short-term research, training, and technology transfer related to the manufacture, use, transportation, disposal, and management of hazardous substances through university research centers and competitively awarded grants to universities.

While the Superfund research program is the responsibility of the Assistant Administrator for ORD, all Superfund resources remain the responsibility of the Assistant Administrator of the Office of Solid Waste and Emergency Response (OSWER), through the Director of OERR. This division of authorities is unique within the EPA research program, and requires extremely close cooperation and working relationships between ORD and OSWER senior managers and technical staff. This is accomplished by formal and informal interactions with OSWER and Regional managers and technical staff.

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LIST OF ACRONYMS

ACL	Alternative Concentration Limit
AIChE	American Institute of Chemical Engineering
ARAR	Applicable and Relevant and Appropriate (Federal and State Standards)
ATSDR	Agency for Toxic Substances and Disease Registry
BDAT	Best Demonstrated Available Technology
CDF	Confined Disposal Facilities
CEAM	Center for Exposure Assessment Modeling
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CLP	Contract Laboratory Program
COLIS	Computer On-Line Information System
CRF	Combustion Research Facility
CSS	Countermeasures Selection System
DOD	Department of Defense
DOE	Department of Energy
EPA	Environmental Protection Agency
E-TEC	Environmental Testing and Evaluation Center
FS	Feasibility Study
FTIR	Fourier-Transformed Infrared
FTTA	Federal Technology Transfer Act
GAP	Graphic Activity Profile
GC/MS	Gas Chromatography/Mass Spectrometry
GIS	Geographical Information System
HEED	Health and Environmental Effects Documents
HRS	Hazard Ranking System
HSRC	Hazardous Substance Research Center
HSWA	Hazardous and Solid Waste Amendments of 1984
IFB	Invitation for Bid
KPEG	Potassium Polyethylene Glycol
MCL	Maximum Contaminant Level
NCP	National Contingency Plan
NEIC	EPA National Enforcement and Investigation Center
NIEHS	National Institute for Environmental Health Sciences
NOAA	National Oceanic and Atmospheric Administration
NPL	National Priorities List
NTIS	National Technical Information Service
OER	EPA Office of Exploratory Research
OERR	EPA Office of Emergency and Remedial Response
ORD	EPA Office of Research and Development
ORPM	EPA Office of Research Program Management

OSC	On Scene Coordinator
OSW	EPA Office of Solid Waste
OSWER	EPA Office of Solid Waste and Emergency Response
OWPE	EPA Office of Waste Programs Enforcement
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PET	Photon Emission Tomography
PCP	Pentachlorophenol
PE	Performance Evaluation
POTW	Publicly-Owned Treatment Work
PPA	Planned Program Accomplishment
PRP	Potentially Responsible Party
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
QARM	Quality Assurance Reference Material
RA	Remedial Action
RAS	Routine Analytical Services
RCRA	Resource Conservation and Recovery Act of 1976
RD	Remedial Design
R&D	Research and Development
RFA	Request for Application
RI	Remedial Investigation
ROD	Record of Decision
RPM	Remedial Project Manager
RQ	Reportable Quantity
RRAR	Regional Risk Assessment Review
SAB	EPA Science Advisory Board
SAR	Structure-Activity Relationship
SARA	Superfund Amendments and Reauthorization Act of 1986
SAS	Special Analytical Services
S&E	Salaries and Equipment
SI	Site Inspection
SITE	Superfund Innovative Technology Evaluations (Program)
SPHEM	Superfund Public Health Evaluation Manual
SRIC	Subsurface Remediation Information Clearinghouse
S/S	Stabilization/Solidification
STARA	Studies on Toxicity Applicable to Risk Assessment (Database)
TCE	Trichloroethylene
TCL	Target Compound List
THC	Total Hydrocarbons
TIX	Technical Information Exchange
TOC	Total Organic Carbon
VOC	Volatile Organic Carbon
XRF	X-Ray Fluorescence

INTRODUCTION

PURPOSE AND SCOPE

This *Superfund Research Plan* describes the Environmental Protection Agency's (EPA's) research program for FY89 and FY90 in support of the nationwide Superfund program to reduce or eliminate risks posed by uncontrolled releases of hazardous substances into the environment. The plan presents the Office of Research and Development's (ORD's) coordinated approach for delivering technical information to Superfund personnel and is intended to help Agency, Office of Management and Budget, and Congressional reviewers understand the details of the Superfund research program. The plan encompasses all research, development, demonstration, and technical assistance undertaken by ORD offices and laboratories in support of the Superfund program, and discusses the coordination of similar research by other agencies.

In September, 1987, ORD updated its *Superfund Research, Development, and Demonstration Strategy and Program Plan*, which presents an overview of the research and development system and sets goals and objectives for the research program over the five-year period FY87 through FY91. The *Strategy* was developed to guide the Superfund office and the Agency in setting research priorities and allocating resources, to aid in coordination among federal agencies that conduct Superfund-related research, and to assist ORD scientists and engineers in understanding the programmatic context of their work. This *Superfund Research Plan* is a companion document to the *Strategy*, covering in more detail the research needs, approaches, and outputs of ORD's Superfund research program for two of the years covered by the five-year *Strategy*.

LEGISLATIVE MANDATE

The original Superfund law, the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), was envisioned as a cleanup effort that would use existing knowledge to assess and clean up the nation's abandoned hazardous waste sites. It was soon recognized, however, that better tools and information would be needed to assess risks at sites, to understand potential effects on human health and the environment, and to provide reliable, cost-effective cleanup solutions.

Although CERCLA did not explicitly authorize EPA to conduct research and development, ORD did provide extensive technical support to the Superfund program in several areas, including development of techniques and procedures needed to assess sites, evaluation of technologies to manage uncontrolled waste sites, and provision of information on personnel protection technologies, direct technical assistance to Superfund, enforcement, and Regional offices, and technical oversight for data quality assurance. These technical assistance efforts are continuing.

The Superfund Amendments and Reauthorization Act of 1986 (SARA), signed by the President on October 17, 1986, made major changes to the original Superfund law. The amendments included strict cleanup standards strongly favoring permanent remedies at waste sites, stronger EPA control in settlements with parties responsible for waste sites, a mandatory schedule for initiation of cleanup work and studies, improved assessments of the

potential threats to human health posed by each waste site, and increased state and public involvement in the cleanup decision-making process. To support this markedly changed approach to managing uncontrolled wastes, SARA explicitly authorized the Environmental Protection Agency, in concert with several other agencies, to conduct hazardous waste research, development, and demonstrations and to aggressively pursue a program of technology transfer and training.

The overall objective of the comprehensive federal research program authorized by SARA is to improve the scientific and technical basis of the Agency's cleanup decisions at sites contaminated by uncontrolled hazardous substances. Two SARA requirements, in particular, directly affect research priorities: the needs for improved human health risk assessments and improved treatment technologies that offer permanent protection of human health and the environment. The new cleanup standards illustrate the statutory intent in these areas. SARA requires that remedial actions protect human health and the environment, be cost-effective, and be in accordance with the requirements of the National Contingency Plan. They must use, to the maximum extent practical, permanent solutions and alternative treatment or resource recovery technologies. Each technology must be evaluated to determine its long-term effectiveness. Remedial actions must comply with applicable federal and state standards, requirements, criteria, or limitations. Finally, if a remedial action results in any hazardous substance remaining on site, the remedy must be reviewed at least every five years and, if needed, additional action must be taken to ensure the protection of human health and the environment.

Superfund research, development, demonstration, and technology transfer programs at EPA and other federal agencies were expanded in FY87 to respond to several specific SARA provisions:

- §311(b) of CERCLA (§209 of SARA) authorizes an EPA program of research, evaluation, testing, development, and demonstration of alternative or innovative treatment technologies that may be utilized in response actions to achieve more permanent protection of human health and environmental quality.

- §311(b) of CERCLA (§209 of SARA) also authorizes EPA to conduct a technology transfer program, including the development, collection, evaluation, coordination, and dissemination of information relating to the utilization of alternative or innovative treatment technologies for response actions.

- §311(c) of CERCLA (§209 of SARA) authorizes EPA to conduct and support, through grants, cooperative agreements, and contracts, research on the detection, assessment, and evaluation of the effects and risks to human health from hazardous substances and detection of hazardous substances in the environment.

- §311(d) of CERCLA (§209 of SARA) authorizes EPA to establish up to ten Hazardous Substance Research Centers to conduct research, publish research results, and provide training on the manufacture, disposal, and management of hazardous substances.

- §104(i) of CERCLA (§110 of §SARA) authorizes a research program at the Agency for Toxic Substances and Disease Registry (ATSDR) to develop appropriate methods to determine the health effects of hazardous substances frequently found at Superfund sites. The research shall also seek to develop methods to determine the health effects of such substances in combination with other substances (complex mixtures).

- §311(a) of CERCLA (§209 of SARA) authorizes a program at the National Institute for Environmental Health Sciences (NIEHS) to develop advanced techniques for detection and evaluation of the effects on human health of hazardous substances; methods to assess the risks to human health presented by hazardous substances;

methods and technologies to detect hazardous substances in the environment; and basic biological, chemical, and physical methods to reduce the amount and toxicity of hazardous substances.

- Title 10, Chapter 160, of the Internal Revenue Code (§211 of SARA) authorizes the Department of Defense (DOD) to carry out a program of research, development, and demonstration on methods for cleaning up hazardous wastes at DOD facilities. The Defense Environmental Restoration Program is directed to reduce the quantities of hazardous wastes; develop methods for treatment, disposal, and management (including recycling and detoxification); identify toxicological data collection needs and methodologies for evaluating exposure risks; and test, evaluate, and demonstrate innovative technologies in the field.

RISK MANAGEMENT FRAMEWORK

In carrying out the provisions of Superfund legislation, EPA's Office of Emergency and Remedial Response (OERR) follows a risk management process to make decisions on cleaning up Superfund sites. A detailed description of the risk management process is contained in the *Superfund Research, Development and Demonstration Strategy and Program Plan*[1] and is briefly summarized here. Risk management encompasses the assessment of human health and environmental risks posed by hazardous substances, consideration of options to reduce those risks, and selection of remedial actions based on technical, economic, and policy considerations. This process requires that government and industry have the capability to assess, reduce, and manage the human health and environmental risks from uncontrolled hazardous wastes.

Risk assessment, the process of defining risks, has emerged as an important means for determining which contamination problems pose significant environmental and human health risk. It is concerned with examining the source of waste at a site, how the hazardous constituents move through the environment, how people are exposed to these constituents, and the effects of that exposure. The risk assessment process leads to the definition of existing or expected risks.

Risk reduction is the identification of technical and management options to protect public health and the environment from predicted risks. While human health and ecological risk assessments define existing or expected risks, implementation of risk reduction technologies actually mitigate or eliminate the risks associated with Superfund sites. Risk reduction can be accomplished by reducing the source of waste, employing treatment techniques to destroy wastes or render them less hazardous, and disposal technologies to contain or immobilize wastes, thereby preventing human and environmental exposures. The principal goal of Superfund risk reduction research is to provide practical cleanup methods.

Integration of risk assessments and risk reduction options form the basis for risk management decisions. Risk management is the process of making judgments on whether to take action and which action to take. It is the weighing of policy alternatives and selecting the most appropriate action by integrating the results of risk assessment and risk reduction analyses and considering legal, social, economic, equity, and other factors.

[1]EPA Office of Research and Development, September 1987, EPA/600/8-87/050.

SUPERFUND REMEDIAL PROCESS OVERVIEW

EPA policies and procedures for implementing the risk management process are contained in the National Contingency Plan (NCP). The NCP, which is being revised, delineates federal and state response authority for abandoned or uncontrolled hazardous waste sites and methods and criteria for when—and to what extent—a removal or remedial response should be undertaken. In addition, the NCP limits long-term, permanent cleanup actions to sites included on the National Priorities List (NPL), which designates the nation's worst hazardous waste sites. The list has grown to 951 sites; it will ultimately be much larger. The remedial process is summarized in Figure 1.

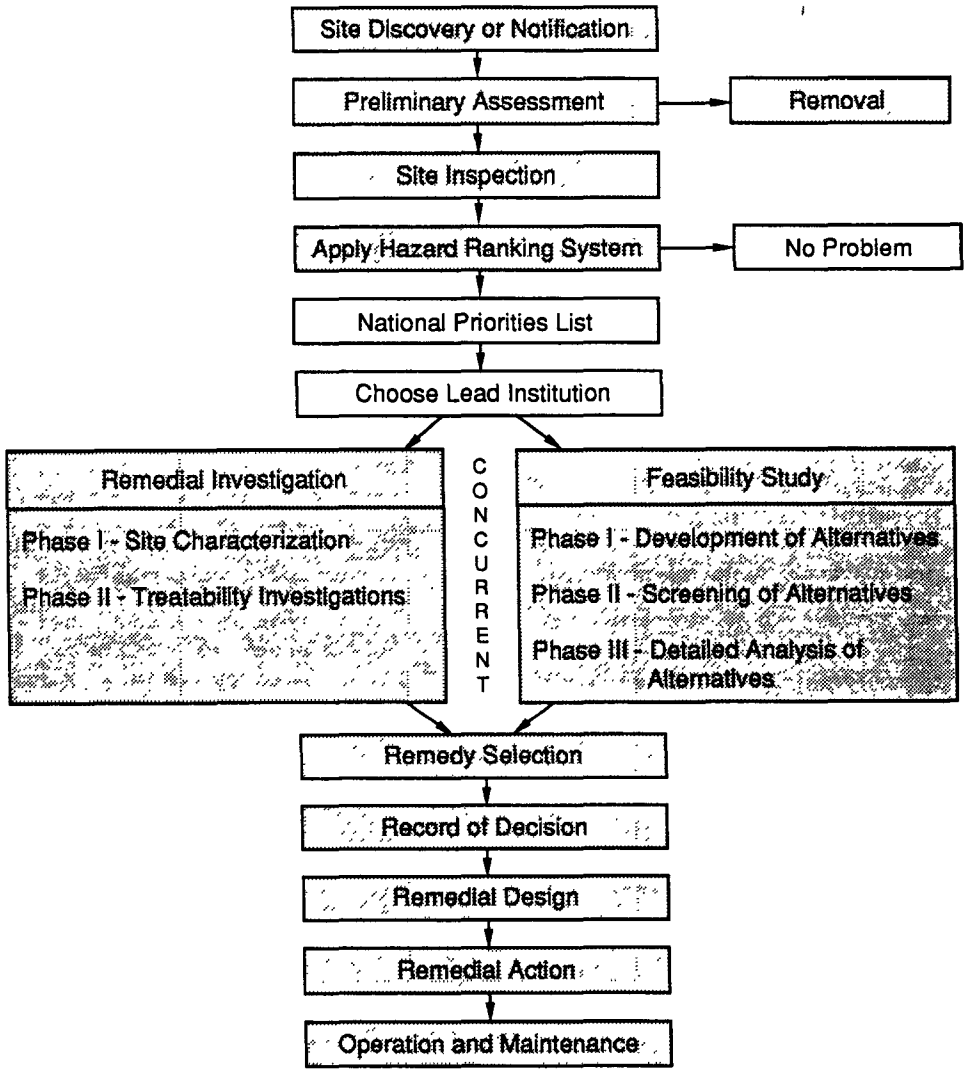


Figure 1. Superfund remedial process. Shaded areas represent those areas of the remedial process that ORD supports.

The first step in EPA's site cleanup process involves receiving a report of a contaminated site. These reports may be generated by local, state, or federal officials or by concerned individuals who have observed possible sources of contamination or illegal dumping. These reports are entered into EPA's database on potentially hazardous sites—the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS). There are now over 27,000 reported sites in CERCLIS.

The next step in the process is the preliminary assessment. Information is obtained from local, state, and federal files to identify the site and perform a preliminary assessment of the site's potential hazards. The preliminary assessment also attempts to develop ideas about the types and quantities of wastes most likely to have been disposed, local hydrological and weather conditions, and the impact on the environment. These assessments may or may not include an actual site inspection.

If a preliminary assessment shows that there is an immediate need to reduce or stop hazardous substance releases or potential releases to the environment, a removal action may be initiated. Removals may occur at any point in the remedial process to abate, stabilize, mitigate, or eliminate the release or threat of release if the lead agency determines that there is a threat to human health or the environment. EPA on-scene coordinators (OSCs) direct Superfund-financed, federal-lead removal activities, which generally do not exceed $2 million or last more than one year.

If a preliminary assessment shows that the site may threaten human health or the environment, a site inspection (SI) will be conducted where inspectors collect sufficient information to rank its hazard potential. EPA currently uses a two-stage approach to site inspections. The first stage involves a quick look for obvious signs of danger, such as leaking storage drums or dead or discolored vegetation. If the initial visit shows potential for hazardous contamination, the second stage of the site inspection is initiated, which involves sampling the soil and water. Site investigators will also analyze the ways in which hazardous materials from the site could pollute environmental resources and determine whether children have access to the site.

After the second site investigation, EPA applies a rank to the site, based on the Hazard Ranking System (HRS). An HRS numerical value over a certain level dictates whether the site is proposed for listing on the NPL. HRS rankings are currently based on numerous factors, including the type, quantity, and toxicity of the wastes involved, the number of people potentially exposed, the likely pathways of exposure, and the importance and vulnerability of the underlying water supply. EPA is in the process of modifying the Hazard Ranking System to incorporate changes mandated by SARA.

Once a site is proposed for, or placed on, the NPL, the lead organization for planning and conducting the long-term, permanent remedial response action is designated. The lead organization may be OERR, the state, or the responsible party; the latter under supervision of EPA's Office of Waste Programs Enforcement (OWPE). If EPA cannot compel potentially responsible parties (PRPs) to undertake the required cleanup activities, OERR or the state may become the lead organization. Legal steps may then be taken to recover costs incurred from responsible parties. When OERR is the lead, the site is eligible for a Superfund-financed remedial response. The remainder of the remedial response activities described here are for Fund-financed, federal-lead cleanups managed by EPA Regional remedial project managers (RPMs). The process is substantially the same for state-lead and PRP-financed remedial responses.

Sites listed on the NPL are subjected to a remedial investigation (RI) to gather data necessary to determine the type and extent of contamination at each site and a feasibility study (FS) to analyze cleanup needs and evaluate alternative cleanup approaches based on their relative effectiveness and cost. The RI and FS are conducted concurrently so that data collected in the RI influences the development of remedial alternatives in the FS, which in turn affects data needs and the scope of treatability studies and additional field investigations. The RI/FS begins with a scoping process to develop initial plans for collecting data and managing the site.

The RI is conducted in two phases—site characterization and treatability investigations. The site characterization includes a field investigation of the physical and chemical characteristics of the site, definition of the sources, nature, and extent of contamination, and comparison with applicable and relevant and appropriate federal and state standards (ARARs). A baseline risk assessment (public health evaluation) is developed to identify the existing or potential risks that may be posed to human health and the environment. If all indicator chemicals at the site have ARARs, the comparison of predicted concentrations of indicator chemicals to ARARs suffice as a baseline risk assessment. In cases where ARARs are not available for all indicator chemicals, the baseline risk assessment will include both a comparison of the degree to which releases violate ARARs and a risk assessment. Information in the baseline analysis is used to develop and evaluate remedial alternatives.

Once the site characterization is complete, the FS process begins. The FS is conducted in three phases—development of alternatives, screening of alternatives, and detailed analysis of alternatives. In the development of alternatives potential treatment technologies are identified, screened, and assembled into treatment alternatives for each contaminated medium at the site. The next step is a limited screening of alternatives with respect to their effectiveness, implementability, and cost in order to reduce the number of alternatives to be analyzed in detail. If necessary, treatability investigations are performed to permit evaluation of a particular technology on specific wastes from a site where existing site or treatment data are insufficient to adequately evaluate the performance of an alternative.

The final step in the RI/FS is the detailed analysis of the alternatives with respect to their ability to meet risk reduction objectives, statutory requirements, and preferences in the legislation. Alternatives are analyzed individually with respect to certain criteria and the effectiveness of each alternative in meeting the criteria are compared. The criteria used include short-term effectiveness; long-term effectiveness; reduction of toxicity, mobility, and volume; implementation costs; protection of human health and the environment; compliance with ARARs; state acceptance; and community acceptance. Once analyzed against these criteria, the information from the RI/FS is summarized and presented to decision makers and the public for review and remedy selection.

After completing the RI/FS, EPA issues a Record of Decision (ROD), which formally sets forth the selected remedy. Once the ROD is signed, the remedial design (RD) is developed, including detailed engineering plans, drawings, and specifications. These are used to solicit competitive bids to implement the remedial action (RA). Site cleanup is conducted during the RA and may involve treatment, disposal, and containment of the hazardous waste and cleanup, restoration, or replacement of the affected resources. The final step in the remedial process is operation and maintenance, which is designed to ensure continued functioning and effectiveness of the remedial response action. The total remedial response process may take four to six years, or more, to complete and may cost millions of dollars.

RESEARCH PROGRAM OVERVIEW

Implementation of the remedial process at Superfund sites is closely scrutinized from all sides—from the local community and national environmental groups to state and other federal agencies to treatment technology developers and PRPs. Remedial decisions are often challenged through the courts, where EPA must present and support the technical and scientific bases of its decisions.

ORD's research, development, and demonstration program is designed to improve the accuracy and timeliness of human health and environmental risk assessments, improve information on the performance and availability of

treatment technologies that offer permanent protection of human health and the environment, and provide direct technical assistance to field personnel involved in the remedial process. The target audiences of Superfund research are EPA Emergency and Remedial Response, Waste Programs Enforcement, and Regional Offices and state and local Superfund site assessment and cleanup personnel, including on-scene coordinators, remedial project managers, independent contractors, emergency response teams, treatment technology firms, and potentially responsible parties.

To organize the research program and assign responsibilities to research offices with the unique capabilities to address specialized needs, the Superfund research program is arranged into eight broad technical issues that together represent the greatest needs of the Superfund program. These issues (Figure 2) provide the framework for planning, budgeting, and justifying the research program.

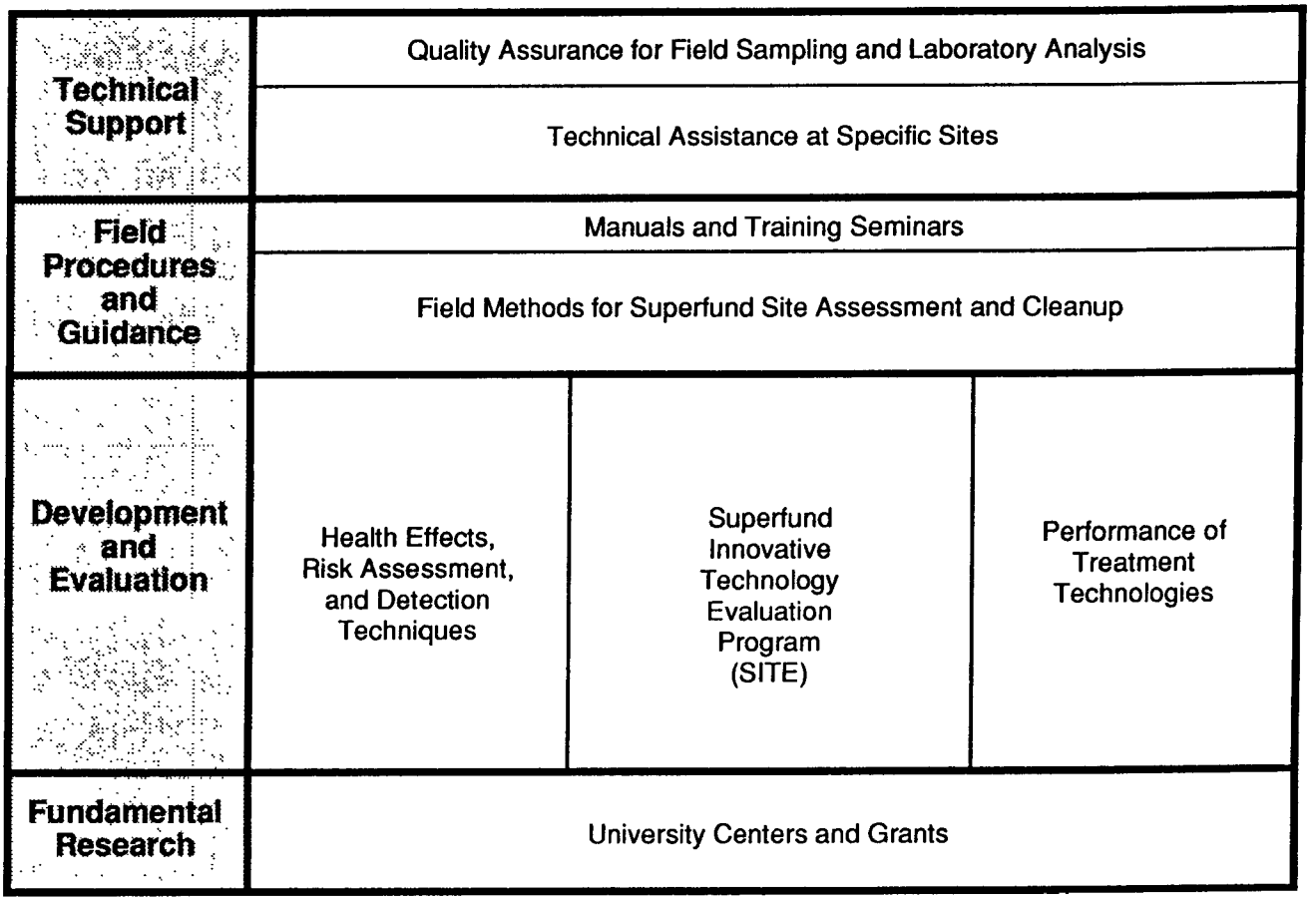


Figure 2. Overview of ORD Superfund research program.

ORD's research program is divided into *fundamental research, development and evaluation, field procedures and guidance,* and *technical support.* This organization reflects ORD's objective of improving risk assessment and risk reduction technologies available for use in the field. *Fundamental research* expands the knowledge base from which innovative methods may spring. *Development and evaluation* utilizes new concepts developed by EPA and the private sector to increase the number and effectiveness of risk assessment techniques and treatment technologies available for use at contaminated sites. The development of *field procedures and guidance* packages information

from development and evaluation to improve their use in the field. *Technical support* supplies direct expert assistance to field personnel in applying the technologies at Superfund sites. Subsequent chapters describe the following broad technical research issues, organized within the overall research framework, in detail:

- *Technical Assistance at Specific Sites.* Reviews RI/FS reports and remedial action, design, and implementation plans, and provides technical expertise and review to OERR, OWPE, and the Regions.

- *Quality Assurance for Field Sampling and Laboratory Analysis.* Ensures comparable environmental measurements of known quality by providing support to the national Contract Laboratory Program and evaluating analytical methods for chemical measurements and characterization.

- *Field Methods for Superfund Site Assessment and Cleanup.* Provides techniques and procedures to allow on-scene coordinators and remedial project managers to quickly and effectively assess the degree of hazard posed by specific sites, including the evaluation of technologies needed to ensure personnel health and safety during removal and cleanup operations; development of information on carcinogenicity and chronic health effects needed to generate reportable quantities for specific chemicals; and development of Health and Environmental Effects Documents for site assessments. An emergency planning and community right-to-know support program will provide data and tools to prepare for, and respond to, emergency and chronic releases of hazardous chemicals.

- *Manuals and Training Seminars.* Disseminates information and conducts training seminars for OERR, OWPE, Regions, states, and local authorities to assist them in Superfund site cleanup.

- *Performance of Treatment Technologies.* Develops and evaluates technologies, techniques, and construction materials that potentially may provide cost-effective control of hazardous waste releases but which still require additional laboratory development to be ready for field application. An integrated biosystems research program will identify and adapt naturally occurring and genetically enhanced organisms for application at Superfund cleanup operations.

- *Superfund Innovative Technology Evaluation (SITE) Program.* Conducts research, development, and demonstrations that promote commercialization of alternative treatment and monitoring technologies. As the availability of technologies ready for full-scale demonstrations decreases, more emphasis will be given to technologies at an earlier stage of development.

- *Health Effects, Risk Assessment, and Detection Techniques.* Conducts research and development to enhance the scientific capabilities to quickly detect potentially hazardous environmental contaminants, evaluate human health effects, and assess risks to human health from hazardous substances. Advanced field monitoring systems research will develop practical, rugged, easy-to-use screening techniques for monitoring Superfund sites.

- *University-Based Fundamental Research.* Provides long- and short-term hazardous substance research, training, and technology transfer related to the manufacture, use, transportation, disposal, and management of hazardous substances through university-based Superfund Hazardous Substance Research Centers and competitively awarded grants to universities.

ORD's research, development, demonstration, and technical support programs help to improve available information and technologies throughout the remedial process. Figure 3 indicates where the work in each research issue assists the Superfund remedial process.

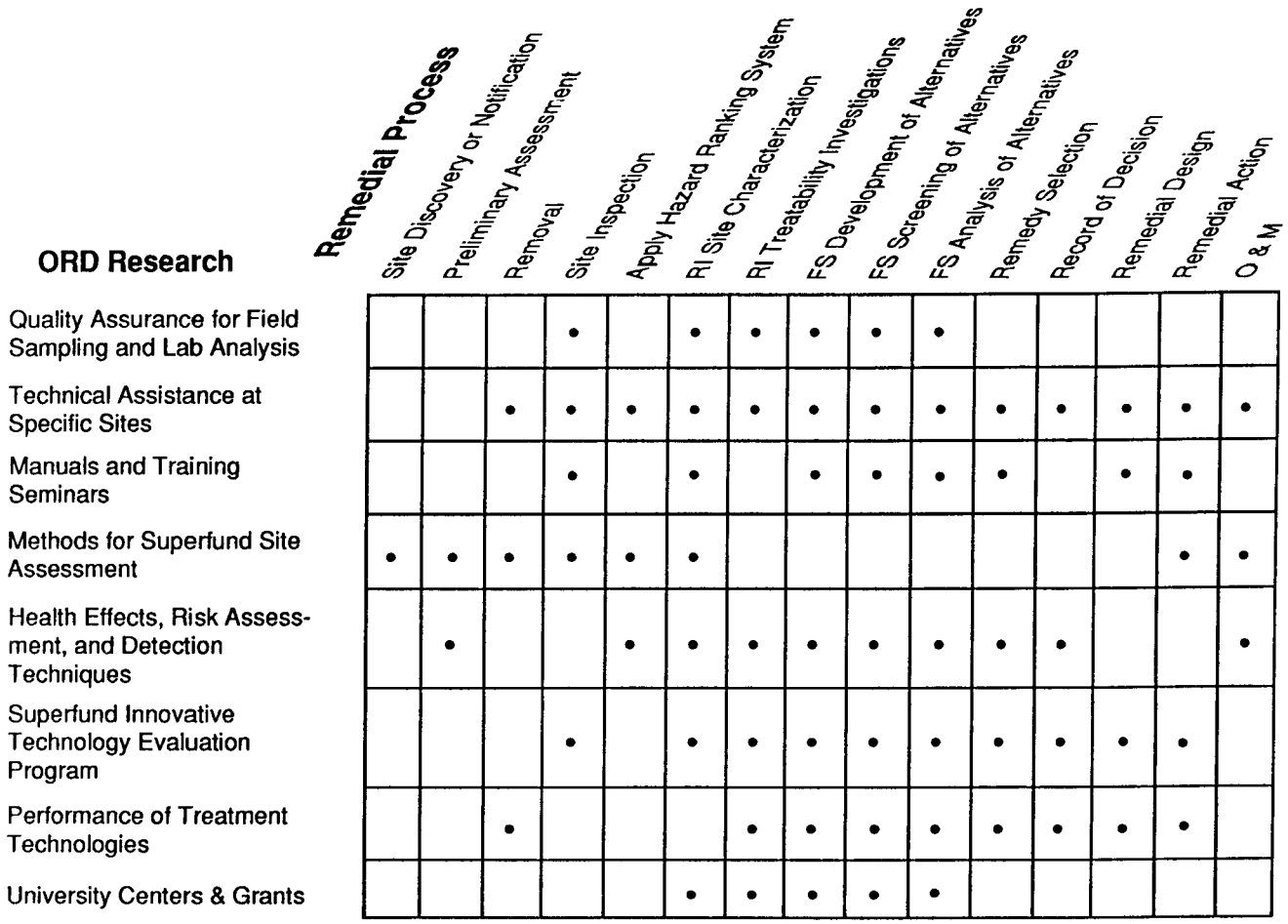


Figure 3. Relationship Between ORD Research and the Superfund Remedial Process

The Superfund research program is managed within budgeting Issues that organize planning, tracking, and assignment of responsibilities. Under each Issue are Planned Program Accomplishments (PPAs), which describe the ORD office (scientific assessments, monitoring systems and quality assurance, health effects, environmental engineering and technology, and environmental processes and effects) contributions to each Issue. PPAs are subdivided into projects that describe the smaller units of work performed at the laboratory level. Projects describe the research product (deliverable) that is being prepared. Most deliverables are final products of ORD research that will be formally transmitted by the ORD Assistant Administrator or an Office Director. Deliverables are assigned to a lead laboratory and are tracked by ORD headquarters. At the laboratory, the projects are further subdivided into specific tasks.

TECHNICAL SUPPORT

The Superfund program is action-oriented. SARA established ambitious schedules for investigating and cleaning up Superfund sites. To help meet these schedules, ORD provides comprehensive technical support to OERR, OWPE, Regional offices, states, and private industry. Technical support involves direct assistance by ORD scientists and engineers. Major technical support activities use ORD's technical expertise and facilities to provide timely technical services, data analyses, guidance and protocols, training, and technology transfer. These activities are primarily site-specific and assist in determining cleanup requirements and the resultant selection of cleanup technologies. This is high-priority work that offers scientists and engineers an opportunity to transfer the latest research knowledge directly to cleanup actions.

Maintenance of a strong research capability is critical to the Agency to ensure that technical expertise is available to promote the latest methodologies and control technologies. ORD's scientists and engineers are at the cutting edge of science and engineering, as it applies to improving EPA's capacity to implement cost-effective and permanent cleanup remedies for Superfund sites.

Technical support to OERR, OWPE, EPA Regional, state, local, and private sector personnel involved in cleaning up Superfund sites is provided through two major programs: ***Quality Assurance for Field Sampling and Laboratory Analysis*** and ***Technical Assistance at Specific Sites.*** Technical assistance involves direct contact with ORD scientists and engineers to provide timely technical services, data analyses, guidance and protocols, training, and technology transfer. These activities are primarily site-specific and assist in determining cleanup requirements and the selection of cleanup technologies. ORD and OSWER together have established Superfund Technology Support Centers in high-priority technical areas: engineering and treatment, monitoring and site characterization, ground-water fate and transport, and exposure and ecological assessment. The Centers are closely linked to OSWER's Superfund Forums to keep informed of Regional needs and promote the use of technical support programs. In addition, health risk assessment technical support includes Regional Risk Assessment Reviews and support in the preparation of site-specific endangerment assessments for OWPE. The quality assurance for field sampling and laboratory analysis supports the Contract Laboratory Program through Routine Analytical Services, Special Analytical Services, laboratory on-site evaluations, data audits, performance evaluations, the Quality Assurance Materials Bank, methods evaluation, and computer systems development.

SUPERFUND PROGRAM NEEDS

CERCLA, as amended by SARA, authorizes EPA to respond directly to releases (or threatened releases) of hazardous substances and pollutants or contaminants that may endanger public health or welfare. Because Superfund is an operational rather than a regulatory program, EPA must strive to use the best technical information and technologies available throughout the remedial process to ensure the scientific defensibility of its decisions.

As the provisions of SARA are implemented, it is estimated that EPA's need for the analysis of environmental samples will grow at an annual rate of 25% to 40% over the next three years. OERR has established the Contract Laboratory Program (CLP) to provide data of known quality that will assist in assessments of risk in remedial actions or in enforcement actions to identify and mitigate threats to public health and the environment. The primary objective of the CLP is to provide a wide range of responsive and carefully monitored analytical services of known and documented quality. A single national program for this effort helps ensure that samples are analyzed according to uniform and consistent protocols, and achieves lower analysis costs through the

economics of scale. All CLP analyses are performed by laboratories of proven ability that have won competitive contract awards, including analysis of performance evaluation samples.

TECHNICAL SUPPORT NEEDS

Cutting across the entire range of ORD's research program is the need to transfer technologies quickly and efficiently to end users. While the transfer of technologies, technical information, and guidance is integrated into the planning of research projects, the effective use of technical research products in the field often requires the assistance of experts. The Agency's enforcement and response programs need rapid access to ORD's technical expertise to review EPA contractor and PRP reports and recommendations and to provide the best available scientific evidence and testimony in support of cleanup decisions. Technical support from experts in ORD is needed in the following areas:

- Engineering and treatment technical support is needed to help in the analysis and selection of effective, permanent Superfund site remedies and in the design and construction of remedial plans.

- Support for the development of monitoring and site characterization procedures is needed to create a sound basis for assessing risks to human health and the environment and analyzing remedy options.

- Because SARA calls for increased consideration of environmental damage at Superfund sites, support is needed for the evaluation of procedures to assess ecological effects of hazardous waste sites.

- The human health risk assessment process is highly decentralized and many risk assessments are performed by the Potentially Responsible Parties or their contractors. There is a need for ORD to make expert review available on request for consistency, specific information, and guidance on conducting assessments.

- Support for the CLP is needed to ensure data integrity, including the provision of standard analytical materials and procedures and evaluations of the performance of contract laboratories.

TECHNICAL SUPPORT APPROACH

Technical support to OERR, OWPE, and Regional personnel involved in cleaning up Superfund sites is provided through two major programs: *Technical Assistance at Specific Sites* and *Quality Assurance for Field Sampling and Laboratory Analysis*. Besides providing much needed support to operational programs, the technical support program keeps ORD managers and technical staff in touch with Regional needs in all major program areas, which leads to a better understanding of field problems and allows fine tuning of the research and development program.

Technical Assistance at Specific Sites

ORD technical expertise and facilities are available on a when-and-where-requested basis to provide site- and case-specific technical support throughout the remedial process. Site-specific support projects have involved such highly publicized sites as the Love Canal, Upper Clark Fork River, Henderson Road, Drake Chemical, French Limited, Sand Springs Petrochemical Complex, Tyson's Dump, Pacific Engineering, Stauffer Chemical, New

Bedford Harbor, Frontier Hard Chrome, Chemical Control Corporation, and Tacoma Tar Pits CERCLA sites. In addition to site-specific technical assistance, the Regions make many non-site-specific requests for technical information, including hundreds of questions that are answered over the telephone by laboratory experts. Many information requests required considerable time and effort to develop state-of-the-science advice.

To provide a central point of contact to the laboratories within high-priority technical areas, ORD and the Office of Solid Waste and Emergency Response (OSWER) have jointly established Superfund Technology Support Centers in engineering and treatment, monitoring and site characterization, ground-water fate and transport, and exposure and ecological assessment (Figure 4). The four Technology Support Centers were initiated in FY88, and in response to Regional requests, conducted over 80 technical assistance projects in support of remedial investigations and feasibility studies at CERCLA National Priority List sites. The Centers are closely linked to OSWER's Superfund Forums, composed of Regional on-scene coordinators and remedial project managers, to keep informed of Regional needs and to further promote the availability of their technical support programs throughout the Regions. In addition to the Technical Support Centers, ORD provides technical assistance for health risk assessments through a Regional risk assessment review group.

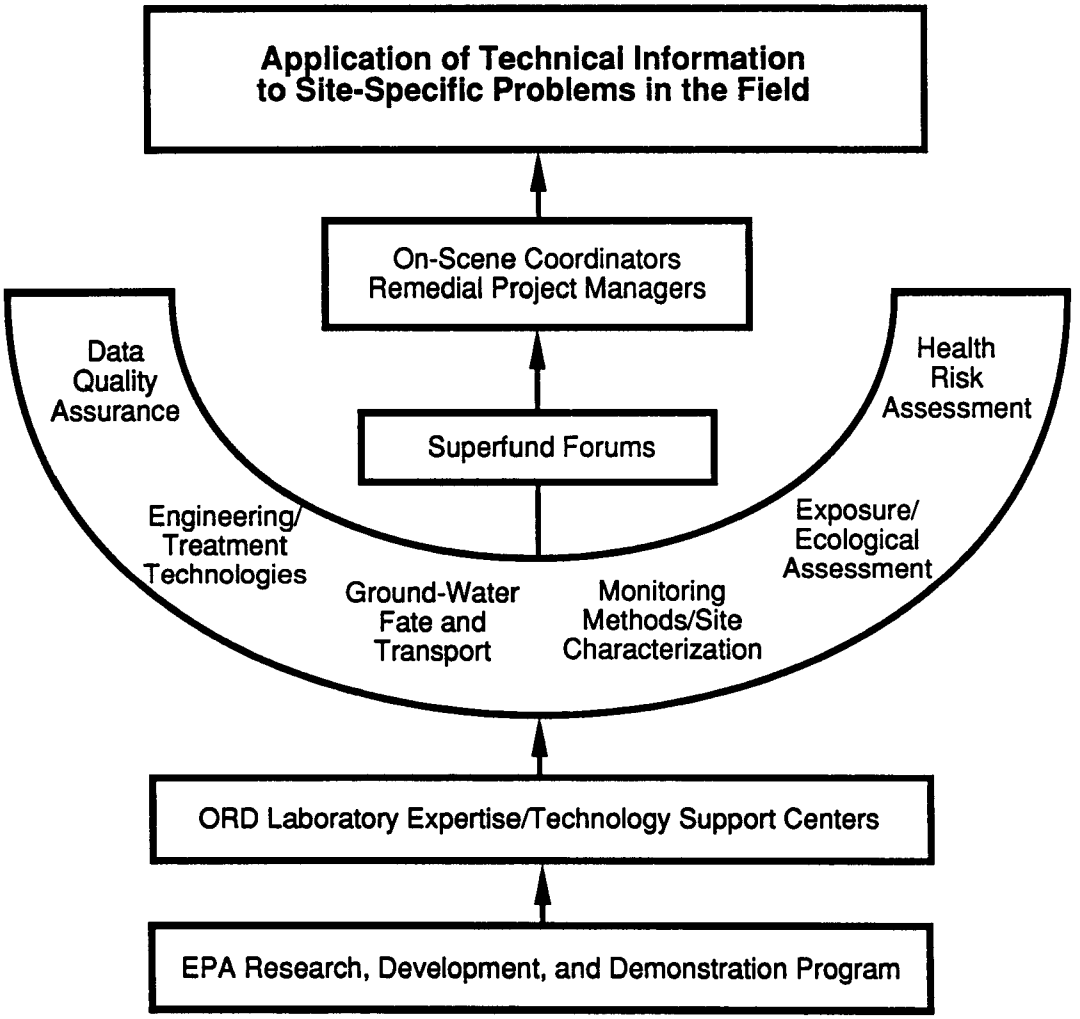


Figure 4. ORD program for providing technical assistance at specific sites.

Engineering/Treatment Technical Support

In order to provide timely technical and scientific information and analysis in support of hazardous waste site litigation and corrective actions, short-term, quick turn-around technical advice and consultation is provided on request to assist in the use of engineering and treatment technologies.

The Engineering Technology Support Center provides site-specific technical support (1) during the RI/FS process by determining treatment alternatives, determining the feasibility of treatment alternatives, and establishing protocols for determining site-specific feasibility of treatment alternatives; (2) during remedial design by determining scale-up requirements, fine tuning designs, and performing treatability studies; and (3) during remedial actions by monitoring scheme development and troubleshooting problems. Other general areas of technical support include reviewing data submitted by liable parties for specific site problems, furnishing expert witnesses when required for litigation procedures, and providing routine technical support in other areas of expertise.

In FY88, the Engineering Technology Support Center provided assistance in evaluating remedial options at 21 sites, including the Stringfellow, Monterey Park, Smuggler Mountain, New Lyme, Marathon Battery, C&R Battery, Baltimore Harbor Chromium, McCall, and Tacoma Tar Pits NPL sites. The technical support projects included treatability investigations of soil washing and natural zeolites, developing sampling and analysis plans for stabilization/solidification (S/S) studies, determining field screening of particles and debris before S/S treatment, identifying remedial alternatives, conducting trial burns, and reviewing field demonstration data from proposed PRP treatments. The same level and types of support are anticipated in FY89, but the exact projects will depend on Regional requests for assistance.

In response to non-site-specific technical requests from the Regions, the Engineering Technology Support Center has developed generic Quality Assurance Project Plans (QAPPs) for soil washing, chemical treatment systems, and low-temperature thermal desorption processes; gathered together experts to develop state-of-the-science remedial action approaches for lead battery, mine tailings, wood preserving, and explosive waste sites; and compared methods for treating rock and masonry debris contaminated with polychlorinated biphenyls (PCBs). Because technical publications often go unused due to time constraints on Regional audiences, half-day sessions in the Regions are being scheduled on major guidebooks and manuals. These courses are not designed to impart expertise but to introduce the product and show how it can be used.

In a major new technical support initiative, ORD has recently signed a Memorandum of Agreement with Region 3, through which the Treatment Technology Support Center would provide comprehensive site-specific technical support for selected Superfund sites from the beginning of the scoping process through the entire site remedial process.

ORD is developing an automated Technical Information Exchange (TIX) to disseminate specialized technical information. The TIX collection currently emphasizes information involving the evaluation of new and novel techniques for the cleanup of ecosystems damaged by spills, underground storage tank leaks, uncontrolled waste sites, urban and non-point sources of stormwater run-off, and identification of environmentally sound methods for the disposal of contaminated wastes associated with cleanup operations. Other information includes products from tests, and evaluations of personal protective clothing, breathing apparatus and other safety equipment and procedures to protect personnel involved in the handling of pesticides and other toxic substances, as well as individuals engaged in emergency response activities at chemical spills and hazardous waste sites.

The Computer On-Line Information System (COLIS) has been developed within TIX to make new technical information more readily available to cleanup personnel. In FY88, databases available on COLIS included:

- The Case History File that contains information on site characteristics, response methods, costs, cleanup problems, and alternative approaches involving spills, waste sites, and underground storage tank management. The information is derived from After-Action Reports submitted by field personnel.

- A Library Search System that allows users to search among several listings of publications related to hazardous chemicals and wastes. The listings include the card catalog of the TIX collection and a listing prepared by the EPA headquarters library on its Hazardous Waste Collection. The system allows users to search the database by key words, author, publisher, call number, and report number.

ORD plans to expand COLIS in FY89 and FY90 to include:

- The Countermeasures Selection System (CSS), a computerized version of the EPA's *Manual of Countermeasures for Hazardous Substance Release*. CSS contains extensive charts and tables on chemical behavior and hazards and the appropriate technologies for dealing with each type of chemical. It will allow users to quickly determine response techniques applicable to particular problem.

- A Performance/Cost Database that will contain information being generated from field evaluations of mobile treatment equipment under the Superfund SITE program, related Resource Conservation and Recovery Act (RCRA) programs, and other sources world-wide.

- A Personnel Protection Technology Field Performance File to support acquisition and use decisions by EPA and contractors relative to safety during Superfund cleanup. The database will also be used as a planning tool in developing or indicating research priorities and needs in the areas of personnel protection procedures, equipment, and detectors.

- A Testing and Evaluation Facility Database that will provide a computerized database of all technical findings from evaluations of treatment technologies.

Monitoring Methods and Quality Assurance Technical Support

The monitoring methods and quality assurance technical support area provides site-specific assistance for monitoring and characterizing air, surface water, ground water, wastes, leachate, and soils in support of Superfund investigations. Technical support is provided in five major areas: remote sensing support, geophysical technical support, geographical information system technical support, quality assurance support to Regional laboratories, and sampling and monitoring technical support. In addition, the Superfund Monitoring and Site Characterization Technology Support Center provides specialized technical and scientific information and expertise to Regions in ground-water monitoring activities.

Remote sensing, including topographic mapping and aerial imagery, is crucial to the Regions for locating old or buried contamination sources and creating topographic maps of Superfund sites. ORD is currently providing about 30 maps and 400 images per year to Regional offices and OERR for CERCLA investigations, with a modest growth expected for FY89. Remote sensing is a highly efficient way to localize and characterize sites, analyze historical development and practices at waste sites, and monitor removal and remedial operations for Superfund.

Four types of remote sensing projects are being conducted: *Emergency Response Projects* requiring rapid acquisition and assessment, *Single Date Projects* to acquire current data, *Intensive Site Analyses* to acquire imagery over a period of time, and *Waste Site Inventories* to establish baseline references over large areas. Remote sensing, complemented by computerized geographic information systems, is being used to perform ecosystem impact analyses and human exposure assessments at several NPL sites. Demonstrations and written guidance on the applicability of these technologies will continue to be provided to OERR, OWPE, and Regional personnel.

Geophysical support includes expert assistance on the use of resistivity, magnetometry, ground-penetrating radar, borehole electromagnetic induction, and other remote devices to characterize the subsurface and locate contamination sources at hazardous waste sites in a non-disruptive manner. Technical support to the Regions includes advice on what tools to use in specific situations and reviews of reports and work plans. In FY88, eight projects in six Regions were conducted. To promote the use of geophysical characterization techniques, a letter was sent in April, 1988, to all ten Regions requesting identification of Superfund sites where geophysical technical support is needed. Within a month, ORD received requests for assistance at 52 Superfund sites. The amount of work to satisfy these requests far exceeds ORD's current capability. To meet this need, ORD and the Regions are working together to identify priorities and exact needs of each project and determine whether ORD or Superfund contractors could provide assistance. Interagency agreements to provide the geophysical field investigations are being established with other federal and state agencies.

Geographic information systems (GIS) allow the integration, display, and analysis of spatially related data for use in vegetation, habitat, land use, water quality, and exposure risk monitoring. EPA has established a GIS in each Region that demonstrated a commitment to develop and maintain the necessary staff expertise. ORD's role is to demonstrate the GIS applicability to hazardous waste sites for the Regions. In FY88, ORD provided GIS demonstrations in four Regions.

ORD evaluates and provides technical support to Regional laboratories in much the same fashion as it does for the Superfund contract laboratories. The support includes providing quality control samples, reference materials, performance evaluation samples, and laboratory audits. The performance of litigant labs at Superfund sites is evaluated at the request of EPA Regions and States. In addition, support is provided to the Contract Laboratory Program, which periodically performs special analytical services that involve the collection and analysis of air samples for specific volatile organic compounds at Superfund sites. The accuracy of the measurement systems used for Special Analytical Services (SAS) are being assessed and the results included with the SAS reports.

Sampling and monitoring technical support includes site-specific, short-term assistance on the development of sampling methods, sampling designs, sampling quality assurance plans, and analytical methods; modification of analytical methods; reviews of data quality objectives, network designs, and spatial statistics; analysis and interpretation of site monitoring data; and provision of monitoring equipment. This project provides the technical assistance required by the Regions to adequately plan and implement Superfund site investigations and to ensure that the monitoring activities provide data of known quality.

The Superfund Monitoring and Site Characterization Technology Support Center assists the Regions in groundwater monitoring by providing "hotline" consultation, on-site technical support, review of monitoring and quality assurance plans, transfer of research and development results, training, and facilities. The Center provides expertise in the areas of vadose zone monitoring, saturated zone monitoring, surface and borehole geophysics, advanced field methods, and underground storage tank monitoring. The Center's technology support program utilizes monitoring research to develop field applications for traditional and innovative sampling analysis and monitoring methods. The

Center's technical assistance program provides site-specific guidance on the use of conventional methods when requested.

In FY88, the Center provided site-specific technical support for 14 NPL sites, including X-ray fluorescence (XRF) screening studies, a ground-penetrating radar survey, soil-gas studies, a wetlands demonstration project, and reviews of sampling plans, remedial plans, and RI/FS reports. Activities in response to Regional requests for non-site-specific assistance included the development and field use of XRF monitoring and soil gas sampling methods, development and conference presentation of geophysical applications, the Second National Outdoor Action Conference, identification of expert witnesses, guidance on soil classification, initiation of a short training program on basic geophysics, and responses to requests for information and site assistance by nine Regions. Goals for FY89 include establishing permanent and mobile facilities, continuing technology demonstrations and site assistance, implementing a geophysics training program, developing workshops on soil gas, XRF, and geophysical techniques, and expanding site-specific technical assistance.

Ground-Water Fate and Transport

The Ground-Water Fate and Transport Technology Support Center consists of a technical support team and a Subsurface Remediation Information Clearinghouse (SRIC). The SRIC was established to provide information pertaining to fate, transport, and *in situ* biotreatability of pollutants in the ground water and soil. A Technical Support Team provides a readily available source of technical assistance and technical review to Superfund remedial action decision makers regarding remediation activities at specific Superfund sites. The Center works closely with two other EPA-sponsored centers: the National Center for Ground-Water Research—a consortium of Rice University, University of Oklahoma, and Oklahoma State University—and the International Ground-Water Modeling Center at Butler University in Indianapolis.

The Center provided site-specific technical support at 34 NPL sites, covering all ten Regions in FY88, including assistance in determining partitioning coefficients, reviewing biodegradation potential, evaluating bioremediation technology, reviewing contractor reports on fate and transport of organic contaminants, reviewing draft RI/FS reports, studying aquifer characteristics, evaluating ground-water contamination in a complex fractured flow system, evaluating soil leaching studies, and reviewing proposed site remediation alternatives. For non-site-specific technical support requests the Center conducted ground-water modeling workshops and training modules for all ten Regions; initiated the Subsurface Remediation Clearinghouse; and reviewed remedial performance evaluations. In addition, the Center developed Superfund issue papers on water level measurements, leaching tests, metals analyses and filtering, fractured media models, facilitated transport, dense non-aqueous phase liquids, soil classification system, and biorestoration in saturated and unsaturated zones. The most commonly requested technical support came in the areas of bioremediation, pump and treat, general geology/hydrology, fractured flow hydrology, development of partition coefficients, and general geochemistry.

The Center's plans for FY89 include: continued site-specific support; continuation of the Subsurface Remediation Clearinghouse; more remediation performance evaluations; development of Superfund issue papers; development of a Site Characterization Seminar in cooperation with EPA's Center for Environmental Information; conducting technology transfer seminars on transport, fate, and modeling; and conducting workshops on selected issues.

Exposure and Ecological Assessment

Environmental processes technical support is provided to assist in conducting exposure assessments and ecological risk assessments. Two Centers have been established to serve as focal points for this technical support: The Center for Exposure Assessment Modeling (CEAM) and the Superfund Ecological Risk Technology Support Center.

ORD's Center for Exposure Assessment Modeling, established in the summer of 1987, maintains and distributes multimedia exposure assessment models and provides technical support and training to personnel who quantitatively evaluate multimedia exposure, bioaccumulation, toxicity, monitoring, and sampling. Requested assistance is provided through expert witness testimony, exposure calculations and assessments for especially difficult or unusual scenarios, review of exposure and ecological risk assessments, and in-depth support for high priority Agency projects.

The Center also maintains a distribution center containing up-to-date models and databases for the user community and their consultants. To improve the communication of exposure assessment information, CEAM maintains an electronic bulletin board through which callers can access current versions of 11 microcomputer models and receive technical assistance. CEAM also distributes and supports more complex models for use on large computers.

Accomplishments in FY88 included the distribution of over 2000 models by diskette and another 250 over the bulletin board; establishing software quality control procedures; debugging 25 CERCLA data sets uploaded to the bulletin board; conducting three training courses; reviewing guidance documents; providing technical assistance for site remediation at 11 CERCLA sites; initiating the development of exposure and ecorisk assessments for the Upper Clark Fork River CERCLA sites; and developing assessment protocols for confined disposal facilities (CDFs).

CEAM's plans for FY89 include expanding the bulletin board communications network; developing new models and databases; increasing site-specific technical assistance; completing the Clark Fork River ecological risk analysis; and applying wood preserving, metals remediation, and CDF models at specific sites. In addition, CEAM will offer a training curriculum at an introductory level for exposure assessment modeling, in-depth training for several models, and advanced seminars on the uncertainties in ecological risk assessment.

The Ecological Risk Technology Support Center provides technical assistance, training, and expert witnesses on the use of bioassays and bioassessment screening protocols being applied during enforcement and remedial investigations of the environmental effects of contaminants at Superfund sites. The Center has developed generic assessment methods for ceramic, battery cracking, and lead smelting sites and provided technical assistance for ecological risk assessments at 11 CERCLA sites, including metals contamination at the Upper Clark Fork River CERCLA sites, confined disposal facilities adjacent to the Great Lakes, sites contaminated by wood preserving facilities, and the evaluation of ecological risks associated with marine Superfund sites.

ORD is evaluating the use of rapid, inexpensive bioassay testing methods, developing quantitative risk assessment protocols for ecological risk assessments, and evaluating ecological factors for inclusion in the Hazard Ranking System. Emphasis is on applications to sensitive environments for site identification and selection, site evaluation before and after remedial operations, and establishing criteria for the removal of sites from Superfund status.

Because organisms integrate only those contaminants that are biologically available, knowing what contaminants are present in surface-water systems does not necessarily indicate which are ecologically relevant. ORD has been working to develop a series of bioassays to enable the assessment of toxicity at Superfund sites. Bioassays provide a means of quickly screening samples to determine their toxicity. They allow the identification of the most severe toxicity cases, thereby helping to prioritize areas for more thorough evaluation, including the direction of chemical analysis. The use of bioassays does not depend upon the identification of potential causative agents or on the availability of numerical criteria for these chemicals.

Quantitative risk assessment protocols are being developed to assist in the evaluation of ecological damage at the ecological, population, and organism levels of response in aquatic environments associated with Superfund sites. The protocols will evaluate current conditions based on proposed remedial activities and the no-action alternative. Quantitative bioassessment protocols are not dependant upon knowledge of the compounds in the waste stream. However, the bioassay is not a replacement for chemical analysis, and it does not factor in bioaccumulation; carcinogenic, mutagenic, or teratogenic effects; or population or system level effects. The key sediment issue faced by the Agency in the evaluation of Superfund sites is how to remedy the ecological damage caused by benthic pollution. The technical contribution to these regulatory decisions lies in the predictive methods for describing contaminant deposition, distribution, bioaccumulation, toxicity, and ecosystem recovery.

Improved ecological factors for the Hazard Ranking System will be developed. Case studies will include application of existing ranking methods, multimedia analysis models, and ecorisk procedures. Results will be used in evaluating existing CERCLA protocols, in transferring technology, and in evaluating the need for more research on pollutant fate and exposure and risk assessment. The occurrence of new hazardous source chemicals will be reported to OERR. The HRS should be able to discriminate better between sites and be on a firmer scientific and ecological basis.

The ecological assessment support program is also evaluating the use of direct (soil) versus indirect (elutriate) tests, laboratory versus field assessments, acute versus chronic testing, and sensitivity of bioassay organisms.

Health Risk Assessment

The health risk assessment technical support program has two main components: Regional risk assessment reviews (RRARs) and technical support in the preparation of site-specific endangerment assessments for OWPE.

A Regional risk assessment review group was established at OSWER's request to coordinate reviews of Regionally prepared site-specific assessments and to provide a focal point for obtaining risk assessment information for the Regions. The review group, composed of ORD scientists, is available for very careful, multidisciplinary reviews of risk assessments at a limited number of Superfund sites. The RRAR is intended to support Regional risk assessors in a consultative role by providing technical assistance in applying EPA's risk assessment guidelines to complex situations. ORD has provided about 15-20 RRARs per year. For FY89 and beyond, 25-30 per year are planned.

ORD's technical support program for OWPE provides rapid response to questions on exposure and toxicity parameters and the state-of-the-art in risk assessments. It is geared towards ensuring that decisions are not overturned in court as "arbitrary and capricious" by being inconsistent with guidelines and methodologies. Site- or chemical-specific assessments are prepared to predict the relative health risks associated with remedial enforcement options. These assessments range from brief hazard assessment summaries for cancer and non-cancer

toxicity, to detailed, peer-reviewed documents for use in negotiations or litigation by OWPE. The review of chemical-specific cancer risks proposed in contractor-prepared endangerment assessments is essential to establishing the credibility of these assessments for use in negotiations or litigation. Additional support includes testimony and participation in negotiations, public meetings, and risk assessments at high-visibility sites. ORD conducts about 10-15 endangerment assessments in any one year.

Quality Assurance for Field Sampling and Laboratory Analysis

The CLP provides a centralized system of laboratory support in response to specific analytical requirements of the Superfund program. The majority of analytical needs are met through standardized laboratory services provided by CLP Routine Analytical Services (RAS). The RAS program provides laboratory services for uniform and high volume analyses of samples collected during hazardous waste site investigations. Other, specialized types of analysis not provided by standardized laboratory contracts may be scheduled under the Special Analytical Services (SAS) program. The SAS program complements the RAS program by providing the capability for meeting specialized or custom analytical requirements, including quick turn-around analyses, verification analyses, analyses requiring lower detection limits than RAS methods provide, identification and quantification of non-priority pollutant and non-Target Compound List (TCL) constituents, general waste characterizations, and analysis of non-standard matrices.

In addition to providing their analytical results to the Regions, the contract laboratories are required to send CLP environmental analytical data to ORD, which is responsible for the independent quality assurance and quality control oversight of the CLP. Each contract laboratory's performance is continuously monitored by ORD through ongoing quality assurance evaluations. These evaluations consist of periodic on-site laboratory inspections and audits on a representative portion of analytical data and supporting documentation to ensure continuing laboratory adherence to analytical, quality assurance, and quality control procedures and that overall performance meets the requirements of the CLP contract. ORD further supports the CLP by providing performance evaluation materials and studies, maintaining the Quality Assurance Materials Bank, participating in the development of methods, standards, and protocols used by the contract laboratories, improving computer systems support, and providing broad support for special, high-priority OERR projects.

ORD also provides an independent, rapid-response referee laboratory for the use of the Regions and Emergency Response Branch. The Quality Assurance Support Laboratory, with the University of Nevada in Las Vegas, provides technical support for the review of methods, referee analyses of preaward and performance evaluation samples, and special inorganic and dioxin performance evaluation materials preparation and distribution. The laboratory distributed approximately 2,000 special performance evaluation materials in FY88.

Laboratory requirements for maintaining document control and chain of custody are incorporated into all CLP contracts. The National Enforcement and Investigation Center (NEIC) supports the CLP through periodic evaluations of laboratory adherence to these requirements to ensure that analytical data are suitable for use in enforcement case preparation and litigation. These evaluations emphasize sample control, laboratory documentation, security of evidence, and document control and inventory, and are coordinated with ORD's routine on-site laboratory evaluations.

Laboratory On-Site Evaluations

On-site evaluations of the contract laboratories are performed at least yearly to assess each laboratory's capacity to produce data suitable for enforcement case preparation and litigation, monitor performance, ensure compliance with contractual requirements, and identify weaknesses in CLP analytical methods. The on-site laboratory evaluation is the quality assurance activity that ties together all the elements of laboratory performance monitoring. Preaward on-site evaluations, together with performance evaluation sample results, are critical factors in the determination of contract awards. Routine on-site evaluations incorporate the findings of performance evaluation studies and data audits to detect and identify problems, bring the problems to the attention of the laboratory personnel, help to resolve them and otherwise monitor the compliance with all contractual specifications. If serious problems are encountered, recommendations are made to OERR for appropriate corrective action. In FY88, ORD conducted over 100 on-site laboratory evaluations.

Data Audit Program

Data audits are managed by ORD and include technical audits of contract laboratory data; monitoring and consulting to improve contract procedures; updating the quality assurance database; developing documentation, checklists, control charts, and scoring systems; providing material for technical presentation or publication, providing statistical support to all aspects of the CLP; and performing methods evaluation.

Technical audits are crucial for providing a detailed working knowledge of what is accomplished by the CLP laboratories. This knowledge base becomes the reference from which all other activities are measured and establishes the credibility of all laboratory performance evaluations. The technical audits are extremely thorough and consequently are conducted on only a small, but statistically valid, fraction of all analytical cases, usually around 4%. A "case" refers to collections of environmental samples from one site over a finite period of time.

Auditing methods establish, on a laboratory-by-laboratory basis, valid statistical levels of data inspection, based on the quantity of data reported and relative frequency of observed defects. They also provides a means for random selection of data to be audited, thus resulting in an unbiased characterization of a laboratory's output. By utilizing a weighted scoring system, with weighs based on the severity of observed defects, appropriate levels of data inspection can be projected.

Performance Evaluation Program

Another major area of quality assurance/quality control (QA/QC) support provided by ORD includes organic, inorganic, and dioxin performance evaluation (PE) materials and studies, through which the accuracy of contract laboratory analytical results is continuously monitored. Performance evaluation materials containing compounds of known concentration are sent to contract laboratories, the laboratories analyze the material to determine chemical concentrations, and the results of their analysis are sent to ORD where they are compared to the known concentrations.

There are two types of PE studies, Preaward and Postaward. A Preaward study is conducted to determine if a bidding laboratory can successfully meet both the analytical and reporting requirements described in a particular Invitation for Bid (IFB) for organic, inorganic, or dioxin contracts. Meeting these technical requirements in a PE study is one factor used in CLP contract award determination. Postaward studies are divided into two categories, recognizable (single blind) and unannounced (double blind) studies. These Postaward PE studies are conducted to

monitor the technical performance of laboratories holding active CLP contracts and they serve to alert OERR of analytical problems by providing a quantitative evaluation of each participating laboratory. "Single blind" materials are provided directly by ORD to the participating laboratories as PE materials. "Double blind" materials are provided to the participating laboratories with the assistance of an EPA Region. The Region camouflages these PE materials as one of its regular environmental samples. Current trends indicate an increasing reliance on single blind studies, which are less expensive.

PE materials and studies are also provided to the Regions and to state and local governments where Superfund issues are involved so that these agencies can evaluate their own analytical laboratories. Additional PE support to OERR may also occur in support of Special Analytical Services study requirements. Sample types for SAS studies are developed upon need and are specific to the SAS requirement.

Superfund Standards Program: The Quality Assurance Materials Bank

Since 1980, ORD has maintained and has continued to expand an inventory of standard compounds used in analytical efforts that support RCRA and CERCLA. This inventory ensures the ready availability of standard materials for evaluating CLP laboratory performance. Quality assurance reference materials, such as calibration standards, quality control samples, and performance evaluation samples, are designed, prepared, and distributed according to uniform and consistent protocols for analysis by contract laboratories.

The inventory is managed by the Quality Assurance Materials Bank and the Repository of Toxic and Hazardous Materials, which are operated under a single contract known as the Quality Assurance Reference Materials (QARM) project. Last year, the Repository of Toxic and Hazardous Materials distributed almost 100,000 ampules to CLP laboratories and to non-CLP Regional, state, and local laboratories. The Quality Assurance Materials Bank supplied almost 40,000 ampules of standards for CLP performance evaluation materials and studies. Through this project, compounds are acquired, reference materials are prepared and characterized, standard solutions are prepared, their concentrations verified, and the reference standards and materials are distributed. Reference standards are provided to both CLP and non-CLP laboratories.

Methods Evaluation

An active area of research is the development of rapid, low-cost analytical procedures and systems to provide data that meets program requirements. This effort involves the development and validation of quality assurance and quality control protocols for use in sample analysis in the field. Prior to FY87, three general methods for CLP analyses were in place: organic, inorganic, and dioxin. Due to changes in Superfund program needs and improvements in laboratory equipment and practices, new analytical protocols are under development. In addition to the development of new protocols, modifications of previous methods have been designed to improve data quality, data quality monitoring, and the information content of data generated.

A related activity is the evaluation of field instrumentation appropriate for use at mobile laboratories, and field activities using portable instrumentation. The Advanced Field Monitoring Methods Program is actively investigating and encouraging the development and validation of field instrumentation. Quality assurance support is provided in the areas of field gas chromatography, mass spectrometry, and X-ray fluorescence. Various commercial systems will be evaluated for incorporation into on-site field investigations to meet Superfund program needs for rapid, low-cost field determinations.

Computer Systems Development and Support

The CLP is such a data-intensive program that the use of automated data processing is an absolute necessity. Computer systems work is emphasizing the areas of program oversight, data entry, and programming. ORD is also developing computer systems to help in data analysis and report generation. The significance of the application of these system techniques to environmental monitoring is profound. They have the potential to create a breakthrough in the long timelines currently associated with environmental remediation. Rapid, automated on-site report generation, quarterly blind scoring, evaluation of data usability, and other rapid automated audits of environmental data may become possible.

A QA/QC Database has been developed and maintained to assess method performance, assess individual and collective laboratory performance, and provide special support to OERR and the Regions. A number of computer programs provide access to the cumulative data files, and permit the identification of trends, evaluation of QC criteria and the updating and development of performance-based QC criteria. The data are obtained from laboratory QA/QC reports, PE evaluation reports, and on-site evaluation summaries. Using the database, internal laboratory control and performance can be evaluated. Performance trends and defects can then be monitored within a given laboratory or between laboratories. Performance-based QC criteria (acceptance windows or surrogate spike recoveries) can be evaluated and updated as needed. The database provides a continuously monitored set of quality control and performance criteria specifying what is routinely achievable and expected of state-of-the-art analytical chemistry laboratories in mass production analysis of acutely sensitive environmental samples.

Special Support Projects

ORD provides intensive quality assurance support to the Regions in selected, high-priority areas. The Love Canal Habitability Study was a major recipient of excruciatingly detailed special support. Support for this project has included on-site laboratory evaluations, review of analytical methods and procedures, review of reporting and procedural practices, development and distribution of PE samples for evaluation of the performance of contract laboratories in this project, and review of data produced by the laboratories.

MAJOR DELIVERABLES

Annual Summary of Air Monitoring Support. Due in November of each year.

Annual Report on the Design, Preparation, and Distribution of Quality Control Samples for Contract Laboratory Program and EPA Regional, State, and Local Laboratories. Due in December of each year.

Annual Report on the Design, Preparation, and Distribution of Performance Evaluation Samples for Organic and Inorganic Analytes in Support of the Contract Laboratory Program. Due in December of each year.

Annual Report on the Design, Preparation, and Distribution of Calibration Standards for the Contract Laboratory Program and EPA Regional, State, and Local Laboratories. Due in December of each year.

Annual Report - Analytical and Sampling Quality Assurance Technical Support. Due in December of each year.

Annual Report on the Quality Assurance Materials Bank. Due in January of each year.

Annual Summary Report on Quality Assurance to Support the Contract Laboratory Program. Due in March of each year.

Annual Report on Exposure and Ecorisk Assessments Performed by the Center for Exposure Assessment Modeling. Due in July of each year.

Technical Assistance to Regions and OSWER on Engineering Studies at Superfund Sites. Continuing.

Review of Designs, Plans, and Specifications for Superfund Sites. Continuing.

Provide Enforcement Case Support, Expert Witnesses and Testimony. Continuing.

Emergency Response Assistance at Releases and Waste Sites Including Technical and Analytical Support. Continuing.

Aerial Remote Sensing Program for Hazardous Waste Sites: FY88 Program Summary and FY89 Management Plan. Due 1/89.

Report on Procedure for Relative Risk Assessment and Ranking for Action among Listed Sites and RCRA Closure Activities. Due 2/89.

Ion Trap Method for Fugitive Polar Organics. Due 5/89.

User's Manual on Use of Geostatistical Models for Managing Soil and Water Contamination. Due 12/89.

Report on Applicable Methods for Estimating the Magnitude and Areal Extent of Ecological Risks at Marine Superfund Sites. Due 9/90.

Report on Plants that Can be Used as Sentinel Species for Phytotoxicity at Hazardous Waste and Superfund Sites. Due 3/91.

Report on Use of DNA Adducts as a Measure of Exposure of Wildlife at Hazardous Waste and Superfund Sites. Due 8/91.

Guidelines for the Evaluation of Marine Ecosystems Associated with Superfund Sites. Due 12/92.

FIELD PROCEDURES AND GUIDANCE

As part of ORD's ongoing effort to provide research and technical support to OERR in the investigation and mitigation of health and environmental problems at Superfund sites, ORD prepares and disseminates standardized guidance, methods, and software for users. New or existing technologies and methodologies must be presented to targeted users in a manner that will enable their most effective use. This entails evaluation of the applications, effectiveness, and utility of methods developed by EPA and the private sector, modification and standardization of protocols, documentation in the form of manuals or computer software, and dissemination through manuals and training. The FY89 field procedures and guidance program will emphasize on-site assessment technologies, particularly for monitoring; protective clothing and equipment; reportable quantities needed for site reporting; and alternative treatment technologies. In addition, research planning for emergencies and community right-to-know information under SARA Title III will continue in anticipation of future funding. The user audience includes Superfund personnel and contractors, state and local governments, local emergency planning committees, industry, as well as private citizens for Title III requirements. Although resources for emergency planning and community right-to-know research needs may not be allocated until FY90, future products are expected to impact the Superfund program. Therefore, Title III research needs and plans are included in this document.

Superfund field procedures and guidance needs fall into four major categories: site assessment, safety procedures and equipment, reportable quantities, and manuals and training. Title III research is an additional need, which will probably be funded in FY90. ORD conducts tests and documents the latest site monitoring and characterization methods to ensure quick, consistent, and effective ***site assessment.*** Emphasis is on *in situ* gas chromatography and air sampling, but other areas such as Health and Environmental Effects Documents and expert systems to evaluate technologies are included. The purpose of the ***safety procedures and equipment research*** is to identify and improve commercially available and prototypical chemical protective materials, clothing, equipment, and procedures that have the potential for significantly increasing the safety and cost-effectiveness of EPA and contractor operations at Superfund sites. CERCLA §103 requires EPA to promulgate and revise, as appropriate, regulations establishing ***reportable quantities*** for hazardous substances, and research provides data necessary for their preparation. ORD ***manuals and training seminars***, authorized under CERCLA §311(b), focus on the use of alternative treatment technologies for remedial action, and target a wide variety of users. Under Title III, EPA is being asked to provide reliable methods for monitoring chemicals released accidentally into communities. When Title III is funded, EPA would like to catalyze industrial modeling and mitigation research while emphasizing validation of new monitoring models and technologies.

SUPERFUND PROGRAM NEEDS

Field procedures and guidance needs of the Superfund program fall into four categories—site assessment technologies, safety procedures and equipment, reportable quantities, and manuals and training seminars. Additional needs include those of the emergency planning and community right-to-know program.

Field-portable, cost-effective instruments, protocols, and guidance to detect and measure chemical concentrations have been urgently requested by personnel engaged in nearly every phase of Superfund cleanup and by local planners who wish to monitor priority compounds for rapid responses to chemical releases. Requested technologies include monitoring methods and equipment for field applications of gas and liquid chromatography, X-ray fluorescence, fiber optic sensors, and immunoassays. Additional needs include

characterization procedures, analytical protocols, and interpretation approaches for air, soil, and subsurface water. Because water contamination is one of OERR's most pressing concerns, the capability of measuring contaminants in water, water-related media, and soil is a priority. Modifications to advanced monitoring technologies such as Fourier-transform infrared techniques and field-portable mass spectrometry are needed to increase their durability and decrease the technical skills required to apply them.

During preliminary investigations, remedial response coordinators need the capacity to rapidly assess hazards to public health and the environment from chemical exposure. To provide such information, chemical-specific, *Health and Environmental Effects Documents* are needed for chemicals of concern. These documents are not definitive risk assessments. However, they offer important source information that may be used in preparing risk or health assessments. Additional source information that may be needed include the requirements set forth in ARARs, toxicological profiles, and other health and chemical information.

As an employer, EPA is obliged to provide its response personnel with chemical-protective clothing, equipment, and procedures that prevent harmful exposure. Field activities at hazardous waste and spill sites have shown that the safety and operational effectiveness of commercially available protective clothing, equipment, and procedures do not meet some EPA requirements. Personnel protection research is needed to improve the safety, consistency, and efficiency of cleanup operations and reduce personnel protection costs. Since all chemical protective clothing, equipment, and procedures have limitations, it is important that these limitations are defined through evaluation and testing to prevent misuse and injury.

CERCLA §103 requires EPA to promulgate and revise, as appropriate, regulations establishing protective quantities for substances on the Extremely Hazardous Substances List and other substances at the discretion of OERR. Hazardous substances detected in the environment in quantities equal to or greater than those established by EPA must be reported to the National Response Center. The statutory reportable quantity (RQ) provides an initial indicator of a problem level of pollution. It is not, however, intended as a measure of potential health hazard.

CERCLA §311(b) authorizes a technology transfer program to disseminate information related to the utilization of alternative or innovative treatment technologies, including effectiveness, cost, and application procedures. Thus, many of ORD's manuals and training seminars for the Superfund program stress the use of alternative treatment technologies for site remedial action.

Under SARA Title III, EPA is directed to establish a new regulatory program that will require disclosure of more information to workers and the public about the risks associated with exposure to hazardous substances and the location of such substances in the community. The intent of Title III is to prevent a tragedy in the United States similar to those experienced at Bhopal or Chernobyl by improving local emergency response capabilities. This will be accomplished primarily by creating emergency response plans for accidental releases and by providing citizens and local governments with access to information about chemicals in their communities. Implementation of Title III will build upon the original EPA Chemical Emergency Preparedness Program, existing state and local emergency response programs, and growing industrial research and awareness programs like those established by the Chemical Manufacturers Association. The primary target audience includes the state emergency response commissions and local emergency planning committees that were established under Title III to provide a structure for planning and coordination.

As the lead regulatory and enforcement agency for Title III, EPA can expect requests for information about reliable methods to monitor accidental releases, mitigate a release, and assess health risk. EPA, in collaboration with

the American Institute of Chemical Engineering has begun to adapt monitoring techniques, mitigation technologies, and toxicological information to accidental releases. EPA anticipates playing a vital role in catalyzing industry modeling and mitigation research.

EPA routinely uses dispersion modeling tools for estimating the range and concentrations of contaminants resulting from continuous releases, but like most monitoring techniques, these tools are either not applicable to accidental releases or are not available at an appropriate level of detail for use by emergency planning committees. Similarly, mitigation technology for accidental releases is generally lacking, although several existing methods show promise for reducing the consequences of a chemical release. There is a need to link dispersion modeling with evaluations of the effectiveness of mitigation technologies for accidental release scenarios.

To design emergency procedures, emergency planning committees need easy access to relevant toxicological and emissions information in a format they can use. While some information is available through various emergency response hotlines, additional information is required, including reliable estimates of annual emissions from industry and field procedures and guidance oriented specifically to authorities responsible for emergency planning, release response, and release prevention.

RESEARCH NEEDS

Field procedures and guidance are needed to ensure that promising technologies and methods are quickly made available to users in the field. Methods and technologies need to be evaluated to define their applicability and to improve and standardize procedures for their use. The research needs include technologies and methodologies related to air, soil, and water in nearly all ORD activities, including monitoring, processes and effects, health effects and safety, environmental engineering, and technology transfer. Current priorities are greatly influenced by program office needs for *in situ* site assessment, safety procedures and equipment, reportable quantities, and treatment technologies, as well as Title III models and information. Based on the field procedures and guidance research needs, the following research objectives have been identified:

- Modify and prepare guidance on site assessment protocols, techniques, and methods with emphasis on gas chromatography and air sampling.

- Prepare sampling, analysis, and applied statistical techniques for rapid on-site waste assessment, including air and soil sampling.

- Prepare support tools including geostatistical simulation methods and an expert system to evaluate the waste characteristics, hydrology, geology, soil characteristics, engineering costs, and effectiveness of technologies used at Superfund sites.

- Provide *Health and Environmental Effects Documents*.

- Evaluate the cost and performance of protective clothing, equipment, and devices that warn of imminent hazard to life and health under typical use conditions and prepare guidance regarding appropriate applications that will improve performance.

- Provide carcinogenicity and chronic toxicity documentation for preparing reportable quantities of substances proposed for listing as hazardous substances; substances on the Extremely Hazardous Substances List; Title III §313 chemicals not currently on the CERCLA Hazardous Substance List; and for other substances designated by OERR.

- Provide OERR with manuals and training seminars on the use of alternative treatment technologies in Superfund cleanups.

- Catalyze industry and state government research efforts to develop dispersion models and mitigation technologies for accidental release situations.

- Design approaches to maximize the reliability of industry's annual emission estimates of hazardous chemicals under §313 of SARA without costly monitoring.

- Fill technology gaps and provide guidance to industry and state and local governments on methods to prevent accidental releases.

- Generate new toxicological, persistence, and bioaccumulation data relevant to accidental releases and provide technical information to communities in a format they can use.

FIELD PROCEDURES AND GUIDANCE RESEARCH APPROACH

The field procedures and guidance research approach is summarized in Figure 5.

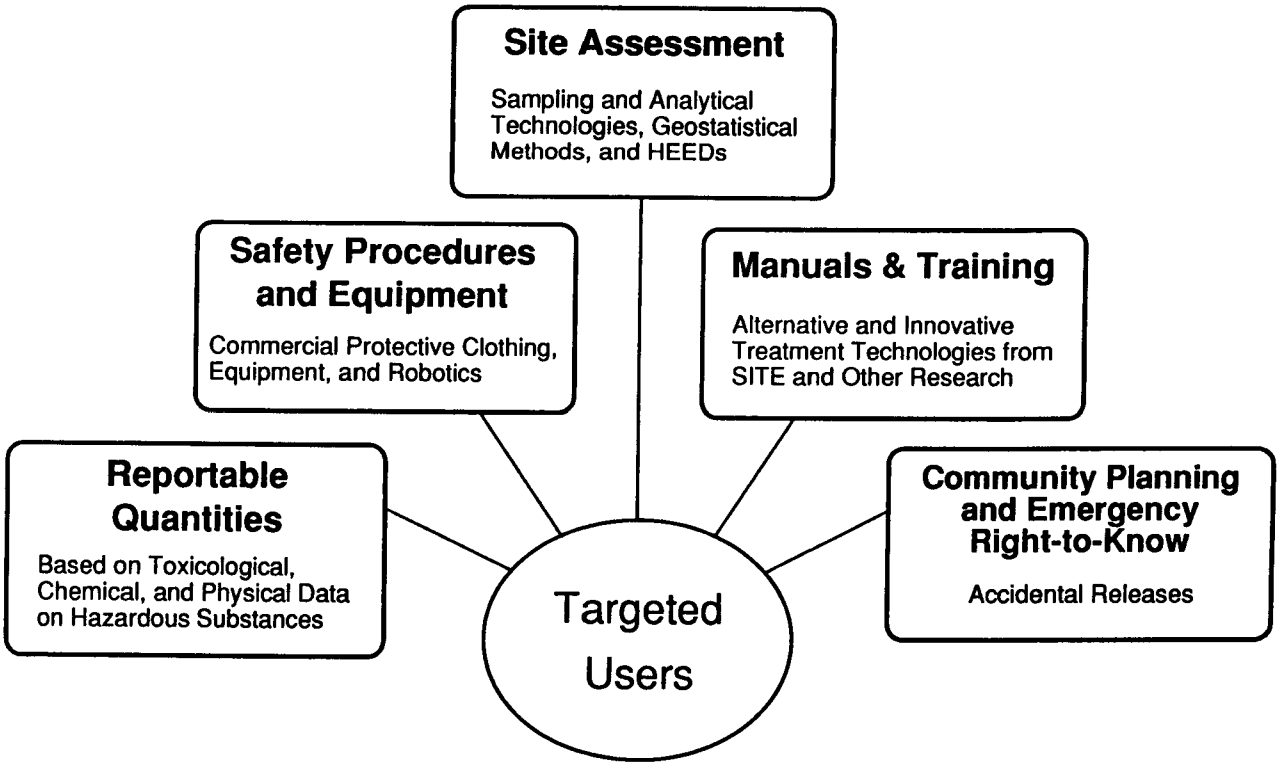


Figure 5. Research to Evaluate, Improve, and Standardize Field Procedures and Guidance.

Site Assessment

As an extension of ORD's Superfund health effects, risk assessment, and detection development and evaluation program, ORD tests and documents the latest monitoring methods, characterization procedures, analytical protocols, and interpretive approaches for use in the field. This ensures that Superfund sites are assessed quickly, consistently, and effectively. The emphasis of current research is on portable gas chromatography, air monitoring techniques for ambient and source sampling, sample preparation methods including soil core procedures, geophysical methods such as high resolution seismic reflection, automated data transfer techniques, and analytical techniques for determining hydraulic properties.

A project is underway to document a gas chromatography/mass spectrometry (GC/MS) procedure for separating and identifying low-concentration organics (0.1 to 10 µg/L) in water-related media. This methodology will also be used to evaluate the effectiveness of remote sensing technologies, such as fiber optic laser fluorescence for detecting water contaminants. For non-volatile compounds, supercritical fluid chromatography and liquid chromatography/mass spectrometry are under investigation through an agreement with Cornell University.

Guidance for newly developed sampling and analysis techniques will be prepared, including air sampling for brominated and chlorinated dioxins, canister-based air samplers for semivolatiles, a prototype continuous formaldehyde monitor, and a procedure to automate identification of source emission patterns. New high-resolution mass spectrometry and Fourier-transformed infrared analytical systems will soon be available to support sample analysis.

The newly developed canister-based sampling systems being tested for field use include a two-stage preconcentrator, sequential sampler, solid sorbent/canister, and portable sampler. Use of a multi-sorbent bed, rather than a reduced temperature strap, has improved sample preconcentration by eliminating the need for mass spectral search routines and liquid nitrogen to reduce the temperature of samples.

With increasing use of methanol fuel, which produces formaldehyde when burned, EPA needs the capability to monitor formaldehyde in the environment. A prototype formaldehyde monitor, based on a Battelle Columbus Laboratories design, will be built after two possible configurations are evaluated. One configuration requires a preconcentrator, the other uses fluorescence detection that eliminates the need for preconcentration.

Techniques and guidance for collecting and handling soils contaminated by volatile organics are being prepared. In support of these methods, new algorithms will be developed for geostatistical simulation software that can determine the uncertainty in spatial contaminant estimates in soil. Geostatistical software for use on a personal computer and a user's guide will be prepared. An experimental soil plot, contaminated with volatile organics, will be prepared for testing the software system.

Preliminary investigations have demonstrated the value of integrating geologic information systems with remote sensing data from aerial photography, airborne multispectral scanning, and satellite digital imagery. Remote sensing and GIS systems for vegetation, habitat, land use, water quality, and exposure risk monitoring will be tested for use in ecosystem impact analysis and human exposure assessments at Superfund sites. Written guidance and demonstrations of the applicability of these systems will be provided to Superfund personnel.

Geophysical, geochemical, and hydrologic surveys have proven effective in locating and mapping contamination at hazardous waste sites, and in determining hydrogeological structures. ORD is developing techniques that will improve their resolution using a computer-based, geophysical expert system to evaluate the applicability of

geophysical methods at Superfund sites. The expert system will include a database of the physical and chemical properties of the top 100 CERCLA contaminants. Surface-to-borehole, cross-borehole, and near-surface seismic reflection geophysical techniques will be evaluated using computer models and field demonstrations.

In regard to other field techniques and procedures, ORD compiles available literature from EPA Regional offices and other federal agencies to identify, review, and summarize current practices. Techniques most suitable for implementation are evaluated and field tested for potential use by the Superfund office. A control contaminated site that provides a homogeneous sampling area for field demonstrations, sampling investigations, and personnel evaluations will be located to support this effort.

Carcinogenicity, mutagenicity, developmental, and reproductive toxicity data are needed for preparation of risk assessments and approximately 60 *Health and Environmental Effects Documents* (HEEDs) each year covering single chemicals and complex mixtures will be funded by Superfund. This represents approximately 40% of the of the total ORD, HEED program. Approximately 75% of HEEDs prepared by ORD are selected by the Office of Solid Waste, which provides about 60% of HEEDs funding. The information, however, is used by both the Office of Solid Waste (OSW) and Superfund. HEEDs provide Superfund personnel with immediate source information on potential human health effects associated with exposures to specific chemicals. They also provide useful information for development of ATSDR's Toxicological Profiles, required by SARA, and supplement health and risk assessment conducted for specific Superfund sites. In the future, HEED exposure analyses will include complex mixtures. The STARA (Studies on Toxicity Applicable to Risk Assessment) database will be maintained as a source of health assessment and chemical-specific information for EPA emergency and remedial response coordinators on a 48-hour turnaround basis.

ORD is preparing tools like the computer-assisted engineering expert system for Superfund personnel to evaluate the effectiveness and cost of remedial action technologies. This expert system is based on survey data and evaluations of the engineering costs, waste characteristics, hydrology, geology, soil characteristics, and effectiveness of remedial technologies used at Superfund sites. In support of its lead exposure and cleanup responsibilities, ORD will continue to conduct workshops to develop consistent protocols for sampling and analysis during abatement demonstration projects. ORD also provides manuals to guide the use of all of its support tools and disseminates technical information for general RI/FS guidance.

Safety Procedures and Equipment

Personnel protection research affects a variety of EPA roles pursuant to CERCLA, including the procurement and use of chemical protective clothing and equipment for laboratory and field operations, development of guidelines for the selection of chemical protective clothing, development of site safety plans, and preparation of safety training courses for EPA employees and client organizations.

Personnel protection research, development, testing, and evaluations support EPA groups such as the Environmental Response Team, Regions, and Occupational Health and Safety Staff that perform CERCLA assessment and cleanup activities. The purpose of the research is to identify and improve commercially available and prototypical chemical protective materials, clothing, equipment, and procedures that have the potential for significantly increasing the safety, efficiency, and cost-effectiveness of EPA and contractor operations at uncontrolled hazardous waste and accidental release sites.

The Superfund personnel protection research program will:

- Conduct desktop, laboratory, and field evaluations of protective clothing and equipment performance.
- Prepare guidance documents regarding the selection and appropriate use of protective clothing and equipment.
- Verify methods for predicting the performance of protective clothing based on characteristics of the clothing, chemicals, and work scenarios.
- Develop methods for testing the effectiveness of chemical protective clothing and equipment.
- Conduct literature searches and state-of-the-art studies on topics of critical concern to personnel protection.
- Analyze the costs and benefits of alternative personnel protection technologies.
- Prepare personnel protection technology research outputs that will enhance safety and flexibility and reduce costs of cleanup operations.

Chemical Protective Clothing and Equipment

Protective clothing and equipment for hazardous operations will be subjected to desktop, laboratory, and field evaluations to address technical issues of interest. The leading candidates for evaluation are disposable protective clothing, vital sign monitors, personal cooling devices, respiratory protection devices, new garment materials, totally encapsulating ensembles, and personal communications devices. To help analyze EPA's personnel protection technology research needs, a "personnel protection technology profile" is being developed that will incorporate EPA personnel protection research needs and ongoing research, development, testing, and evaluations. It will also include an inventory of protective clothing and equipment and a categorized mailing list for Agency staff with operational or regulatory roles that require up-to-date information on the capabilities and limitations of personnel protection technology.

Work in this area will (1) develop a protocol for segregating protective clothing into non-hazardous and hazardous waste categories; (2) examine available research information on the effects of temperature and humidity on respirator performance and providing improved guidance on selection of respirators under abnormal humidity and temperature conditions; (3) improve the performance of disposable protective clothing; and (4) exchange research information with EPA and its contractor user community.

Personnel Protection Procedures

The safety, efficiency, and cost of CERCLA operations are influenced by the availability, appropriateness, and reliability of a wide range of personnel health and safety procedures. One of the most promising new developments is the application of automation and robotics to field monitoring procedures to eliminate the need for exposing personnel to hazardous conditions.

A preliminary study of the use of robotics for improving safety and productivity in hazardous response operations has shown that application of a robotic system to air monitoring and sampling is technically feasible and economically beneficial. ORD will, therefore, conduct a performance demonstration of the use of a commercially

available robotic navigation platform for conducting continuous and automatic air monitoring and data handling around a site perimeter, which is often tedious and hazardous, but necessary.

Coordination with Other Research and Development Activities

Several civilian federal agencies, recognizing their common interest in personnel protection research, formed a work group to better coordinate efforts in this area. The work group consists of representatives from EPA, U.S. Coast Guard, Federal Emergency Management Agency, National Institute of Occupational Safety and Health, and Occupational Safety and Health Administration. The work group meets semiannually and is preparing a combined research summary and a mailing list of persons with an interest in research products generated by work group members. EPA and its contractors also participate in industry and manufacturing groups concerned with developing test methods for protective clothing.

In FY89, no new activities will be initiated, and this research element will be phased out by FY91. Much of the basic research has been concluded, and EPA believes that future evaluations and innovation of commercial equipment is more cost-effectively better left to the private sector and to other agencies such as OSHA and State worker protection offices.

Reportable Quantities

The RQ is used to specifically identify that quantity of a hazardous substance that, if exceeded in a release into the environment, requires notification to the National Response Center at EPA. RQs are prepared from chemical-specific data regarding the potential carcinogenicity, chronic toxicity, mammalian toxicity, aquatic toxicity, reactivity, and ignitability in any media and route of exposure. Quantities (in pounds) developed from each category of data are subjected to previously established criteria and the lowest RQ among them is selected for a given chemical. To be able to rank RQs, only "generic" data are used. Thus, RQs are designed for initial Superfund site reporting purposes, and are not intended to reflect the potential for a human health hazard.

FY89 research plans call for completion of RQs for substances on the Extremely Hazardous Substances List; preparation of RQs for inclusion in approximately 60 HEEDs each year (as part of OERR's HEED funding); revision of RQs for approximately 125 chemicals from the Extremely Hazardous Substances List; and evaluation of approximately 100 chemicals for possible designation as CERCLA hazardous substances and possible RQ development.

Manuals and Training Seminars

The following manuals and seminars related to treatment technologies are planned for FY89 and FY90:

Summary and Evaluation of Alternative Technologies Demonstrated in the SITE Program

Several approaches are planned for disseminating information on alternative remedial technologies generated by the SITE program to a large and diverse audience. Detailed project research reports, the Superfund Clearinghouse, and annual SITE reports to Congress will be used to address some of these user groups. This project will develop a series of capsule reports on SITE program technologies for wide distribution throughout the Agency, states, educational institutions, consulting firms, public interest groups, and others. The high-visibility reports will provide concise technical information on alternative technologies (based on SITE demonstrations and other research)

including: technology description, variations, applicability, limitations, technology status, construction and pretreatment requirements, performance, reliability, safety considerations, potential for adverse environmental impacts, residual handling, cross-media considerations, costs, and references. The reports will be published periodically throughout FY89 and FY90.

Immobilization Technology for Remedial Project Managers

Remedial project managers, who have responsibility for the selection of remedies and oversight of Superfund cleanups, require additional technical and policy information for implementation of S/S technology including the types of wastes that are amenable to treatment. They also require appropriate testing procedures for evaluating processes under consideration. ORD will conduct five to six workshops and develop a handbook to provide engineering guidance on S/S technologies. Final results and proven practices will be emphasized. Case histories will be used to introduce research findings and technologies not yet applied in practice. General topic areas will include chemical and physical testing protocols, evaluation of treatability testing performance, interpretation of test data to provide the best engineering design, selection criteria, costs, and state-of-the-art construction equipment. The seminars and handbook will be completed by the end of FY89.

Physical and Chemical Treatment of Hazardous Waste

Physical treatment processes are those that utilize physical characteristics to effect a separation or concentration of constituents in waste products. Physical treatment processes include gravity separation, phase change (evaporation or distillation), and dissolution (soils washing or filtration). Chemical treatment serves to separate, change, or otherwise reduce or eliminate toxicity, and includes such processes as *p*H adjustment, oxidation, and reduction. Physical and chemical technologies provide an ultimate treatment and can be effective in the preparation of materials for other alternative treatment technologies. However, many of these technologies have been used with insufficient concern for the excessive quantities of sludge and additional hazardous products that result from their use that are often difficult to manage.

ORD will develop a series of four or five workshops to address the judicious utilization of physical and chemical treatment technologies. The workshops will be conducted for federal, state, and private sector personnel. Recent developments in the SITE program and information obtained from field operating experience in utilizing various physical and chemical processes will be presented. Materials recycling will be incorporated where appropriate. The seminars will be completed by May, 1990.

Design and Operation of *In Situ* Treatment Systems

In situ treatment systems are those that provide treatment in place and offer the greatest potential for cost-effective cleanup of contaminated soils and ground water. There is, however, minimal operating experience in the use of *in situ* treatment of contaminated soils and ground water. Similarly, information on the design of *in situ* treatment systems is generally based on theory, bench studies, and in a few instances, pilot studies rather than on full-scale evaluations or actual case studies. There is a significant amount of on-going research on *in situ* treatment processes within EPA that needs to be transferred to actual practice.

A series of ten seminars and a publication will be developed to serve as a forum to transfer research into practice and to share case history information on *in situ* treatment systems. Presentations will be targeted to federal and state remedial project managers as well as remedial contractors. These presentations will be tailored to highlight research

results that are sufficiently developed to have full-scale applicability to the design and operation of *in situ* treatment systems. Case history information will be compiled and presented on actual full-scale applications. The seminars and publication will be completed by the end of 1989.

Remedial Action Costing Procedures

To evaluate and select a specific treatment technology, it is necessary to estimate costs for several likely remedial action alternatives. ORD has developed two publications on costing remedial actions: *Compendium of Costs of Remedial Technologies* and *Remedial Action Costing Procedures Manual.* These documents contain analyses of actual expenses incurred during the remedial responses for several major types of engineering technologies and specific procedures for cost estimating and economic analysis. In order to provide this information in a more useful format, ORD is developing a microcomputer-based software package for estimating remedial action costs. Detailed procedures will be included for generating estimated capital and annual operating costs, calculating annual costs for each remedial action alternative, and performing sensitivity analyses of the cost estimates to determine the impact of changes to various cost input parameters. The software is expected to be available by the end of FY90.

Leachate Plume Management

Contamination of subsurface drinking water supplies is one of the more serious problems encountered at Superfund sites, and one of the most intractable. Nearly 70 percent of the sites now undergoing remedial action have contaminated ground water. Movement of liquid waste to the ground water regime is possible where the geologic material between the waste site and water table is permeable. By far the most predominant means of contaminant movement to the ground-water system is via dissolution by infiltrating precipitation. Wastes dissolved into infiltrating solutions are carried through the site and underlying soil along solution channels or seepage paths to the ground water. Solutions containing dissolved waste constituents are called leachates. Once in the ground water, contaminants are not diluted and flushed from the system to the extent they would be in surface water because flow rates are slower and flow paths more tortuous. As a result, contaminants tend not to disperse, but form slugs or plumes. The management of leachate plumes has been constrained to some extent by a lack of understanding of plume dynamics and the various remedial options available.

ORD is implementing a program to assess and disseminate information on technologies and procedures related to plume management. Technical guidance on leachate plume management has recently been revised to include lessons learned and new technologies. The revised document will be the basis for a series of five or six seminars that will provide the latest information on leachate plume dynamics and plume management alternatives. Presentations will stress factors that affect leachate plume movement, key considerations in delineating the current and future extent of leachate plumes, technologies for controlling the migration of plumes, and criteria for evaluating and selecting plume management alternatives.

Emergency Planning and Community Right-to-Know

State and local governments, the public, and the private sector will need information from EPA on reliable test methods for monitoring chemicals released accidentally into their communities. However, reliable methods or criteria do not yet exist for many chemicals. EPA's approach is to catalyze industrial modeling and mitigation research and emphasize validation of new models and technologies. Resources, however, have not yet been committed.

Through the International Vapor Cloud Research Committee, EPA is playing an active part in a coordinated international effort to meet research needs in dispersion modeling for monitoring hazardous gas cloud movements and in mitigation of accidental hazardous chemical release. The International Vapor Cloud Research Committee includes representatives from the American Institute of Chemical Engineering Center for Chemical Process Safety (AIChE/CCPS), several federal agencies, and representatives from a number of petroleum and chemical companies world wide. AIChE/CCPS is acting as the coordinating secretariat of the Committee. The intent of the Committee is to avoid costly duplication of research effort, explore opportunities for co-funding of expensive research projects, and share information world wide. At the request of EPA, the AIChE/CCPS ranked modeling research priorities, based on the availability of data and adequacy of existing models, for presentation to the Committee this year.

In addition to modeling and mitigation research, there is an immediate need for approaches that maximize the reliability of annual emissions estimates by industry under SARA §313. However, before such guidance can be developed, data and methodological deficiencies must be overcome in emission estimation techniques and quality assurance methods. ORD will also encourage the release of proprietary information vital to the public safety.

Chemicals included on the §313 list for emissions reporting must have been demonstrated to cause acute human health effects, cancer, birth defects, serious or irreversible reproductive dysfunctions, neurological disorders, heritable genetic mutations, or other chronic health effects. However, because methods and evaluation tools are lacking, significant health effects data are missing for §313 chemicals. Ecological effects data are also lacking. EPA plans to generate methods and data and make them available to Title III users in an appropriate format.

COORDINATION WITH OTHER AGENCIES

SARA authorizes Superfund research, development, and demonstration on hazardous wastes by the Department of Defense with funds from a special account set up by Superfund. DOD is required under SARA to consult with EPA to conduct an environmental restoration program to perform response actions for hazardous substance releases at DOD facilities and vessels. A DOD and EPA work group was established in 1985 to explore cooperative research efforts that could be undertaken on hazardous waste technology. In 1986, the Department of Energy (DOE) joined the work group. While not directly authorized to conduct Superfund research, DOE is interested in participating in the development and demonstration of cost-effective and long-term solutions to hazardous waste problems that may be applicable to DOE facilities. Over 30 cooperative research, development, and demonstration projects are currently underway as a result of this collaboration.

MAJOR DELIVERABLES

Sixty Health and Environmental Effects Documents with Reportable Quantity Chapters. Each Year.

Approximately 100 Reportable Quantities. Each Year.

Application of Near-Surface Seismic Reflection to Hazardous Waste. Due 4/89.

Interim Report on Improvement of Worker Safety via Robotics, Automation, and Task Modification. Due 7/89.

Report on Optimization of Treatment for Superfund Remedial Actions. Due 9/89.

VOC Sampling System for Site Characterization. A sampling system for measuring volatile organic compounds (VOCs) will be described. Due 10/89.
Emerging Technologies for the Treatment of Metal-Bearing Wastes. Due 10/89.

Report on an Analytical Technique for Determining Hydraulic Properties. Due 12/89.

Soil Sample Preparation Manual. Due 12/89.

Review of Feasibility Project Plans and Reports from a Remedial Action Options Perspective. Due 12/89.

Immobilization Technologies for Remedial Project Managers. The product includes a seminar series and manual. Due in FY89.

Physical/Chemical Treatment of Hazardous Waste. The product includes 4-5 workshops. Due in FY89.

Report on Evaluation and Improvement of Protective Clothing, Equipment, and Procedures for Hazardous Substance Response Operations. Due 9/90.

Summary Evaluation of Alternative Treatment Technologies Demonstrated in the SITE Program. The product includes a series of capsule reports. Due in FY90.

Design and Operation of In Situ Treatment Systems. The product includes a seminar series. Due in FY90.

Remedial Action Costing. This is a microcomputer program. Due in FY90.

Leachate Plume Management. The product includes a seminar series. Due in FY90.

DEVELOPMENT AND EVALUATION: TREATMENT TECHNOLOGIES

SARA contains requirements that directly affect research priorities: the need for better assessment of health risks posed by Superfund sites and for treatment technologies that offer permanent protection of human health and the environment. The legislation specifically addresses the need for a comprehensive federal program promoting research, development, and demonstration activities to improve databases, risk assessment methods, and control technologies. While the human health and ecological risk assessments define existing or expected risks, it is implementation of control technologies that actually mitigates or eliminates public health and ecological hazards.

The Superfund Program is somewhat different than most other Agency programs in that it is a response rather than a regulatory program. EPA must manage actual cleanup operations rather than just develop and enforce regulations. Because public funds are used to clean up Superfund sites, it is incumbent upon EPA to ensure that sufficient remedial technologies are available and that removal and remedial managers have performance and cost-effectiveness information on available technologies to enable defensible remedial decisions. ORD must provide support for feasibility studies, remedy selection, remedial design, and remedial action in Superfund cleanups by developing control technologies based on strong scientific principles and conveying this information to the public and private sectors.

EPA's research promoting treatment or control technologies is of critical importance in enabling the Superfund program to meet the cleanup standards mandated by SARA. For this reason, a significant portion of ORD's Superfund budget for FY89 and FY90 is directed toward the development and evaluation of alternative and innovative treatment technologies. ORD research in this area incorporates the development and evaluation of technologies, techniques, and construction materials that require additional laboratory development to be ready for field application, as well as research, development, and demonstrations that promote commercialization of alternative treatment and monitoring technologies.

ORD and OSWER have established a formal program to accelerate the development, demonstration and use of new or

Treatment technology research develops and evaluates technologies that require additional laboratory development before field application, and conducts demonstrations to promote commercialization of alternative treatment and monitoring technologies. The program is divided into two subprograms: ***Performance of Treatment Technology*** and ***Superfund Innovative Technology Evaluation*** (SITE). The former evaluates the performance of unproven treatment technologies and develops the most promising to a point where the private sector can commercialize them with the help of SITE and cooperative research agreements authorized by the Federal Technology Transfer Act of 1986. This research is conducted in six areas: biosystems, physical and chemical *in situ* control technologies, on-site control technologies, combustion techniques, best demonstrated available technologies for RCRA, and expert systems. A multi-purpose facility is being constructed to expand these studies. The goal of the SITE program is to increase the use of alternative treatment technologies in cleaning up Superfund sites and encourage the development of innovative monitoring techniques. The SITE Commercial Development and Demonstration Program evaluates commercially developed technologies through demonstrations in the field—29 thermal, chemical, biological, and physical technologies have been accepted into the demonstration program. SITE also includes the Monitoring Technology Development and Demonstration project and the Emerging Technologies Testing and Evaluation Program to assist in the development of emerging technologies.

innovative technologies. In CERCLA §311(b), EPA is directed "to carry out a program of research, evaluation, testing, development, and demonstration of alternative or innovative technologies ... which may be utilized in response actions to achieve more permanent protection of human health and welfare and the environment." In addition, our ability to characterize or assess the extent of contamination, the chemical and physical character of the contaminants, or the stresses imposed by the contaminants on complex ecosystems is limited, and new, innovative technologies are needed in this area as well. These program areas comprise the Superfund Innovative Technology Evaluation program. The primary purpose of SITE is to enhance the development and demonstration and thereby establish the commercial availability of innovative technologies at Superfund sites as alternatives to the containment systems presently in use.

Another recently enacted statute, the Federal Technology Transfer Act (FTTA) of 1986[2], will have a major impact on EPA's ability to increase the availability of proven treatment technologies at Superfund sites. The FTTA authorizes EPA and other federal agencies to enter into Cooperative Research and Development Agreements on a non-competitive basis with individual private firms or consortia. Under such agreements, EPA may agree to allow the private firm to patent any new inventions that may be developed under the agreement or make a commitment to give the firm an exclusive license to make use of such inventions. In consideration for the above concessions, EPA is authorized to receive direct funding from the firm for the joint research and development and use of the firm's facilities, equipment, services, or staff. EPA is also authorized to provide the same services to the private firm, with the exception of direct funding. The FTTA thus offers EPA opportunities to lower the cost to EPA of developing new and innovative treatment technologies to the proof-of-concept stage and to increase the number of commercially available waste treatment technologies.

SUPERFUND PROGRAM NEEDS

Superfund sites contain an enormous number of hazardous substances, often in complex chemical mixtures. This difficult cleanup problem is exacerbated by inadequate or costly technologies for the cleanup of hazardous releases from uncontrolled hazardous waste sites and spill incidents. With the exception of certain forms of incineration and chemical fixation, cost-effective permanent technologies are generally not available for the broad range of Superfund wastes and the matrices (liquids, sludges, soils, and debris) in which they are found. The goal of control technology is to provide permanent treatment technologies for the cleanup of Superfund sites and associated contaminated ground-water aquifers.

Response to an uncontrolled site typically involves efforts to stabilize the situation, to identify and quantify areas of contamination, followed by efforts to remove contaminants by current technologies. Treatment of contaminated soils is a particularly under-developed technology area, formerly solved by simply transferring the contaminants from the uncontrolled site to landfills—risking the creation of future waste site problems elsewhere.

To prevent the creation of new Superfund sites during the cleanup of existing sites, the Hazardous and Solid Waste Amendments (HSWA) of 1984 requires that, prior to disposal of Superfund wastes in a RCRA facility, the hazardous waste must be treated to a point where its concentration is no longer considered hazardous or meets the standard of the best demonstrated available technology (BDAT). This means that Superfund site wastes will have to be treated to BDAT levels before being removed and transported to a permitted RCRA facility. The Office of

[2]The FTTA is an amendment to the Stevenson-Wydler Technology Innovation Act of 1980, and is further strengthened by Executive Order 12591.

Solid Waste in OSWER is planning, within the next two to three years, to set pretreatment standards for all soils and debris contaminated by listed wastes. To solve the problems caused by these land disposal restrictions on the remediation of Superfund sites, additional treatment and disposal techniques must be made available and information on their performance and costs determined.

There are many technical problems associated with implementation of the remedial process and the land disposal restrictions:

- Although the number of treatment technologies is rapidly expanding, many are still under development or have not been demonstrated in the field. Personnel responsible for the selection of site remedies are reluctant to use untried or unproven remedial techniques.

- The land disposal restrictions for Superfund wastes has caused a great demand for treatment technologies capable of effective treatment of excavated soils on site or treatment of contaminants in place, but there are a limited number of proven on-site and *in situ* treatment technologies, and information on their performance and cost is limited.

- Material handling and pretreatment methods for the disposal of Superfund wastes at RCRA facilities, especially for large volumes of contaminated soils and debris, have not been developed. In general, the treatment of contaminated soils and debris is an area for which sufficient data to make treatment decisions are lacking.

- After removal or remedial actions at Superfund sites, there are often large volumes of soils and ground water containing low levels of contamination that remain on site and must be treated to attain safe levels. Moving or treating such materials with current technology becomes less cost-effective as the volumes of material to be treated increases.

- Many chemicals found at hazardous waste areas are slow to biodegrade because initial microbial attack involves reactions that are slow, highly specific, and energy demanding. In addition to chemical and physical treatment and removal techniques, biodegradation using enhanced indigenous microorganisms has great potential to be more cost-effective for cleaning up many Superfund sites than more conventional methods. However, relatively little is known about which contaminants are amenable to *in situ* biorestoration, the controlling process, engineering design criteria, comparative costs, by-products, and effectiveness of the technologies under different conditions.

- Due to the physical and chemical characteristics of subsurface deposits, it is difficult to deliver *in situ* treatment materials uniformly or to totally recover contaminants. In addition, the lack of understanding of basic chemical and physical processes that control the effectiveness of in-place treatments makes it difficult to determine which treatment technologies are most effective and how to enhance their effectiveness.

RESEARCH NEEDS

Each technology currently under evaluation or development has its own information gaps and associated developmental problems. In order to increase the number of effective, permanent treatment technologies available for Superfund site cleanups, the following research needs are being addressed:

- Biosystems research to evaluate and develop naturally occurring and enhanced microorganisms for the degradation of low levels of hazardous substances in soils and ground water.

- Cost and performance evaluations and development of on-site treatment technologies involving extraction and on-site physical and chemical treatment.

- Cost and performance evaluations and development of physical and chemical *in situ* treatment technologies including delivery and recovery systems.

- Best demonstrated available technology evaluations for particular waste and technology combinations to be used in setting pretreatment standards for Superfund site wastes disposed of at RCRA facilities.

- Technical information transfer to Regional Offices and OWPE, especially in the applicability of expert systems to remedial action method selection, design, and costing techniques.

- Test and evaluation facility establishment at which cleanup technologies can be tested, with all necessary safety features, emission controls, and logistical support in place.

- Demonstrations of promising innovative technologies under actual use conditions to provide reliable performance and cost information for future site characterization and cleanup decision making.

- Identification and removal of informational impediments to the use of alternative technologies.

- Procedure and policy development to encourage the use of alternative treatment remedies at Superfund sites.

- Encouragement for the development of emerging technologies.

The Superfund technology testing and evaluation program is divided into two complementary subprograms: Treatment Technology Performance Evaluations and the SITE program (Figure 6). The first evaluates the performance of unproven treatment technologies and develops treatment technologies to the proof-of-concept stage so that information on the appropriate use of treatment technologies is available for Regional cleanup managers and so that the private sector, through SITE and the provisions of the FTTA, can make the technology commercially available. The overall goal of the SITE program is to maximize the use of alternative technologies in cleaning up Superfund sites and to encourage the development and demonstration of innovative measurement and monitoring techniques.

PERFORMANCE OF TREATMENT TECHNOLOGY RESEARCH APPROACH

This portion of the treatment technology research program emphasizes: 1) development of new and innovative treatment technologies to the pilot-scale or proof-of-concept stage in preparation for full-scale field demonstrations; and 2) evaluations of the cost and performance of available treatment technologies developed by EPA and the private sector. Treatment technologies are developed by the Agency when there is low commercial interest, low potential for profit, or high economic risk associated with development of the technology.

Technology-specific evaluation and development will be in the major technical areas of *in situ* and on-site treatment. *In situ* treatment provides physical and chemical treatment technologies for the immobilization or detox-

ification of contaminated soils and sediments left in place, systems to deliver treatment technologies to contaminants left in place, and systems for the recovery of contaminants without excavation. On-site technologies include other contaminant treatment systems that require excavation of soils and debris prior to treatment. Such systems are typically flow-through processes utilizing physical and chemical means to extract or concentrate contaminants for subsequent treatment, to immobilize contaminants within a particular soil ("matrix"), to contain contaminants and reduce their rate of release to the environment, or to degrade or detoxify contaminants.

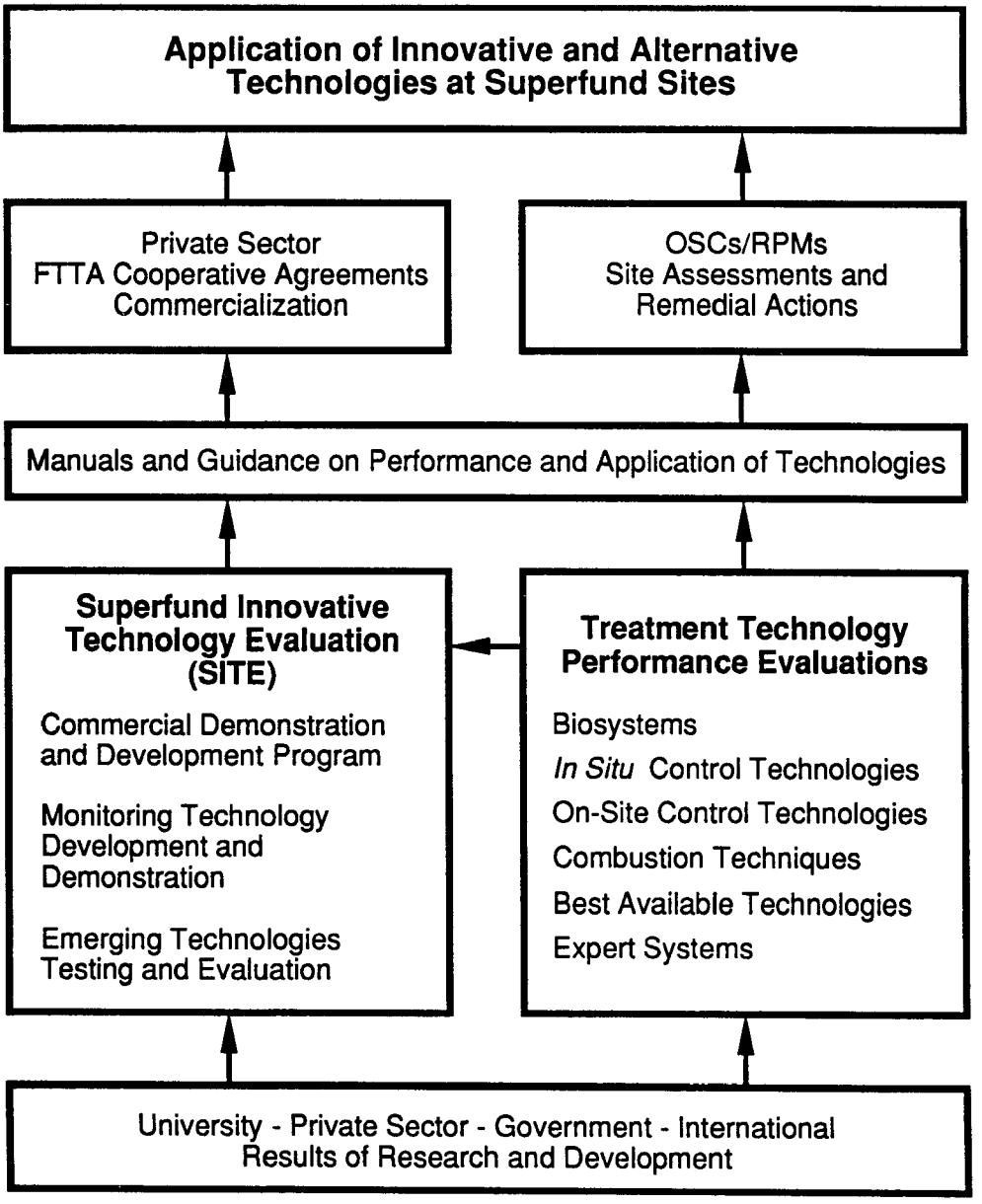


Figure 6. Development and Evaluation of Treatment Technologies Research Program

Research into the biological degradation of Superfund contaminants is a major ORD research initiative and is discussed separately from other treatment technology testing and evaluation because of the special coordination required between EPA biologists and engineers. Two other projects conduct research to determine the best

demonstrated available technology required for RCRA land disposal restriction standard setting and to evaluate and develop expert systems for comparing the performance of treatment technologies under various site conditions. In addition, a multi-purpose Environmental Testing and Evaluation Center is being constructed to expand studies of the performance of a wide variety of physical, chemical, thermal, and biological treatment technologies.

When the concepts behind technologies selected for development and evaluation under this research issue have been proven, the technologies are either handed off to the SITE Program for further development and full-scale demonstration or cooperative R&D agreements are sought with private firms interested in commercializing the technologies for further development under the provisions of the FTTA.

Biosystems

Biological degradation treatment systems (biosystems) are processes for the organized and controlled use of microorganisms and their products for cleaning up toxic and hazardous wastes. Biosystems offer the potential to significantly reduce the cost of safe, effective cleanup of hazardous waste contaminants at many Superfund sites. Current physical and chemical treatment processes either move the chemical from one location to another or attempt to confine further dispersion. Both techniques may leave the waste essentially intact, and they do not always restore the site to its original state. Biological treatment can degrade the chemicals, *in situ*, to benign products that are cycled within the biosphere. Biosystems offer additional benefits for Superfund cleanups including utilization of the broad versatility of microorganisms for degrading mixed wastes; the ability to tailor treatment processes toward specific compounds or groups of compounds at specific sites; the potential to eliminate excavation and transportation costs; and minimization of air emissions associated with the movement of contaminants.

Microbial treatment has already been successfully used in the United States and other countries for on-site and *in situ* treatment of organic contamination of soils at hazardous waste sites. Research and actual cleanup of soils and aquifers contaminated by hydrocarbons, phenols, cyanides, and chlorinated solvents such as trichloroethylene (TCE) have been conducted. Application of this technology to the cleanup of Superfund sites is becoming possible because of greatly increased volumes of information on the biology of the degrading microorganisms and their associated treatment. The biosystems initiative will take advantage of this newly acquired information by applying it to the development of an inexpensive and effective biological approach to cleaning up Superfund sites and other hazardous and toxic waste sites.

The objective of the biosystems program is to develop and demonstrate biological treatment systems for reducing or eliminating the risk from hazardous wastes and other pollutants that have been accidentally or deliberately released into the environment. In addition to the development and evaluation of biosystems, ORD will also work to make new biological treatment systems acceptable to the user community and the public at large. A critical aspect of the biosystems research program is the integration of the technical expertise of ORD biologists and engineers.

Biological research will include characterizing basic biological processes that result in degradation of pollutants, enhancing biological organisms to increase their ability to degrade pollutants, determining the risks involved in releasing biotreatment products, and developing the means to mitigate adverse consequences of biotreatment products. The microorganisms used in the biosystems treatment process are either selected from natural populations or genetically enhanced to carry out specific metabolic functions at an increased level. Biosystems research will, within the next few years, take advantage of the rapidly expanding capabilities in biotechnology, a term currently used in the Agency to refer to the use of microorganisms that have been genetically engineered to accomplish

biodegradation. Researchers use the term "genetically engineered" microorganisms to refer to those in which the chromosomal genetic material has been manipulated and "enhanced" microorganisms to refer to those in which plasmids—discrete packages of extra-nuclear genetic material—have been manipulated in order to speed up the natural selection process. Acceleration of the natural selection process is also accomplished by mixing microbial cultures with contaminants and evaluating survivors.

Knowledge that a particular waste is biodegradable based on laboratory experiments does not necessarily mean that a biological treatment process will be successful in the field. Engineering efforts will draw from biological studies to evaluate, develop, and demonstrate the application of biological agents as pollutant control technologies. Specific engineering aspects will be considered, such as getting nutrients and other amendments to the microbial communities, delivering the microorganisms to the contaminants, removing inhibitory materials, accounting for environmental factors like climatic conditions, and determining whether treatment systems could best be applied *in situ*, on site, or at a centralized treatment facility.

The practical use of a particular bioremediation process requires information on its cost, time required, and level of contaminant reduction. This evaluation will include comparison with conventional methodology, the use of multiple unit operations to treat complex waste mixtures, engineering scale-up and evaluation, specific data needs, and methods for evaluation and field-scale verification of developed technology. Contaminated sites that represent a wide range of common contaminants and hydrogeologic settings, have been conventionally characterized, and will be accessible over a long period of time will be selected to develop biological treatment systems to the field-scale. Data from the field projects will be used to develop mathematical models for use in remedial action decisions, prepare guidance documents for evaluating the use of biorestoration at sites, and design biorestoration projects.

The research plan for the development of biological treatment strategies has been divided into six major categories based on the type of treatment process involved. This organization emphasizes the development of field applications while maintaining enough supporting research to further our understanding of biological treatment processes. Brief descriptions of the projects planned for FY89 and FY90 are included below.

Liquid treatment systems for treating low levels of contaminants in water on site will include:

- *White Rot Fungus Field Test.* Utilize the wood rotting fungus *P. chrysosporium* in a rotating biological contactor to degrade hazardous liquid wastes.

- *Two-Sludge Anaerobic/Aerobic Treatment of CERCLA Leachates in POTWs.* Modify the operational mode of Publicly-Owned Treatment Works (POTWs) to provide improved control of toxics in CERCLA leachates discharged in POTW systems.

- *On-Site Biological Pretreatment Followed by POTW Treatment of Leachates.* Compare three biological pretreatment alternatives for CERCLA sites to improve overall toxics control in leachates discharged through POTWs.

Biological treatment systems for application to Superfund soils and sediments will include:

- *White Rot Cultivation for Soil Treatment.* Demonstrate a soil contamination treatment technology based on the white rot fungus *P. chrysosporium* application to wood treating waste contaminated soils.

- *Feasibility Studies for the Decontamination of PCB-Containing Sediments.* Provide information on those environmental and microbiological factors that might enhance the extent and rate of PCB biodegradation under laboratory conditions. Evaluate this information for its potential application to the biological cleanup of PCB in estuarine environments. Develop bench-scale treatment systems using contaminated soils from New Bedford Harbor.

- *PCP Anaerobic Degradation in Sediments.* Utilize Anaerobic dechlorinating consortia for enhancing degradation of pentachlorophenol (PCP) in contaminated field samples.

Combined treatment systems include chemical or physical treatments to reduce contaminant concentrations to low levels and biological treatment systems to complete the elimination of contaminants:

- *Combined use of KPEG Chemical Treatment and Anaerobic Treatment for Remediating Contaminated Soil.* Assess the utility of combining treatment with potassium polyethylene glycol (KPEG) and anaerobic biological treatment for remediating soils heavily contaminated with toxic organic chemicals.

Sequential application of selected treatment systems will be investigated for degrading mixtures of wastes and particularly recalcitrant compounds:

- *Anaerobic Degradation of Mixed Organic Wastes.* Develop strategies for the anaerobic degradation of mixtures of wastes containing fuel oil, cresols, chlorophenols, PCP in a mixture of fuel oil, chlorinates, benzenes, and PCBs, by natural anaerobic communities.

- *Enhanced Degradation of Creosote.* Apply multiple approaches in biodegradation technology to give the most extensive degradation of creosote in contaminated soils.

Ground-water treatment systems will include:

- *Anaerobic Biological Processes for the Reclamation of Aquifers Contaminated with Carbon Tetrachloride.* Characterize the rates of secondary substrate utilization, and the transformation pathways for the anaerobic cometabolism of carbon tetrachloride supported by denitrification of acetone or isopropanol, and demonstrate the biodegradation of carbon tetrachloride.

The characterization of new metabolic processes, while not directly linked to field application projects, is required as part of the biosystems research program to further the understanding of the biodegradation potential of indigenous microorganisms. Several projects are included that will expand our knowledge of the diversity of metabolic processes and possibly indicate a means by which new processes could be created through selection or genetic engineering. As this understanding advances, new treatment technologies will become evident.

- *Degradation Potential of Microbial Oxygenase Enzymes.* Determine whether novel and useful oxygenase activities can be genetically selected for in microbial cultures by specific enrichment procedures.

- *Dehalogenation Potential of Sulfate Reducing Organisms.* Evaluate the degradative potential of organisms that can degrade chlorinated aromatic hydrocarbons under sulfate reducing conditions.

- *White Rot Fungus Enzyme Development.* Identify the major enzyme contributions to the extracellular oxidation of organic pollutants by *P. chrysosporium* and use this information to improve the performance of both water and soil treatment technology under development, and determine the principle contributors to xenobiotic degradation.

Private firms have expressed interest in using cooperative agreements under the provisions of the FTTA to develop and commercialize biological treatment systems. The move into cooperative agreements will proceed slowly in FY89 to make sure that Agency procedures are followed correctly, but once the first few cooperative agreements are signed, progress toward including the private sector in EPA biosystems research is anticipated to markedly increase.

In Situ Control Technologies

To ensure the availability of cost-effective technologies for the cleanup of hazardous waste sites that pose an unacceptable risk to human health or the environment, the research program on *in situ* technology evaluates the effectiveness, costs, and cross-media impacts of chemical and physical *in situ* technologies and develops concepts for *in situ* treatment to bench scale. *In situ* treatments are needed when an uncontrolled site has large volumes of wastes or soils with low levels of contamination and the cost of excavation for off-site disposal or on-site treatment are high in relation to the risk. The challenge of this program is to provide cost-effective control technologies that can treat the complex mixtures found at Superfund sites and achieve high risk reduction efficiencies for pollutants that are toxic at very low concentrations without further damaging the environment.

Delivery of treatment systems to contaminants and recovery of the contaminants without excavation of soils are essential elements of most *in situ* processes and remain the biggest engineering obstacle to their application at Superfund sites. The development and evaluation of delivery and recovery systems will therefore continue to be emphasized in FY89 and FY90. Two of the most promising techniques to be investigated for improving *in situ* delivery and recovery processes are hydrofracturing and pulsed pumping and injection.

Hydrofracturing is a technique borrowed from the oil industry, where wells in low-permeability rock are pressurized with water to create cracks in the surrounding environment. Porous sand is then pumped into the wells to form long sand-filled lenses that open the system and increase recovery of contaminants.

Pulsed pumping from extraction wells (turning the pump off and on) may avoid the expense of pumping and treating large volumes of water to remove a small quantity of contaminants. This problem is commonly encountered after pump-and-treat systems have been in operation over long periods of time. Pulsed pumping allows time for contaminants to diffuse out of low-permeability zones and allows flushing of hydrodynamically stagnant zones. Work is continuing on site-specific pulsed pumping schemes that do not allow contaminants to be swept past extraction wells along with the flow of ground water during periods when the wells are not pumping.

Most contaminant recovery processes involve removal of contaminants through the water phase. A new area of investigation into improving recovery of contaminants *in situ* includes the evaluation of vapor-phase extraction of contaminants from the soil's unsaturated zones. Initially, subsurface processes that control transfers of contaminants between liquid and gas phases will be studied in order to improve the selection and efficiency of treatment technologies. This work will use data generated on major contaminant groupings to investigate whether it would be more effective to recover contaminants using technologies based on removal in the vapor phase. Two

promising vapor-phase recovery technologies that will be evaluated include vacuum extraction for recovering volatiles and steam-assisted vacuum extraction for recovering less volatile contaminants.

The *in situ* research program will continue to address the problem of selecting remedial technologies during Superfund feasibility studies by evaluating the costs and performance of *in situ* treatment technologies as they are developed by EPA and the private sector. This information will be readily accessible to field personnel through the creation of a database on the costs of *in situ* treatment technologies.

The *in situ* research program, over the past few years, has emphasized performance evaluations of available treatment, delivery, and recovery systems. This will be shifted somewhat in FY90 toward the development of new treatment systems. In preparation for the move toward more developmental work, available information on the major problem contaminants will be organized as a basis for selecting technologies for development. Case studies of completed and on-going remedial actions will be assembled to identify problems and promising technologies. It is anticipated that developmental research will emphasize more cost-effective chemical and photochemical processes. Selected concepts will be tested in field feasibility studies; those showing potential for success or commercialization will be transferred to the SITE Program.

More emphasis will also be placed on the effect of site characterization on the cost and effectiveness of treatment processes. The sampling strategies employed at a couple of Superfund sites will be analyzed to determine whether sufficient data has been collected to form a basis for selecting and using remedial technologies. By integrating the analysis of sampling strategies and site characterization information requirements with performance data on appropriate *in situ* cleanup technologies, less expensive remedial technologies and plans can be selected.

On-Site Control Technologies

The goal of on-site control technologies research is to influence and encourage the commercial development and utilization of viable systems for on-site treatment of excavated soils, sludges, and sediments at Superfund sites. This will be accomplished through the development and field testing of promising pilot-scale systems using technical approaches not currently being addressed by the commercial sector. On-site treatment technologies reduce the toxicity, mobility, or volume of contaminated materials to provide alternatives to land-filling. Both mobile cleanup equipment and on-site technologies will be developed. Such systems are typically flow-through types of processes utilizing physical or chemical means to extract, degrade, detoxify, or immobilize contaminants.

An important component of the on-site research program is understanding the treatment problems at Superfund sites in order to direct development and evaluation work to treatment technology gaps. A series of workshops among vendors and academic and government technical experts is planned to actively develop and maintain interactions with on-site technology users and the private sector. The on-site program is also working to characterize problems related to three major contaminant categories: organics, metals and inorganics, and radioactive wastes. The nature of contaminants and soil samples from Superfund sites are being examined to determine the effectiveness of on-site treatment technologies and to anticipate technologies that will need to be used in their treatment.

A number of technologies are now, or will soon be, under development in the on-site research program. Soils washing technology testing will emphasize removing lead, other inorganics, TCE, and other volatile organics from soils. Laboratory studies will be conducted to improve technologies to extract organics from soils and sediments using surfactant and chelating agents. A sequential batch reactor for microbial mineralization of excavated soils and a system for vacuum-assisted steam stripping of low molecular weight organics are also being studied.

Other activities that support Superfund remedial decisions include the maintenance of information systems on the performance of treatment systems at bench-, pilot-, and full-scales, and conducting treatability studies to meet specific Regional needs. A pilot-scale plant is needed that is mobile and can be moved to Superfund sites to conduct treatability studies.

Combustion Techniques

Some contaminated soils are not amenable to treatment by lower-cost chemical, physical, or biological processes. In these cases, combustion processes may be a suitable alternative. To address the need for thermal destruction research, ORD constructed the Combustion Research Facility (CRF) at the National Center for Toxicological Research in Jefferson, Arkansas. The specific mission of this facility is to conduct pilot-scale research and provide data on the thermal destruction of hazardous wastes from existing Superfund sites so that combustion technologies can be used to treat or destroy these hazardous wastes while protecting the environment and promoting public health and safety.

The pilot-scale research incinerators at the CRF include a rotary kiln system and a liquid injection system. Each system incorporates primary and secondary combustors and associated waste handling equipment, process controllers, safety equipment, and air pollution control devices. The CRF is fully permitted to test the entire range of hazardous wastes normally encountered in the hazardous waste treatment industry. The research constraints that result from the pilot-scale size of the CRF will be remedied by an expansion of the facility in FY89. Also, permit modifications will be pursued to allow testing of air pollution control devices and combustors not currently located at the facility.

Thermal destruction research is conducted on synthetic soils to develop knowledge and understanding of the:

- Characteristics of wastes that affect their thermal destruction, including chemical composition, physical state, heating value, incinerability, corrosivity, toxicity, and reactivity;

- Behavior of waste matrices and definition of the thermal conditions needed to effectively treat various matrices from Superfund sites;

- Operational characteristics of equipment such as kilns, liquid-fed incinerators, boilers, process heaters, and other innovative thermal devices that are used, or proposed for use, to destroy hazardous wastes; and

- Operational interactions between combustion equipment and air pollution control devices so that the control of metal emissions and other particulates can be made more effective.

In addition to evaluations of the performance of combustion technologies on synthetic soils, samples from Superfund sites are shipped by the Regions to the CRF to conduct treatability tests of thermal processes for destroying Superfund contaminants and cleaning the soil. Projects for FY89 will include treatability studies of contaminated soils from the McCall and Purity Oil Superfund sites in Region 9 using the rotary kiln incinerator; studies of the fate of metals in incinerated contaminants; and maintenance of a database on waste and combustion results.

Best Demonstrated Available Technology for SARA Wastes

The objective of this research is to provide performance and cost data on key technologies that will be used to treat wastes from Superfund sites. OSWER will use these data to establish best demonstrated available technology levels for contaminated soils and debris at Superfund sites. In response to the RCRA land disposal restrictions, OSWER is developing standards for the pretreatment of Superfund wastes that will be disposed of in RCRA facilities. These standards will establish treatment levels through the evaluation of readily available treatment technologies. In the future, Superfund wastes meeting these levels or standards may be deposited in land disposal units. The distinction between BDAT evaluations and the development and evaluation of biosystem, *in situ*, and on-site treatments is that BDAT research evaluates readily available treatment technologies to develop standard pretreatment levels, while the others are more concerned with making more technologies readily available.

Technologies that have been tested to date in the Superfund BDAT program include high temperature incineration for high hazard contaminants, solidification and stabilization methods for inorganic wastes, low-temperature thermal desorption of volatile organic compounds, the KPEG process for certain contaminated soils, and soil washing techniques for extraction of organic or inorganic contaminants.

Stabilization and solidification processes involve the addition of binders to a waste material to alter its form and decrease contaminant mobility. Solidification increases bearing strength and eliminates free liquids in a waste. Stabilization (synonymous with fixation) converts the waste to a more stable form, thus limiting contaminant mobility and decreasing the surface area available for leaching.

Low-temperature thermal desorption involves heating organic-contaminated soils in a furnace to prescribed temperatures. As heating occurs, contaminants are released from the soil as gases, which are then purged from the system. The cleaned soils can then be disposed of on site or in a RCRA facility.

KPEG treatment of contaminated material involves mixing the waste with potassium hydroxide and polyethylene glycol and heating the waste and reagent mixture. After the excess reagent is removed, the clean soil is discharged. Decontamination is achieved through chemical dehalogenation of the aryl halide to form water-soluble reaction products. The process has been successfully demonstrated for treatment of soil containing chlorinated biphenyls, dioxins, and furans.

Soils washing involves washing waste soils with water, water containing additives, or organic solvents to reduce the volume of soils requiring treatment. After the soils are washed and wet-sieved for particle size separation, large volumes of cleaned soils containing the larger sized soil particles can be returned to the environment. Soil washing has been demonstrated to work for both organic and inorganic contaminants.

Evaluations of the performance of these same technologies, except for incineration, on additional Superfund soils and wastes are planned for FY89 and FY90. Various treatment trains consisting of one or more of the five processes in series will also be evaluated. One to three additional technologies will be selected for BDAT evaluations at the bench- or pilot-scale over the next two years. Candidate treatment technologies include biological treatment systems, wet air oxidation of organics, and ultraviolet ozonation of liquid wastes and organics.

Expert Systems

An expert (or knowledge-based) system is a computer program that incorporates the knowledge and simulates the decision-making processes of human experts in order to achieve a high level performance for a particular task. The benefits of expert systems are that the expertise of a few can be shared with many; consistent decisions can be made across Regions even when data is limited or uncertain; individual and group productivity can be increased, reducing project costs; and complex technical problems can be solved. Expert systems provide advice based on the thought processes of experts, state-of-the-art scientific results, and latest regulations and guidance.

In response to OSWER needs, ORD began development of expert system prototypes in FY85. The potential of these prototypes prompted discussions between ORD and OSWER in FY87 about the validation, long-term support, and future development of expert systems for OSWER. Decision areas have been selected for expert system development based on the input of the targeted user community, regulatory personnel at Headquarters, and independent persons knowledgeable about CERCLA remedial programs. Highest priority was given to systems that offer the possibility of significant time savings and cost reductions. An expert system shell (software designed to facilitate expert systems development) will be designed for each system to ensure easy access by targeted. The expert systems selected for development in FY89 are:

- A *Construction Design Review* system that conducts pre-final review of design plans and specifications will ensure that they are biddable, constructable, operable, and consistent with applicable environmental regulations. It will reduce project review time, increase productivity, and reduce the number of change orders.

- A *Construction Claims Advisor* will advise site engineers on identifying potential for a claim, recommend follow-up steps, and minimize liability when a change in work activity occurs on site. The *Construction Claims Advisor* will assist in determining whether a contractor's proposal for a change order is appropriate, suggest a response to a variety of unpredictable events (delays, disruptions, additional work, contract disputes), and help determine, once a change order has been approved, whether there is a legal basis for recovering costs.

- A *Technical Screening and Selection of Remedial Alternatives* system will screen and select site remedies based on cross-media regulations, contaminant characteristics, media, storage techniques, and other relevant information. The system will also attempt to identify combinations of technologies as a single alternative. It will decrease staff workloads, improve screening uniformity, and reduce resource requirements throughout the feasibility and remediation design phases.

- A *Risk Assessment* system will help assess health risks associated with hazardous waste exposure, utilize information on appropriate alternative concentration limits (ACLs) and maximum contaminant levels (MCLs), and select models and methodologies. It will save resources and improve the timeliness of risk assessments.

- A *Sampling Quality Assurance/Quality Control* expert system will assist in review of plans to look for conformance with agency guidelines and procedures and ensure that developed data will be of known quality and be precise and accurate enough to support regulatory/cleanup actions. It will reduce staff time and improve data collection and the consistency of analytical techniques.

  The expert systems selected for initial development in FY90 are:

- *Applicable or Relevant and Appropriate Regulation Screening*, a screening tool that identifies federal and state regulations that are applicable or relevant and appropriate in making waste management decisions. These

regulatory sections are identified based on waste characteristics, treatability options, and site location. It will save resources and increase completeness and consistency by identifying cross-media issues in selecting and evaluating cleanup remedies.

- *Hazard Ranking System Screening*, an automated system to assist in preparation of the HRS package by collecting all necessary information pertaining to drinking water sources in the area surrounding a site. The system will speed evaluation of candidate sites and ensure consistent quality in technical evaluations of potential drinking water contamination.

- *Scope of Work Generator*, an expert system that generates site-specific scope of work, cost and schedule estimates based on generic site class scopes of work modified for site-specific conditions. Applications include RI and RD scopes of work. It will reduce costs and turn around time, improve consistency, reliability, and increase staff productivity.

- *Sources Catalog*, a guide to existing computer tools and relevant information bases, guidance, and important charts and technical papers. Improves use of existing expertise and resources. Provides a cost effective method of issuing timely, accurate updates.

An advisory group comprised of targeted users, experts, and regulatory personnel will be set up to guide the development and testing of each system. ORD will develop and maintain the expert systems and assist in training end users, while OSWER will fund end-user training and system support and maintenance.

Test and Evaluation Facility

The major objective of the proposed Environmental Testing and Evaluation Center (E-TEC) is to develop, evaluate, and conduct laboratory-scale research on new and innovative hazardous waste treatment technologies that provide alternatives to land-filling. The facility is needed to accelerate the availability of technologies essential to implement the new cleanup standards requiring a greater reliance on permanent remedies at Superfund sites. In addition, the facility represents a unique and mutually beneficial partnership between government, academic, and industry organizations engaged in the study and mitigation of the hazardous and toxic waste disposal problem.

The proposed facility is to be located in Edison Township, New Jersey, utilizing existing government-owned land and buildings. Activities conducted by EPA at the facility will generate information on the technical and economical feasibility of new and innovative waste management technologies, analytical capabilities, processes, methods, and devices. Treatment technologies may include any of a range of chemical, physical, biological, and thermal processes. They will be capable of operating in either batch, continuous, or *in situ* modes to accomplish extraction, immobilization, destruction, or detoxification of wastes. Performance tests will determine the effectiveness of treatment technologies, and reliability tests will determine operating ranges and safety characteristics. Prototype equipment, small-scale units, and full-size modular waste treatment units will be evaluated in the facility. Criteria for selecting technologies to be tested will include safety requirements, needs for specialized equipment, quality assurance/quality control needs, and lower costs.

Experiments conducted by ORD will provide analytical data, demonstrate performance capabilities of new hazardous waste treatment technologies; tailor existing technologies for application to new waste types; and improve existing technologies with respect to their efficiencies, performance capabilities, and potential environmental impacts. Testing at the E-TEC facility may also be necessary prior to SITE demonstrations to determine appropriate

design details, reliability, and economics. The FY89 budget provides for the purchase of specialized equipment for the facility. This will include monitoring systems for NO_x, SO_2, total hydrocarbons (THC), total organic carbon (TOC), O_2, CO, and CO_2; including sample collector, conditioning, and transport assemblies and a dual-bank, high-efficiency particulate air filter with vapor-phase activated carbon. Water treatment equipment will also be installed.

The proposed E-TEC facility will be fully permitted for the testing and evaluation of Superfund waste treatment technologies. Air and water pollution control equipment will be installed to prevent uncontrolled releases. Technologies to be tested at the facility will generally come equipped with their own pollution control devices. In addition, the facility will provide backup emission controls that may, if necessary, be operated in tandem to ensure adequate treatment of residues from the experimental process. Further, safety cutoffs and emergency shutdown procedures will be activated in the event of process irregularities.

MAJOR DELIVERABLES

Annual Report on the Combustion Research Facility. This is developed annually to summarize the results of research tests of soils and incineration technology for Superfund. The report on FY88 activities covers nine projects, including demonstration and evaluation of the American Combustion Pyretron Burner for the SITE program. Detailed technical reports on each project are available from the CRF. Due 1/89.

Alternative Treatment Technology Evaluations of CERCLA Soils and Debris. This report will combine results from FY87 and FY88 BDAT research on the relative effectiveness of soil washing, KPEG low temperature thermal desorption, incineration, and solidification/stabilization. The results of performance tests using synthetic and Superfund site soils will be compared. Due 9/89.

Construction Claims Module for Differing Site Conditions. A site engineer's advisor and manual will be developed to identify potential for a claim, recommend follow-up steps, and minimize agency's liability when a change in work activity occurs on site because site conditions are discovered to be different than originally thought. Due 9/89.

Sample Quality Assurance/Quality Control Expert System for Metals in Soils. An expert system and manual on its use will be developed to assist in review of plans to look for conformance with agency guidelines and procedures and ensure that collected data will be of known quality and be precise and accurate enough to support the characterization of metals in soils. Due 9/89.

Human Health Component of Risk Assessment Expert System. The human health component of risk assessment will be incorporated into an expert system to help assess health risks associated with hazardous waste exposure. Due 9/89.

Expert System for Technical Screening and Selection of Remedial Alternatives. An expert systems and manual for its use will be developed to screen and select site remedies based on cross-media regulations, contaminant characteristics, media, storage techniques, and other relevant information. Due 12/89.

Report on Enhancing Biodegradation of a Gasoline Spill in Ground Water. This report will detail the results of the bioremediation of ground water contaminated by a fuel spill in Traverse City, Michigan, through the addition of amendments to the ground water intended to stimulate nitrate-respiring microorganisms. Due 5/90.

Handbook on On-Site Cleaning Equipment. The handbook will describe a variety of currently available technologies for treating excavated soils, sludges, and sediments. It will include test results of thermal, physical, and biological extractive treatment technologies, including the soils washer, mobile incinerator, KPEG, and mobile carbon regenerator. Due 6/90.

Handbook on In Situ Treatment of Hazardous Waste Contaminated Soils. Incorporates work done for the *Handbook on Innovative Methods for Minimizing the Extent of Contamination.* Updates the 1984 report *Review of In-Place Treatment Techniques for Contaminated Surface Soils.* Will include information on how to use available technologies including *in situ* delivery and recovery systems, control of volatilization, and *in situ* extraction, immobilization, degradation, and attenuation technologies. Due 9/90.

Construction Claims Module for Site Event Conditions. A site engineer's advisor and manual will be developed to identify potential for a claim, recommend follow-up steps, and minimize agency's liability when a change in work activity occurs on site because of unpredicted events at a site, including construction delays, additional work, and contract disputes. Due 9/90.

Report on Development of Procedures for Biological Cleanup of Trichloroethylene-Contaminated Hazardous Waste. This document will report the results of the development of bench-scale systems for the bacterial mineralization of trichloroethylene and assess the feasibility of enhancing *in situ* biodegradation by the natural flora of a contaminated site. Due 12/90.

SUPERFUND INNOVATIVE TECHNOLOGY EVALUATION APPROACH

EPA has established a formal program to accelerate the development, demonstration, and use of new or innovative treatment technologies, and to demonstrate and evaluate new, innovative measurement and monitoring technologies. This program is the SITE program, which assists technology developers in the development and evaluation of new and innovative treatment technologies, and thus enhances the commercial availability and use of these technologies at Superfund sites as alternatives to the land-based containment or disposal systems presently in use.

The overall goal of the SITE program is to maximize the use of alternative technologies in cleaning up Superfund sites and to encourage the development and demonstration of new, innovative measurement and monitoring techniques. SARA defines "alternative technologies" as:

> those technologies, including proprietary or patented methods, which permanently alter the composition of hazardous wastes through chemical, biological, or physical means so as to significantly reduce the toxicity, mobility, or volume (or any combination thereof) of the hazardous waste or contaminated materials being treated. The term also includes technologies that characterize or assess the extent of contamination, the chemical and physical character of the contaminants, and the stresses imposed by the contaminants on complex ecosystems at sites.

There are a number of obstacles inhibiting the acceptance and use of alternative technologies for the treatment of hazardous wastes at Superfund sites. These technologies often have not been proven to be effective on a commercial scale or have not been used for specific applications at hazardous waste sites. As a result, it is difficult to assure potentially responsible parties, site owners, and the affected community that technologies that have not undergone full-scale demonstration will be effective in remediation of a site. A key component of the SITE program is the removal of these informational impediments by supporting demonstrations that will provide reliable

performance and cost data. The SITE program is intended to help provide the treatment technologies necessary to implement the cleanup standards specified in SARA that require greater reliance on permanent remedies at Superfund sites. Components of the SITE program include the:

- *Monitoring Technology Testing and Demonstration* project to enhance, evaluate, and validate newly developed techniques and systems for characterization and assessment of contamination at Superfund sites.

- *Emerging Technologies Testing and Evaluation Program* to assist both ORD and private industry in the development of emerging technologies from the conceptual stage to pilot-scale demonstration. This program encompasses two special initiatives—the *Emerging Biotechnology Program* to evaluate, develop, and demonstrate emerging biosystems technology for the detoxification or destruction of hazardous wastes at Superfund sites; and the *Innovative Development and Evaluation Program* to test, evaluate, and demonstrate promising technologies developed by ORD.

- *Commercial Development and Demonstration Program* to assist the private sector in developing promising technologies that can be used at uncontrolled hazardous waste sites. The core of the program has been the demonstration of selected technologies to provide sound engineering and cost data on their full-scale operation. The demonstrations are designed to provide information to potential users on site-specific applicability, effectiveness, and cost of each technology. The results of the demonstrations also identify limitations of the technology and potential operating problems, and permit estimation of long-term operating and maintenance costs and long-term risks.

Monitoring Technology Development and Demonstration

The Monitoring Technology Development and Demonstration Program was established as a part of the SITE Program to enhance newly developed techniques and systems for characterizing contaminants at Superfund sites. Its purpose is to speed up the application of promising new monitoring technologies to Superfund problems by providing access to Superfund sites, quality assurance oversight, and in some cases, cost sharing of demonstrations and development. The advanced field monitoring methods research under the direction of ORD will demonstrate innovative measurement, screening, and monitoring technologies; evaluate field-deployable equipment suitable for rapid on-site monitoring; stimulate the development and demonstration of new technologies from the private sector; and share technologies with other agencies.

Current analytical methods for monitoring toxic compounds from various complex chemical sources either involve a time delay between field and laboratory analysis, or a costly, time-consuming separation of the mixture into its components prior to analysis. New technologies are available for rapid field data generation; the appropriateness and potential of these technologies need to be demonstrated under field conditions. The commercial sector will be leveraged to provide technology for EPA field monitoring. Emphasis will be on field deployable methods and procedures for implementation of these methods for quantification of toxicants on site. Simple, rapid, and inexpensive field measurement methods—immunoassays, ion mobility spectrometry, fiber optic sensors, remote mapping and data transmission—will be selected, evaluated, and demonstrated at field sites.

A number of promising technologies are being adapted for use in the Superfund program. The development, evaluation, and validation process has begun for fiber optics/chemical sensors, immunoassay systems, high-volume stack samplers, air emission canister technology, X-ray fluorescence, soil gas analyzer, geophysical equipment for

remote sensing of buried waste, and cone penetrometers for rapid and extended-depth soil sampling. When appropriate, data management for these evaluations will use Geographic Information System computer technology.

Immunoassay Monitoring Development and Demonstration

As part of this research program, haptens (an antigen) are being synthesized for antibody production against several chlorobenzene compounds. Monoclonal antibodies will be produced for these compounds as part of a cooperative agreement with the University of California, Berkeley. Under a cooperative agreement with the University of California, Davis, work has been initiated on several nitroaromatic compounds. Haptens have been synthesized and antisera has been produced. A cooperative agreement is being negotiated for immunoassay development for benzene, ethylbenzene, toluene, and phenol. Two requests for information regarding the development and availability of immunoassays were issued—one in the *Commerce Business Daily* and one in *Science*. The availability of funding from the Department of Agriculture is being negotiated. A field demonstration of the pentachlorophenol immunoassay at a Superfund site is being planned.

Future immunoassay research plans include the compilation of a list of EPA priority compounds for potential immunoassay applications. ORD will also investigate currently available standard delivery systems to determine potential use for Agency monitoring activities. ORD intends to integrate its immunoassay techniques with ongoing fiber optics research. Applying these tools jointly in Superfund site assessment will serve as a means to cross check data generated by each method.

Mobile X-Ray Fluorescent Analyzer

ORD scientists have developed a uniform method for on-site analysis of inorganics using the field-portable XRF system. This includes on-site sample preparation and analysis and set up of calibration standards for XRF instrumentation. Future plans include visits to selected sites to demonstrate the capabilities of the field method. The goal of this project is to transfer this technology to the Regions. A 15-minute video tape has been produced on the portable XRF technology and its applications to screen for inorganics at hazardous waste sites. It includes step-by-step procedures for conducting a field screening exercise. ORD is working through a cooperative agreement with Kansas State University to demonstrate and evaluate this mobile XRF monitoring system.

Fiber Optics

A patent is being sought on a fundamental design for a fiber optic chemical sensor amenable to commercial manufacture. This new design is a result of the collaborative developmental efforts of EPA, National Oceanic and Atmospheric Administration (NOAA), American Society for Testing and Evaluation, and Lockheed Engineering and Science. One of the key elements of the design provided by EPA is the incorporation of the newly developed Winston Cone used to make low-loss optical connections for the communications industry.

Plans for fiber optics research include development for aqueous-phase measurements to extend its application to *in situ* ground-water monitoring. With adequate improvements in sensitivity, another potential application for the chloroform sensor would be for monitoring trihalomethanes in drinking water. Other planned research areas include the development of several compound-specific sensors for gasoline, aviation gasoline, and trichlorethylene.

Emerging Technologies Testing and Evaluation Program

The Emerging Technologies Program is designed to test, evaluate, and develop technologies that can be used for the cleanup of hazardous waste sites. The primary goal of the program is to foster technologies developed under ORD's basic engineering program (Performance of Treatment Technologies) that show promise for commercialization by the private sector. The testing and evaluation of these technologies will provide additional alternatives for cleanup. Currently, ORD is developing technologies at the bench-, laboratory-, and pilot-scale for use at Superfund sites. In addition, the private sector is being given an opportunity to submit candidate technologies through published solicitations. The most promising will be further developed and tested. Successful technologies will be available for full-scale demonstration at EPA test and evaluation facilities or Superfund sites.

SITE Emerging Biotechnology Program

ORD's emerging biotechnology research program is designed to evaluate, develop and demonstrate emerging biosystems technology for the detoxification of hazardous wastes at Superfund sites. The program will provide alternative, cost-effective biological technologies to effectively control and destroy hazardous wastes at Superfund sites. It will center on the development of field-scale technologies to deal with wastes found difficult to treat by existing technology. Activities in this area will consider the evaluation of new or proprietary strains of microorganisms for suitable application to waste treatment at Superfund sites. This evaluation will include comparison with conventional methodology, the use of multiple unit operations to treat complex waste mixtures, engineering scale-up and process evaluation, specific data needs and methods for evaluation, and field-scale verification of developed technology. The scope of treatment types to be developed under this program span from *in situ* to specific reactors.

SITE Innovative Development and Evaluation Program

Over the past few years, ORD has developed alternative technologies for the destruction and cleanup of hazardous waste. Research has progressed to the point where several of these technologies have approached the field evaluation and demonstration stage necessary for application to Superfund wastes. After the technologies are satisfactorily demonstrated on Superfund wastes, it is expected that they will be commercialized and marketed by private industry through the FTTA. It is expected that market risk will be reduced and development accelerated by conducting field evaluations and, in some cases, field demonstrations under the SITE Program. The SITE Program will also actively disseminate information concerning these technologies. Some of the innovative technologies currently under development include:

- An *EPA Mobile Incinerator System* consisting of a rotary kiln, secondary combustion chamber, and air pollution control equipment mounted on four trailers. The system was used successfully to process dioxin-contaminated materials from various Superfund sites and is now operating at the Denney Farm Superfund site in Missouri to process pesticide wastes.

- An *EPA Mobile Soils Washing System* designed for the extraction of a broad range of hazardous materials from contaminated soils using water as the extraction solvent. The prototype, developed using conventional equipment for screening, size reduction, washing, and de-watering of soils, is being transferred to industry under the provisions of the FTTA.

- An *EPA Mobile Carbon Regeneration System* designed for field use in reactivating spent granular activated carbon used in spill or waste site cleanup operations. The system utilizes a carefully controlled thermal process to remove dissolved organics from water, and is being transferred to industry under the provisions of the FTTA.

- A *KPEG Chemical Detoxification* process to dechlorinate toxic organochlorine compounds, like PCBs, dioxins, and furans. EPA's mobile field equipment is undergoing a series of tests and evaluations at Superfund and other sites.

SITE Commercial Demonstration and Development Program

The primary goal of this program is to evaluate commercially developed pilot-scale and full-scale technologies through demonstrations in the field. As legislatively mandated, at least ten demonstration or development projects will be initiated each year for the five-year period beginning in FY87. ORD and OSWER cooperate to conduct the SITE Program. ORD is responsible for conducting the technical aspects of the demonstration and development projects, while OSWER is responsible for matching technologies to appropriate sites and implementing the community relations and technology transfer programs.

Each year, EPA solicits proposals from developers of technologies that destroy, immobilize, or reduce the volume of hazardous wastes. Generally, the technology developer pays to erect and operate the equipment and to dismantle and remove it, while EPA pays for the costs of sampling and analysis, quality assurance and quality control, evaluating data, and preparing reports. EPA will also assist the developer in obtaining required permits. Under SARA, federal assistance can now be provided for part of an applicant's full-scale field demonstration project if the applicant can show that he cannot obtain private financing on reasonable terms and conditions sufficient to carry out such demonstrations. The developers are provided extensive data that validate their capabilities while EPA is able to assess the performance, reliability and cost of technologies. This information will be used directly by Regional and State personnel responsible for the selection of remedies and responses at Superfund sites.

Once EPA has selected technologies that are ready for demonstration, EPA determines which hazardous waste site is most appropriate for each demonstration. Superfund sites are generally used for SITE demonstrations. However, EPA will also consider Departments of Defense and Energy, state, and private site cleanups. The overriding criterion for site selection is a location at which the demonstration can be performed expeditiously and the most useful information gathered. Demonstrations must take place under conditions that duplicate or closely simulate actual wastes and conditions found at Superfund sites to assure the reliability of the information collected and the acceptability of the data by users.

The SITE program was established less than two years ago. To date, 29 developers have been accepted into the demonstration program, including eight thermal processes, three chemical treatments, five biological processes, five physical treatments, and eight solidification/stabilization processes. Seven SITE demonstrations have been completed. In addition, seven applicants have been accepted for award of cooperative agreements under the Emerging Technologies Program. Table 1 presents the status of current SITE demonstration projects.

Two major reports are produced as a result of each completed demonstration. A *Demonstration Report* documenting the performance data resulting from the demonstration is prepared first. The report includes testing procedures, data collected and quality assurance/quality control measures, and summarizes the results in terms of performance and cost. The demonstration report also addresses applicability, pre- and post-treatment requirements,

and its advantages and disadvantages compared to available technologies. However, successful demonstration of a technology at one Superfund site does not necessarily imply that it will be adopted for full-scale use at other sites. To encourage the general use of demonstrated technologies, ORD prepares a second report that evaluates the applicability of each technology to other sites and wastes, and provides cost estimates for these applications. This information is disseminated to potential users through an *Applications Analysis Report* for each technology tested.

Table 1. Summary of SITE Program Demonstrations

Developer	Technology	Status
SITE 001		
American Combustion Technologies	Pyretron Burner	The demonstration, conducted at EPA's Combustion Research Facility on waste soils from the Stringfellow Superfund site in California, is complete. The draft demonstration report is under final revision and the draft applications analysis is being reviewed.
Haztech/Shirco	Infrared Thermal Destruction Process	The demonstration, conducted on waste oil sludge at the Peak Oil Superfund site in Florida, is complete. The final demonstration report is complete and the applications analysis report is under review.
Shirco Infrared Systems, Inc.	Infrared Thermal Destruction Process	The demonstration on contaminated soils from the Rose Township Superfund site in Michigan is complete. The final demonstration report is under revision and the applications analysis report is being written.
Hazcon, Inc.	Solidification/ Stabilization Process	The demonstration on contaminated soils at the Douglassville Disposal Superfund site in Pennsylvania is complete. The final demonstration report is complete, the applications analysis report is under revision, and a draft report on the six-month sampling results is complete.
Westinghouse	Pyroplasma System	Westinghouse has received a RD&D permit for the Waltz Mill Facility site in Pennsylvania. The demonstration is planned for that facility subject to approval of the permit by the state and availability of a suitable waste.
Westinghouse	Electric Pyrolyzer	Due to a two-year delay by Westinghouse in starting this demonstration, the project may be removed from active status.
Terra Vac, Inc.	*In Situ* Vacuum Extraction	The demonstration on waste soils from the Groveland Wells Superfund site in Massachusetts is complete. The demonstration report is almost complete and the applications analysis is under review.
Ogden Environmental Services (formerly GA Technologies)	Circulating Fluidized Bed Combustor	Current plans are for treatability testing on McColl waste at the Ogden facility with a pilot-scale unit and a one-month field-scale demonstration at the McColl site using a 100 ton/day transportable unit.
Resources Conservation Co.	Basic Extraction Sludge Technology	A tentative site has been chosen in Region 5 where the demonstration may be piggybacked onto a removal action at a waste oil recycling site.

Table 1. Summary of SITE Program Demonstrations (Continued)

Developer	Technology	Status
International Waste Technologies	*In Situ* Stabilization/ Solidification Process	The demonstration on PCB-contaminated soils at the General Electric Superfund site in Florida is complete. The demonstration report is under revision and the applications analysis report is under review.
DETOX Industries, Inc.	Biological Degradation Process	The demonstration will be conducted at the United Creosote Superfund site in Texas. Soil samples for the treatability study are being held until the developer is ready to proceed with the bench-scale study.
SITE 002		
Air Products and Chemicals, Inc.	Fluid Bed Biological Systems	A Region 8 site has been rejected by the developer. A Region 2 site is under consideration.
GeoSafe Corporation	*In Situ* Vitrification	Sites in Washington and Michigan are being considered for the demonstration.
CF Systems Corporation	Solvent Extraction with Liquified Gas	The demonstration was recently completed on PCB-containing soils from the New Bedford Superfund site in Massachusetts. Analysis of the results is underway.
Chemfix Technologies, Inc.	Chemical Fixation/ Stabilization	The demonstration is being conducted on soils from the Portable Equipment Co. Superfund site in Oregon.
MoTec, Inc.	Liquid Solids Contact Digestion	Treatability studies of soil and sludge samples from sites in Regions 3 and 7 are underway. The demonstration plan is undergoing final review.
Retech, Inc.	Centrifugal Reactor	The Butte-Silverbow Superfund site in Montana has been selected for the demonstration. The demonstration plan is being revised to incorporate public comment and the demonstration is scheduled for May, 1989.
Sanitech, Inc.	Ion Exchange Technology	Several sites are under consideration for a demonstration with ground water contaminated by heavy metals.
Separation and Recovery Systems, Inc.	Solidification/ Stabilization	The process of locating a site is continuing.
Solidtech, Inc.	Solidification	The draft demonstration plan is under revision following an intergovernmental review.
WasteChem Corporation	Volume Reduction Solidification	WasteChem has decided to terminate the demonstration. A final report will be prepared that will include all the data developed to date.
Zimpro Environmental Control Systems	Powdered Activated Carbon Treatment	Portions of the demonstration plan are complete. The planned site at the Lowery Landfill, Arapaho County, Colorado, is now in question due to waste components that are not amenable to biological treatment.
SITE 003		
Biotrol, Inc.	Soils Washing	A demonstration of soil washing on PCP-contaminated soils at the McGillis and Gibbs Superfund site in Minnesota is planned for June, 1989.

Table 1. Summary of SITE Program Demonstrations (Continued)

Developer	Technology	Status
Biotrol, Inc.	Biological Treatment of Ground Water	Demonstration of the biological treatment of ground water contaminated with wood-preserving chemicals from the McGillis and Gibbs site is planned for June, 1989.
CBI Freeze Technologies, Inc.	Freezing Technology for Separation	The demonstration plan is under development and site selection is proceeding.
Chemical Waste Management (CWM)	Rotary Thermal Desorber	The demonstration plan is being prepared and a demonstration is scheduled for late spring of 1989.
Detox, Inc.	Submerged Aerobic Fixed Film Reactor	The SITE contractor is proceeding with the demonstration plan. Efforts are under way to locate a site.
E.I. DuPont de Nemours and Co.	Membrane Microfiltration	The SITE contractor is proceeding with the demonstration plan. Efforts are under way to locate a site.
Freeze Technologies Corp.	Freezing Technology for Separation	Work on the demonstration plan has begun. Site selection activities are underway.
Silicate Technology Corp.	Silicate Adsorption/ Stabilization	A demonstration of this process on wastes contaminated with higher-weight organics and inorganics in soils from the Tacoma Tar Pits Superfund site in Washington is planned for August, 1989.
Toxic Treatments USA, Inc.	*In Situ* Steam/Air Stripping	Combining the demonstration with a remedial action at the GATX site in San Pedro, California, is being considered. Work on the demonstration plan has begun.
Ultrox International, Inc.	Ultraviolet Ozone Treatment for Liquids	Combining the demonstration with a remedial action at a site in San Jose, California is being considered. The demonstration plan is under review.

SITE Information Clearinghouse

The dissemination of information on the performance of technology demonstrations and applications of the technologies is crucial once the results from the demonstration projects are available. If alternative technologies are to be applied broadly at Superfund sites, Agency personnel, engineers, and others must have access to reliable technical information. The clearinghouse component of the SITE program is intended make technical information from the SITE demonstrations available in a timely manner.

Recognizing that access to this and other treatment information is essential to the acceptance and use of alternative technologies, the SITE program developed an information clearinghouse to collect, synthesize, and disseminate technology performance data. The clearinghouse has several components: a hotline will provide up-to-date information on SITE projects, demonstration schedules and the availability of the results, and will also refer callers to other sources of information; an electronic bulletin board, part of a planned computerized database network, provides summary information on the SITE projects, demonstration schedules, and results; a reference bibliography—a collection of reports, journals, and other documents—is housed in the EPA Library's Hazardous

Waste Collection, and is available at EPA's ten Regional and five laboratory libraries. The bibliography is accessible by personal computer.

The SITE Clearinghouse will eventually include pertinent data generated by other EPA programs, such as RCRA trial burn data, Superfund treatability studies, and other federal agency and state hazardous waste cleanup projects. The expanded Clearinghouse will enable a user to access a central source of information on hazardous waste treatment technology that can search all of the existing data sources, provide comprehensive searches of on-line databases like the one at the National Technical Information Service (NTIS), conduct technical evaluations of existing data, and serve as an interface with the various EPA research laboratories.

MAJOR DELIVERABLES

Annual Report on the Development and Demonstration of Immunoassay Detection System for Rapid Screening at Superfund Sites. This report will highlight new applications of immunoassay techniques developed during the year. Due 1/89.

Annual Report to Congress. This is the annual report requested by Congress on the progress of the SITE program. It will contain summaries of the program's operation and status of selected technologies. Due 1/89.

Emerging Technology Reports. Eighty-four preproposals were received and seven Cooperative Agreement applications were selected for award; four for waste-water treatment and three for soil treatment. The first annual report will be due 9/89.

Annual Summary on Demonstration of Fieldable and Portable X-Ray Fluorescent Analyzer System. Due 9/89.

Demonstration of Mobile Carbon Regenerator. This report will describe the results of demonstration at the Stringfellow Hazardous Waste Site in California. This technology will be transferred to the private sector for demonstration. Due 12/89.

Demonstration of Mobile Soils Washer. ORD will prepare a final report on demonstration of this technology. This technology will be transferred to the private sector for demonstration. Due 12/90.

KPEG Technology - Field Testing. The report will discuss dechlorination of aromatic organic compounds to reduce toxicity. Pilot tests with the U.S. Navy (Guam) and Region 2 will be described in the final report on commercial interest and Superfund site cost and applicability. Due 12/90.

DEVELOPMENT AND EVALUATION: HEALTH EFFECTS, RISK ASSESSMENT, AND DETECTION

SARA mandates the assessment of potential threats to human health posed by each uncontrolled waste site and explicitly authorizes EPA to conduct and support research in detection, assessment, and evaluation of the effects on, and risks to, human health from exposure to hazardous substances. The health effects, risk assessment, and detection programs focus on research activities that are in direct support of the Superfund process. In addition, the programs are designed to anticipate future Superfund needs for such research.

Health-based data are used during three key phases of the Superfund process: RI, FS, and post closure. In order to project the incidence of adverse health effects in exposed populations, EPA conducts baseline risk assessments. Because of the importance of risk assessment in protecting the public health from hazardous substance exposure, ORD's highest priority health research is directed toward developing new and improved risk assessment methodologies. Four risk assessment research objectives will be addressed: (1) methods and assumptions to assess risk from exposure to ***chemical mixtures***; (2) genetic, neurological, and reproductive ***biomarkers*** to reconstruct exposures and predict likely effects from exposure; (3) mathematical ***dosimetry*** models to predict target tissue doses across species and age groups following exposure, especially to inhaled substances (rather than use the amount of chemical estimated to be at the body surface); and (4) user friendly tools including structure-activity relationship systems and graphic databases for use in weighing evidence when data are and are not available on the chemicals of interest during the ***hazard identification*** phase of risk assessment. Additional research is committed to evaluating the potential health impact of ***cleanup options***, particularly emissions from hazardous waste incinerators, and to designing bioassays for ***post-closure monitoring*** of Superfund sites. ***Detection*** research provides accurate, rapid, and affordable field-portable monitoring and analytical methods to replace the time-intensive laboratory-based approach now used.

SUPERFUND PROGRAM NEEDS

While a primary goal of the Superfund legislation is protection of human health, health-based data are used during only three key phases of the Superfund process: the remedial investigation, feasibility study, and post-closure monitoring phases. The greatest need for health-based data occurs during the remedial investigation/feasibility study (RI/FS) phases. The purpose of the RI/FS is to characterize the nature and extent of risks posed by uncontrolled hazardous waste sites and to evaluate potential remedial options. Once a site has been cleaned up, additional health-based data are needed to assess the adequacy of the remediation at post-closure followups.

To characterize the nature and extent of site-specific risks during the RI phase, EPA conducts a Baseline Risk Assessment, the procedures for which are detailed in the *Superfund Public Health Evaluation Manual* (SPHEM). Risk assessment is a term that has come to refer to the formal process by which knowledge about the potential of substances to produce toxicity (hazard identification) is combined with: (1) knowledge about the relationship between the amount of the substance arriving at a "target" in the body (dose) and the magnitude of effect (dose-response assessment), and (2) knowledge of the magnitude of exposures likely to occur (exposure assessment). Based on assessment of this information, the risk is characterized and expressed as a numerical estimate, accompanied by a discussion of the assumptions and uncertainties on which the estimate is based (Figure 7). Quantitative risk estimates provide risk managers with a better alternative than treating all potentially hazardous substances as if they have the same potency and also provides a basis for

setting priorities and comparing cleanup alternatives. In contrast to many other regulatory programs, SARA does not require toxicity testing of substances found at waste sites. Rather, risk to public health posed by a site is generally estimated based on existing toxicity data.

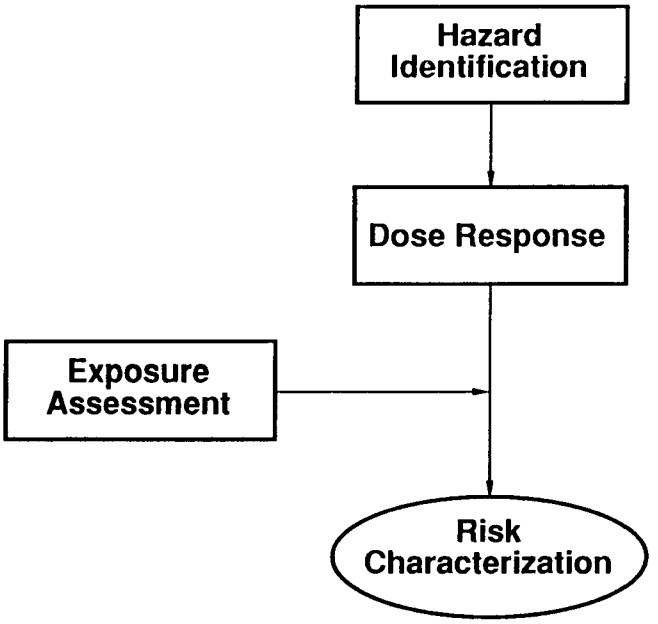


Figure 7. Baseline Risk Assessment Process

Risk assessments are not the same as the health assessments prepared by ATSDR for sites on the NPL. Risk assessments include quantitative information about the degree of risk. Health assessments, on the other hand, are brief, *qualitative* evaluations of the potential public health impact of a site. They provide an early overall medical or public health opinion, essential for deciding whether emergency removal actions are necessary to protect the health of nearby communities. Health assessments are also used to advise medical personnel of potential human health effects and to determine whether additional information on human exposure and associated health effects is needed at a site. Additional human health studies may include pilot studies of health effects for selected groups of exposed individuals, epidemiological studies, and establishment of a health surveillance program and registry of exposed persons. As a qualitative document, a health assessment is not intended to substitute for the more comprehensive, toxicity-based risk assessment required in the RI/FS process.

Although risk assessment is not yet a perfected science, it has emerged as the method of choice for making the public health decisions required under SARA. Risk assessment is used in the Superfund process for defining the degree of human health risk caused by exposure to hazardous substances, pollutants, or contaminants at Superfund sites, for establishing safe levels of exposure, and for developing performance goals for cleanup alternatives. Therefore, it is necessary that risk assessments be realistic and defensible in the courts.

Because of the importance of risk assessment, the Superfund program's priority needs are improved risk assessment methodologies and requisite data. Of particular concern is the significant improvement in the capability to assess genetic, nervous system, and reproductive system risks from chemical exposure as well as combinations of effects from exposure to complex chemical mixtures. The ability to fully assess these risks would provide risk managers with a comprehensive and realistic understanding of the serious health hazards resulting from exposure to site contaminants.

Additional program office concerns include the use of assumptions in the dose-response phase of risk assessment, especially for inhaled pollutants like volatile organic compounds. There is also concern about how best to handle the many data gaps and uncertainties evident in the hazard identification phase of risk assessment. For example, in weighing evidence that a chemical has the potential to produce toxicity, the Regional risk assessor may encounter chemicals that have never been tested adequately for toxicity. Alternatively, toxicity data may be

available, but their relationship to other toxicity data on the same compound may not be evident. Improvements in both dose response and hazard identification are likely to have a major impact on the accuracy and scientific credibility of Superfund risk assessments.

Existing technologies for detecting hazardous substances in the environment have been found to be insufficient for Superfund needs. The Agency, therefore, is putting increasing emphasis on evaluating new technologies as well as improving existing sampling and analytical techniques to improve the speed and affordability of hazardous substance detection without compromising data quality. The growing number of new sites on the NPL are stretching Superfund resources and burdening the nation's analytical laboratories. Delays between the collection of samples and their analyses and a lack of real-time data make it difficult to keep track of rapidly changing situations and add to the cost of site cleanup. Thus, cost-effective, on-site technologies to replace the laboratory-based approach now used to detect contaminants at a site are a high priority for the Superfund program. Particularly needed are real-time, portable technologies that are selective enough to accurately quantify complex chemical mixtures at concentrations above typical environmental backgrounds. Also needed are methods for monitoring trace contaminants in ground water, since collecting subsurface water samples is not possible at all locations and can be prohibitively expensive. The use of field screening technologies would decrease the cost and time required for sampling and analysis and help the Agency shorten the RI/FS process from the current 30 month average to less than 18 months.

RESEARCH NEEDS

To improve risk assessments, research is needed in the areas of complex chemical mixtures, biomarkers, dosimetry, and hazard identification. The principal research needs related to complex chemical mixtures are to further validate assays for identifying health hazards from mixtures and improve the scientific basis of assumptions, especially additivity. Currently, the SPHEM recommends using a variant of the risk assessment guidelines for chemical mixtures. In the absence of evidence to the contrary, a major assumption in these guidelines is that hazard or risk posed by a chemical mixture is equivalent to the sum of the hazards posed by the individual constituents. Determining the constraints that should be placed on this assumption is a major Superfund need.

Biomarkers are measures from biological samples that indicate internal organism exposure, effect, or susceptibility to effect. While human exposure to hazardous substances is an event to be prevented, in many instances, exposure has already occurred. Biomarkers provide the means to reconstruct possible exposures and to determine and predict whether biological and health changes have occurred or will occur, including genetic and non-carcinogenic effects. Biomarker data may also be used to improve the scientific basis of requisite assumptions in the exposure phase of risk assessment.

Study of the relationship between exposure and the concentration and location of chemicals in the body (dosimetry) is needed for constructing physiologically based pharmacokinetic models that accurately predict target tissue dose across species and in different age groups. Many risk assessments make the assumption that the likely exposure to a compound (*i.e.*, an estimate of the amount of compound applied to the body) is equivalent to the dose of the compound at its site of action in the body. While in many instances it is possible to estimate exposure (*e.g.*, how much of a compound is likely to be inhaled, applied to skin, or ingested), there is not a one-to-one relationship between the amount of a compound that is applied and the amount that is actually absorbed (absorbed dose). Further, there is no relationship between the amount that is absorbed and the amount that is actually delivered to the target site in the body (target dose). Since determining the absorbed and target doses are critical to accurate dose-response assessments, research is needed to facilitate the accurate determination or prediction of these factors.

Many data gaps and uncertainties have become evident in hazard identification. Typically, either the chemical of concern has never been adequately tested for toxicity, or the available data are too different to compare. When data are lacking, guidance is needed for predicting toxicity (biological activity) based on available structure-activity relationship (SAR) data from structurally related chemicals. When toxicity data are available but their relationship to other data on the same compound are not evident, it may be difficult for the risk assessor to determine whether a particular study is an "outlier" whose conclusions should be viewed with great caution, or a study representative of many studies performed on the compound. Under these circumstances, a user friendly database is needed to provide a framework for assessing the many studies that may be available on a single compound.

In addition to risk assessment needs, research is needed to improve the evaluation of cleanup options, monitoring methods for closed sites, and field screening methods for site monitoring. Failure to select an appropriate cleanup option may pose a significant health risk during cleanup, or may affect the final hazard posed by the site. Thermal treatment is considered to be a plausible remedial option for Superfund. However, the potential toxicity of emissions from hazardous waste incineration have not been determined, because methods for characterizing their potential toxicity have not been evaluated. Thus, careful evaluation of the health risk posed by various cleanup options, especially incineration, is needed. Although there is no mandate for biological monitoring of closed sites, ORD anticipates such a need and plans to consider various options, one of which is biological monitoring of site toxicity. Advanced field screening technology research is needed to support a critical need of the Superfund program for rapid, inexpensive, monitoring technologies. It will also support ORD's efforts to obtain accurate exposure estimates for risk assessments.

HEALTH EFFECTS, RISK ASSESSMENT, AND DETECTION RESEARCH APPROACH

ORD is taking an empirical and a theoretical approach involving laboratory and field studies to accomplish its Superfund health and detection research objectives. Products of the research may include new assays, biomarkers, models, databases, software, and detection technologies as well as procedures for evaluating mechanisms of toxic action and for comparing toxic effects from exposure to different substances. Much of this research is coordinated with EPA's other research programs and other federal agencies.

Approximately 82% of ORD Superfund health research is committed to improving the accuracy of risk assessment (Table 1). ORD conducts research in four critical areas for improving Superfund risk assessments. In addition to this work, approximately 12% of ORD Superfund health research is committed to developing

Table 1. Emphasis of the Superfund Health Research Program

Health Research Area	% of Total	Subtotals
Baseline Risk Assessment		**82.0%**
Chemical Mixtures		
Comparative Potency	9.8%	
Testing Methods	12.3%	
Mechanisms	4.9%	
Additivity	0.0%	
Biomarkers		
Genetic	29.5%	
Neurological	5.7%	
Reproductive	4.9%	
Dosimetry	12.3%	
Hazard Identification		
Structure-Activity Relationships	0.8%	
Graphic Activity Profiles	1.6%	
Cleanup Options		**12.0%**
Post-Closure Biomonitoring		**6.0%**

a basis for evaluating the health impact of various cleanup options during the FS phase. The remaining 6% will be used to address future needs for biomonitoring closed Superfund sites. Detection technology is a separate research area, supporting the entire remedial process.

Improve Baseline Risk Assessments

Research to improve baseline risk assessment focuses on chemical mixtures, biomarkers, dosimetry, and hazard identification (Figure 8). Because the SPHEM is used to manage the risk assessment process during RIs, risk assessment research is targeted to produce products that will be useful for, and may lead to, revision of the SPHEM. In turn, revisions of the SPHEM (being revised in FY89) include research needs identified by manual users.

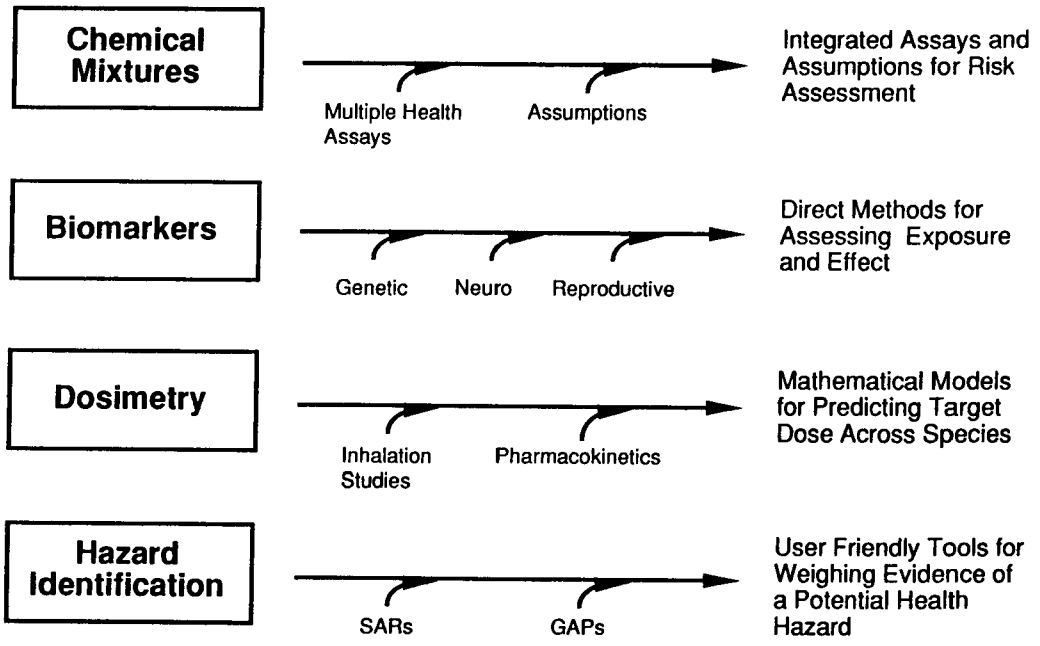


Figure 8. Research to Improve Risk Assessment

Chemical Mixtures

Most Superfund sites contain more than one chemical, but typically, toxicity data on mixtures of chemicals at a site are not available. Consequently, to provide a conservative risk estimate, additivity of health risk posed by the constituents is assumed. Relatively few data exist to evaluate the validity of the additivity assumption, even within a particular health endpoint like neurotoxicity, and virtually no data exist to predict the impact of toxicity on an untested organ system based on its impact on another organ system or from a different chemical. Thus, the focus of chemical mixtures research in FY90 will be on evaluating the constraints that should be applied to the additivity assumption, to increase accuracy of Superfund risk assessments.

Two primary approaches apply to determining the constraints that should be applied to the additivity assumption. The first is an empirical one, in which commonly occurring mixture constituents are tested individually and in combination using a variety of health endpoints to test the presumption of additivity. The second approach

is more mechanistically based, and depends on developing an understanding of the mechanisms responsible for biological interactions that may occur between different chemicals or chemical classes.

Alone, each of these approaches has serious limitations that make it unrealistic to expect data of practical utility within a short time frame. The main limitation of the empirical approach is that the number of possible chemical mixtures needed to be tested is so large that the approach is not feasible for all mixtures. On the other hand, the mechanistic approach is at least partially dependent on an understanding of the biological mechanisms of toxicity, and this understanding has only been partially achieved, and only for certain endpoints. Thus, the approach adopted by ORD is a hybrid of the empirical and mechanistic approaches, to capitalize on the strengths of each. Regardless of the approach, addressing questions of mixtures in risk assessment is expected to require modification and further validation of existing test methodologies. Consequently, an underlying activity in this project is the maintenance of a small effort to improve the test methods.

While many different chemicals are found at Superfund sites, certain chemicals are found frequently and often together as pairs. Consequently, ORD will focus its empirical evaluation of the additivity assumption on frequently occurring chemical pairs and perhaps trios. The evaluation will concentrate on important health endpoints rather than attempt to screen all possible endpoints. When preliminary tests of the pair-forming chemicals indicate that there are multiple endpoints, research protocols will be developed that are capable of handling the important endpoints. A coordinated strategy for linking different test protocols together will be developed to maximize return on the research dollar. ORD developed an integrated bioassay protocol for acute and subchronic *in vivo* assessments of neurotoxicity, developmental toxicity, renal (kidney) toxicity, hepatotoxicity (liver toxicity), and general toxicity in FY89. The protocol is being evaluated while investigating the toxicity of a selected set of Superfund priority chemicals and will be ready to apply directly to issues of additivity during FY90.

Based on existing data, certain organ systems appear to be more likely targets for biological interactions than others. The liver is one such organ system for which toxicological-biological interactions have been well described for some classes of compounds. Many chemicals found at Superfund sites are known to be hepatotoxicants, and for these reasons, the mechanistic approach to evaluating the additivity assumption will focus initially on hepatotoxicity. Current efforts are committed to (1) validating an *in vitro* test of hepatotoxicity against an *in vivo* model for predicting biological interactions produced by chemical mixtures; (2) assessing potential interactions among selected primary contaminants; and (3) determining the mechanisms involved in selected interactions with an appropriate *in vitro* model.

Biomarkers

Biomarkers are measures of variations in cellular or biochemical components, processes, structure, or function that indicate organism exposure, effect, or susceptibility to effect through the detection Generally, biomarkers are not measures of disease, but if an association between a biomarker and disease is well-validated, the biomarker may be a good predictor of disease.

Biomarkers are required to evaluate the extent to which actual exposure to hazardous substances may have already occurred (biomarkers of exposure) and whether biological/health changes have occurred as a consequence (biomarkers of effect). Their development will provide regional risk assessors with a powerful new tool for more directly estimating exposure and effect. It will also provide the Agency with an opportunity to learn how to interpret and use biomarker data, which will be useful since the Agency is likely to be faced with biomarker data that it did not generate but which it may be asked by the affected community to interpret. Some biomarkers may be readily

measured and can be made available to risk assessors in the near future. Others, however, will require more extensive research to resolve fundamental issues before they can reach their full potential as tools for the Superfund program. This is especially true of genetic biomarkers.

ORD, ATSDR, and NIEHS have active Superfund-funded biomarker research programs, but each addresses different issues. The ORD biomarker research program's objectives are to: (1) improve understanding of site-specific human genetic biomarker data for estimating exposures; (2) improve understanding of site-specific human male reproductive biomarker data for estimating exposures and effects; (3) develop biomarkers of neurotoxic effect for use at Superfund sites; and (4) provide recommendations for biomarker procedures and interpretation of data when site-specific epidemiology studies are performed. This program is complemented by the ATSDR program, which focuses on biomarkers of hepatic, renal, and immunological function, and the NIEHS program, which focuses on basic research in the development of novel biomarkers for specific kinds of substances.

The approach to achieving these goals includes five major activities: (1) an evaluation of the relationship between exposure to Superfund chemicals and binding of these chemicals to proteins (hemoglobin adducts) or to DNA (DNA adducts) in lymphocytes and target tissues, with a subsequent determination of the relationship between adduct formation and genetic damage in rodents; (2) development of procedures for evaluating protein and DNA adducts in humans, with particular emphasis on adducts resulting from exposure to chemical mixtures; (3) measurement of marker levels in humans at baseline, high-dose, and low-dose exposures; (4) validation of automated measurements of sperm velocity/motility in rodents and validation of recent biochemical measures for predicting subtle reproductive dysfunction following exposure to Superfund chemicals; and (5) development of assays to detect markers of neurotoxic damage in rodent brain, and a determination of the feasibility of measuring these or related markers in blood or urine for eventual application to humans that may be exposed to neurotoxicants at Superfund sites.

Genetic biomarker research is intended to provide surrogate molecules (DNA or hemoglobin) as primary or secondary dosimeters of genetically-mediated mutagenic and carcinogenic changes. Adducts were selected because they can be used to integrate dose over extended time periods and quantify exposure to specific chemicals. Although progress is being made in the production of genetic biomarkers, their quantification in biological samples must be improved to an ultratrace level for adequate discrimination of chemical effects. The capability of markers to predict real and irreversible effects must also be demonstrated. To improve the detection of DNA adducts, ORD is evaluating new and improved electron-capturing reagents for labeling DNA bases and nucleosides at ultratrace levels in biological samples and is improving sample preparation techniques. The measurement of DNA adducts in the blood of exposed organisms is a crucial step in estimating target tissue dose. However, dosimetry studies of the persistence, half-life, and clearance of adducts will also be conducted to relate adduct levels at a single point in time to predictions of target dose.

To test the usefulness of genetic biomarkers in quantifying cancer, sister chromatid exchanges, micronuclei, and DNA adducts will be measured in human and rodent blood lymphocytes exposed to polynuclear aromatic hydrocarbons, common at Superfund sites and as incineration by-products. In another human population, the frequency of adducts in blood cells will be measured prior to, during, and after breast cancer treatment. Blood samples will be collected from women with a mass in the breast and from controls with benign disease.

Reproductive biomarker research will target sperm measures, mutagen markers, endocrine function, and internal dosimetry for predicting effects from exposure to hazardous substances. Sperm velocity/motility was selected

because it is a known indicator of reproductive health and an acceptable alternative to the lengthy and expensive multi-generational reproductive screening procedures.

A commercial semen analyzer is being evaluated using rat spermatozoa to determine its accuracy and sensitivity for detecting toxicant-related differences in sperm motility. The analyzer is capable of determining sperm counts, percent of motile sperm, and sperm velocity over a range of sperm concentrations and collection intervals. Protocols will be produced and tested for use in assessing toxicant effects on sperm motility. Sperm motility changes will also be compared with endocrine changes, gonadal organ size, and potential toxicant effects on sperm maturation. The objective is to provide *in vitro* methods to monitor sperm maturation during toxic stress by correlating epididymal cell function and sperm motility. Since subtle changes in sperm maturation can be detected in the protein function of *in vitro* epididymal cells, homogeneous epididymal cell cultures are being grown for use in these tests. Other *in vitro* tests being investigated include sperm microinjection for assessment of sperm and oöcyte function and cultures of preimplantation embryos.

Some reproductive biomarker research will be conducted on human populations occupationally exposed to hazardous substances to validate the predictive capability of biomarkers for human health hazards. Cooperative agreements for these studies are in place, and experimental protocols have been completed and approved.

Biochemical methods for assessing the functional integrity of the nervous system of toxicant-treated animals will be evaluated for use as biomarkers. Preliminary studies of several neurotoxic endpoints indicate that neurotoxicity methodologies most likely to succeed as screens for hazardous wastes are *in vivo* protein assays that are specific to the nervous system. Among the variety of proteins that have been selected for study, a glial protein has shown particular promise. The concentration of this protein significantly increases in experimental animals exposed to known quantities of neurotoxicants. This and other protein assays will be further refined and evaluated using a variety of toxic chemicals separately and in selected combinations. The product of this research will be part of a biochemical testing scheme for characterizing central nervous system neurotoxicity. In the future, ORD will develop and validate *in vitro* screens, such as the use of brain slices and tissue cultures to determine the structural integrity of a toxicant-exposed central nervous system.

Dosimetry

ORD expects to improve the scientific basis of exposure and dose-response estimates in risk assessment by generating relevant empirical data and constructing mathematical models. Emphasis will be on construction of physiologically based pharmacokinetic models (dosimetry models) for predicting doses from the inhalation of hazardous substances.

Superfund risk assessments require estimations of exposure and determinations of dose-response relationships. While ambient chemical concentration information may be available for air, water, and soil, the critical exposure data are those that indicate the amount likely to be absorbed and transported to the target tissue (dose). Dosimetry models are mathematical descriptions of the disposition of a chemical and its metabolites in the body, usually expressed in experimentally measurable physiological rates and capacities. When properly formulated and tested, such models can predict dose among species and under untested exposure conditions.

Since dose cannot easily be determined by direct experimentation, dosimetry modeling has become the only practical means for obtaining such information. As a relatively new science, dosimetry models for dose-response assessments require pharmacokinetic data and the construction and validation of methodologies.

For a few chemicals, dosimetry models exist for predicting dose in laboratory animals[3]. However, models for predicting dose absorbed by inhalation that are based solely on animal exposure data are likely to be inaccurate. This is due, in part, to significant species and age differences in the respiratory tract. The purpose of the project is to construct dosimetry models that take airway geometry into account and can be used to make age-appropriate quantitative predictions of dose delivered to human lung and other tissues for inhaled compounds, including particle-bound organics. These models should significantly increase the accuracy of risk assessment.

The research approach requires formulation of physical lung and larynx casts and models to represent the air fluid dynamics of inspiration as it relates to particle distribution and deposition in the airways. Data obtained from these systems will be used to develop theoretical, mathematical models to characterize airway deposition. Single-photon-emission computerized tomography (PET) techniques will be used to validate the models *in vivo*. Additional data will be generated on volatile organic compounds in blood and body tissues and used against the mathematical models to validate models use inter- and intra-species comparisons.

Hazard Identification

Hazard identification is the first phase of a risk assessment. In this phase, a weight-of-evidence judgment is rendered on the existence of a potential hazard at a Superfund site. Typically, the judgment about a potential hazard is based on a subset of existing data for some of the chemicals at the site. Often, however, data are lacking or difficult to interpret. The objective of this research is to provide user friendly tools for weighing the evidence that a particular effect might occur when data are lacking or when data are available but are difficult to compare.

This research will develop a similarity index, based on toxicity data from structurally similar chemicals, for making quantitative predictions of the biological activity of Superfund chemicals, particularly polycyclic aromatic hydrocarbons (PAHs). A quantitative structure-activity relationship model of PAH toxicity using current test data and analyses of structural information will provide a means for using existing toxicity data from structurally related compounds when data are lacking. Additional research will apply graphic activity profiles (GAPs) to Superfund priority chemicals and determine the feasibility of expanding the database to include developmental toxicants. This will provide a user-friendly, computer-based program that graphically presents toxicological data of greatest utility in predicting human health effects.

Evaluate Health Impact of Cleanup Options

During the FS, consideration must be given to different cleanup options. One option that has potential for many Superfund sites is incineration. However, emissions from incinerators constitute a form of complex mixture whose potential toxicity has not been considered. Since emissions from incinerators are truly complex mixtures with many more constituents than can be monitored readily, alternative strategies must be used for evaluating their potential health impact. A strategy recommended by the National Academy of Sciences for estimating the toxicity of incinerator emissions is the comparative potency approach (Figure 9).

The comparative potency approach for Superfund compares the effects of a number of different substances (or mixtures) based on the outcome of a restricted series of bioassays, principally mutagenicity bioassays. Gas or

[3]Physiologically based pharmacokinetic models that accounted for differences in metabolic rates and saturation levels between humans and rodents were used in 1987 to update EPA's risk assessment document for dichloromethane (methylene chloride).

liquid chromatography is used to separate (fractionate) and quantify chemicals in the emissions, and bioassays are used to identify biological activity. The choice of mutagenicity bioassays is based on some evidence supporting the assumption that if the relative potency of different carcinogens in different bioassay systems is constant, then the mutagenicity produced by a particular emissions mixture may be related to human cancer potency. The comparative potency approach has been applied to emissions from other combustion sources like diesel exhaust and wood stoves. The purpose of this project is to evaluate its utility for characterizing the potential toxicity of hazardous waste incinerator emissions.

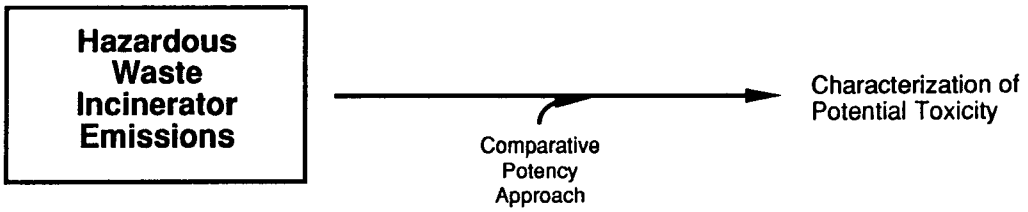


Figure 9. Research to Evaluate Health Impact of Cleanup Options

Since incinerator emissions are known to contain substances that are not readily detected by conventional mutagenicity assays (such as chlorinated organic compounds), new bioassays capable of detecting the mutagenicity of these compounds are being developed and validated. They will be used to compare the mutagenic potential of the hazardous waste incinerator emissions with the toxicity of emissions from residential heating sources. In order to relate mutagenicity and carcinogenicity data, organic extracts of incinerator emissions will be evaluated for their ability to initiate mouse skin tumors. Bioassay-directed fractionation techniques are being developed and will be applied to the problem of identifying the most active constituents in emissions.

Develop Test Methods for Post-Closure Biomonitoring

Many Superfund sites will require periodic post-closure reviews to determine the potential of residual toxicity. For this reason, a simple, short-term bioassay will be evaluated for use as a sentinel surveillance system at closed sites (Figure 10). Based on the present state of bioassay development, the tests most likely to be available within the next few years are those of genetic toxicity. Since animal genetic studies are expensive, *in situ* plant assays are being evaluated as potential surrogates for on-site animal studies of genetic toxicity.

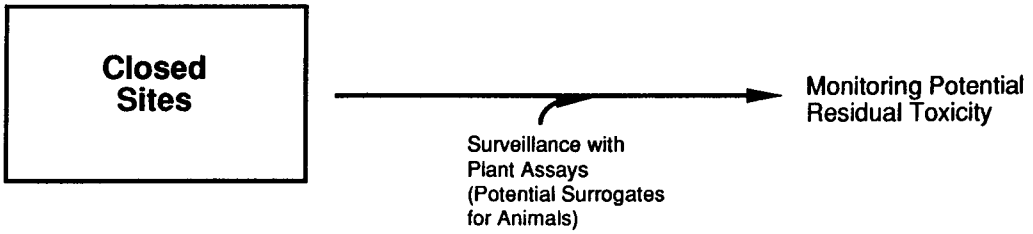


Figure 10. Research to Test Methods for Post-Closure Biomonitoring

Two species of yellow and green maize (*Zea*) plants will be used to measure gene mutation, and *tradescantia* and *vicia* plants will be used to measure chromosome aberrations at test and control sites. The validation of the *tradescantia* and *vicia* plant assays are already underway with chemicals frequently found at hazardous waste sites. A national workshop was convened to assess the current status of *in situ* monitoring and to help chart the future course of the project. Next steps include performing on-site studies at selected sites before and after cleanup and relating *in situ* data to laboratory-derived data on the same samples. Future steps include evaluating the feasibility of developing animal *in situ* models as well.

Advanced Field Screening Technology

To meet the need to replace costly and time-intensive laboratory analyses now used to detect Superfund site contaminants, several emerging technologies that can quantify on-site contaminants and provide rapid results are being evaluated (Figure 11). The emphasis is on highly sensitive, *in situ* methods using portable instrumentation, including remote sensing techniques. *In situ* screening provides almost immediate results and is less expensive than laboratory-based sampling approaches that require off-site removal of hazardous substances.

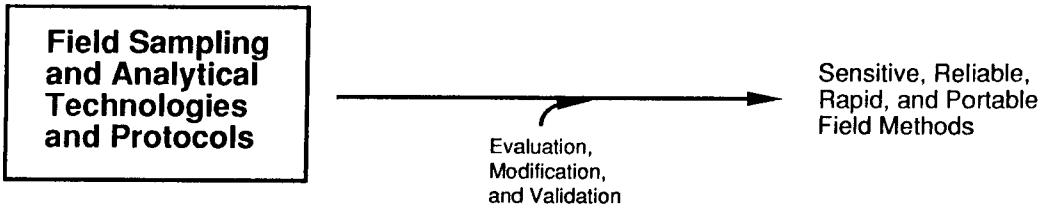


Figure 11. Research to Evaluate Detection Technology

Available field sampling and analytical instruments are primarily designed to detect vaporized chemicals and do not provide the specificity required by the Superfund program for exposure estimates. Technologies for Superfund need to be applicable to solid, liquid, and vapor media; sufficiently sensitive to accurately resolve concentrations of chemicals against typical environmental backgrounds; capable of rapid qualitative and quantitative analysis; easily deployable; reliable under field conditions; and affordable. The quality of exposure estimates for risk assessment depends on the accuracy of contaminant concentration measured in the ambient environment. The Agency has identified a number of emerging technologies that appear capable, with modification, of meeting all of these needs.

New technologies include a prototype, field-portable, XRF system for heavy metal screening; field portable gas chromatography; fiber-optic and related sensors (primarily utilized for *in situ* ground-water monitoring); soil gas methods; canister-based field sampling methods for detection of volatile organics; immunoassays; and portable Fourier-transformed infrared (FTIR) spectrometry. Additional methods based on photoacoustic spectroscopy, developed for military use, and ion mobility spectrometry also show promise. Multi-sensor arrays coupled with multivariant pattern recognition techniques, thermal or laser desorption gas chromatography/mass spectrometry, and multi-detector gas chromatography also are possibilities. To more fully characterize the biological activity of complex environmental samples, chromatography and other field screening techniques can be coupled with bioassays and biomarkers of genotoxicity.

Modified XRF systems will provide EPA with field portable, *in situ*, heavy metal detectors that can identify high concentrations of copper, zinc, and lead in soil. These systems, which do not require sampling, analyze approximate metal concentrations quickly enough for site managers to know at the end of each day exactly where the next day's cleanup should be directed.

Chromatography is used to separate and quantify toxicants. Chromatographic processes are based on the absorption, adsorption, ion-exchange, or size properties of materials in a column used to separate and quantify toxicants. The mobile phase in the column, which may be gas or liquid, generally contains the solvent used for separation. Advances in column technology have revolutionized detection of toxicants in complex mixtures. Recent advances in detector technology have increased the number of detectors available for identifying the specific compounds swept through the column by the mobile phase.

Gas-liquid chromatography is the method most commonly used for quantifying organic toxicants. A field portable unit is being evaluated for use at Superfund sites. In the meantime, ORD is trying to bring into immediate use a gas chromatograph that contains flame ionization and electron-capture detectors to rapidly detect volatile organic compounds. The chromatograph, which is not yet portable, will be used in conjunction with canister-based air samplers. Work continues on a remote air monitoring capability using FTIR systems and on other forms of chromatography needed to identify a variety of different compounds.

Mass spectrometry is often coupled to chromatographic systems to provide a highly sensitive detection method. When chromatography and mass spectrometry are used together, a portion of the toxicants separated by chromatography pass into a mass spectrometer, where it is bombarded by an electron beam. Ions separated by the beam are accelerated through a magnetic field where they are identified by their response to the gravity induced by the magnetic field. Computers are used to analyze their response and to compare the results to a library of patterns characteristic of known molecules.

Remote, *in situ* detection and quantification of a variety of contaminants in water-related media is now possible using fiber optics coupled to a laser fluorimeter. The system eliminates the need for sampling and provides near-real-time measurements of trace concentrations of contaminants underground or at remote locations up to 500 meters from the analyzer. When light from the laser impinges on a contaminant molecule or atom, the light is absorbed. As the molecule or atom loses its excitation energy, it emits radiation, a process called "fluorescence." This fluorescent energy is returned through the fiber to a remote location where it is detected and analyzed using computers. Optical fibers and a laser to provide a source of high-energy light, yield near-maximal sensitivity.

The field screening program relies on a competitive solicitation process to identify potential technologies and conduct applied research for the adaptation of selected technologies. Limited EPA resources are extended by establishing partnerships with the private sector and other federal agencies. For example, the cost of developing the XRF was borne by the National Aeronautical and Space Administration and EPA. The private sector is taking on much of the cost of developing immunoassays such as monoclonal antibodies, which are applicable to the detection of a wide range of hazardous substances.

Advanced field screening technology research products include improved field portable *in situ* technologies, standardized field sampling protocols, and preliminary performance evaluation reports. When sufficiently developed, technologies may be recommended for demonstration in the SITE program and the preparation of procedures and guidance documents for their use.

COOPERATION WITH OTHER AGENCIES

SARA divides the responsibilities for conducting Superfund health research among three agencies—EPA, ATSDR, and NIEHS. Each provides important, complementary health information to the Superfund program. SARA requires that the agencies coordinate research with programs under other legislative mandates and with each other to avoid duplication of effort and to ensure completion of their responsibilities. Senior managers and scientific staff of ATSDR, NIEHS, and EPA meet regularly to coordinate their respective activities.

ATSDR's principal research responsibilities under SARA include preparation of health assessments, toxicological profiles, a national registry of serious diseases and illnesses, a national registry of persons exposed to toxic substances, health advisories, and health consultations in emergencies. Toxicological profiles on each of approximately 275 substances commonly found at sites on the National Priorities List are required under §104 of SARA. They include an evaluation of available toxicological and epidemiologic information on specific hazardous substances, and will be used, in part, to determine whether new toxicological and exposure research is needed and as input to ATSDR's health assessments for NPL sites. As a result of EPA's experience in toxicology and risk assessment, the Agency is assisting ATSDR by producing the first 25 toxicological profiles. EPA expects to be involved in the preparation and update of additional profiles.

NIEHS supports a basic research program in epidemiologic and ecologic studies. This includes advanced techniques for the detection, assessment, and evaluation of the effects of hazardous substances on human health; methods to assess risks to human health presented by hazardous substances; methods and technologies to detect hazardous substances in the environment; and basic biological, chemical, and physical methods to reduce the amount and toxicity of hazardous substances. Although the NIEHS Superfund research program is not directed toward the responsibilities that drive much of EPA's research (risk assessment, cleanup, and regulations), cooperation between the two agencies is routine.

MAJOR DELIVERABLES

Proceedings of the First International Symposium on Field Screening Methods. Due 2/89.

Draft Report on Evaluation of Uncertainties in Pharmacokinetic Models. Due 3/89.

Report Comparing Monitoring Data and Computer Modeling at Five NPL Sites. Due 5/89.

Interim Report on In vitro to In vivo Extrapolation, Metabolic Parameters. Due 10/89.

Report on Adaption of Prototype Data Telemet/Locator System to Portable X-ray Analyzer. Due 12/89.

Final Report on Portable X-ray Fluorescence for Characterization of Hazardous Waste Sites. Due 12/89.

Annual Report on Markers and Dosimetry Research Activities for Exposure Monitoring. Due 12/89.

Report on Portable X-Ray Fluorescence for Characterization of Hazardous Waste Sites. Due 12/89.

Statistical Methods for Integrating Biological Monitoring Data into Public Health Evaluation and Quantitative Risk Assessments. Due 1/90.

Report on Mutagenicity of Superfund Chemicals, Including Chlorinated Compounds Found at Superfund Sites. Due 5/90.

Report on Dermal-Absorption Pharmacokinetic Model. Due 6/90.

Genetic Activity Profiles on Hazardous Substances Listed Under SARA §110 and Toxicity Information for SARA Title III. Due 6/90.

Report on Chemical Mixture Interactions Between Ground-Water Contaminants. Due 7/90.

Final Report on Multiple-Compound Pharmacokinetic Modeling. Due 9/90.

Quantitative Dosimetric Models for Inhaled Compounds to Refine Exposure/Dose Assessment Animal-to-Man Extrapolation Models. Due 10/90.

Report on Hemoglobin Adduct Bioassay for Use in Assessments of Human Exposure to Hazardous Chemicals at Superfund Sites. Due 10/90.

Report on the Use of Integrated Bioassay Testing Protocols in Hazard Assessments of Superfund Sites. Due 11/90.

Report on Two-Tiered Testing Strategy for Using Nervous System-Specific Proteins as Biomarkers of Neurotoxicity. Due 12/90.

Artificial Intelligence SAR Computer Program Based on Chemical Similarity Measures that Can Estimate Relative Toxicity within Classes of Superfund Chemicals. Due 8/91.

Detailed Report to Characterize Mutagenic and Cancer Health Effects of Incinerator Emissions and Residuals. Due 9/91.

Report on Comparative Metabolism of Selected Site-Specific Chemicals for Exposure/Dose Assessment Extrapolation Methods. Due 9/91.

Report on Utility of Sperm Quality as an Endpoint for Predicting Reproductive Impairment and for Validating Additional Biomarkers Used in Reproductive Hazard Identification. Due 9/91.

Report on Methods to Quantitate Internal Human Dose from Exposure to Superfund Chemicals for Risk Assessment. Due 10/91.

Report Evaluating Methods for Detecting Genetic Damage Directly in Humans Applicable to Biochemical Epidemiologic Studies of Superfund Chemicals or Superfund Sites. Due 10/91.

Report on Sentinel Surveillance Methods for Hazard Identification at Uncontrolled Industrial Waste Sites. Due 12/91.

FUNDAMENTAL RESEARCH

OSWER is responsible for implementing laws designed to mitigate or prevent environmental pollution. Central to the execution of its responsibility is the availability of reliable, high-quality scientific and technical information. Recognizing that some of the information needed to address current or emerging problems is not available, Congress has enacted legislation to authorize EPA funding of university-based basic research programs that support OERR's mission.

Section 311(d) of CERCLA authorizes EPA to establish five to ten University Hazardous Substance Research Centers (HSRCs), whose mission is to conduct long-term and short-term research, training, and technology transfer on problems in the manufacture, disposal, and management of hazardous substances that are crucial to the specific geographic area served by each Center.

In 1980, EPA initiated a research grants program within the Office of Exploratory Research (OER) to provide support for long-term university research in areas relevant to its regulatory mission. With the enactment of SARA, the exploratory research program was expanded in 1987 to include grants for Superfund-related basic research. CERCLA §311(c) explicitly authorizes grants for the detection of hazardous substances in the environment and the evaluation and assessment of the effects and risks posed to human health.

Recognizing that some fundamental information needed to fulfill OERR's mission is not available, Congress has enacted legislation to authorize EPA funding of university research centers and university research grants. EPA has established five ***University Hazardous Substance Research Centers***. Lead institutions are the New Jersey Institute of Technology, Kansas State University, University of Michigan, North Carolina State University, and Stanford University. Each Center performs innovative long-term research and technology transfer activities related to the manufacture, use, transportation, and management of hazardous substances. EPA's competitive ***university research grants*** program is intended to expand the scientific basis for solving Superfund program needs and to maintain strong ties to the academic community. Grants are selected on the basis of technical merit, potential relevance to EPA research needs, and contribution to a balanced research program. The grants stimulate university scientists to work on EPA's technical problems, complement existing EPA programs, and provide a stronger creative base for mission-oriented research needed for EPA's regulatory and enforcement programs.

FUNDAMENTAL RESEARCH APPROACH

EPA has established five University Hazardous Substance Research Centers and a competitive grants program to expand the scientific basis for solving Superfund program needs and to maintain strong ties to the academic community. Grants are an important means by which EPA funds research on relevant environmental topics in the academic sector.

University Hazardous Substance Research Centers

The purpose of the Hazardous Substance Research Centers is to conduct research and training related to the manufacture, use, transportation, and management of hazardous substances. Each Center performs innovative long-term research and technology transfer activities relating to key hazardous substance problems experienced by the Regions served by the Center. The Centers combine leading-edge research with a familiarity and concern for grassroots needs. Under the statute, the federal share of a grant cannot exceed 80 percent of the costs of

establishing and operating the Center and conducting research activities by the grant recipient. Grant funds cannot be used in the acquisition of real property or construction of any building.

In March, 1988, EPA published a solicitation to seek proposals for the establishment of five university-based Hazardous Substance Research Centers. The solicitation specified that academic institutions with significant research and training programs in areas relating to hazardous substances were invited to submit proposals. The solicitation also specified that competing universities would have to be located in the geographical region that they proposed to serve. Thirty-three proposals representing 96 universities and colleges were received by the closing date of June 27, 1988. To comply with authorization language and to facilitate Regional interaction with the Centers, ORD partitioned the country into five pairs of EPA Regions (Figure 12).

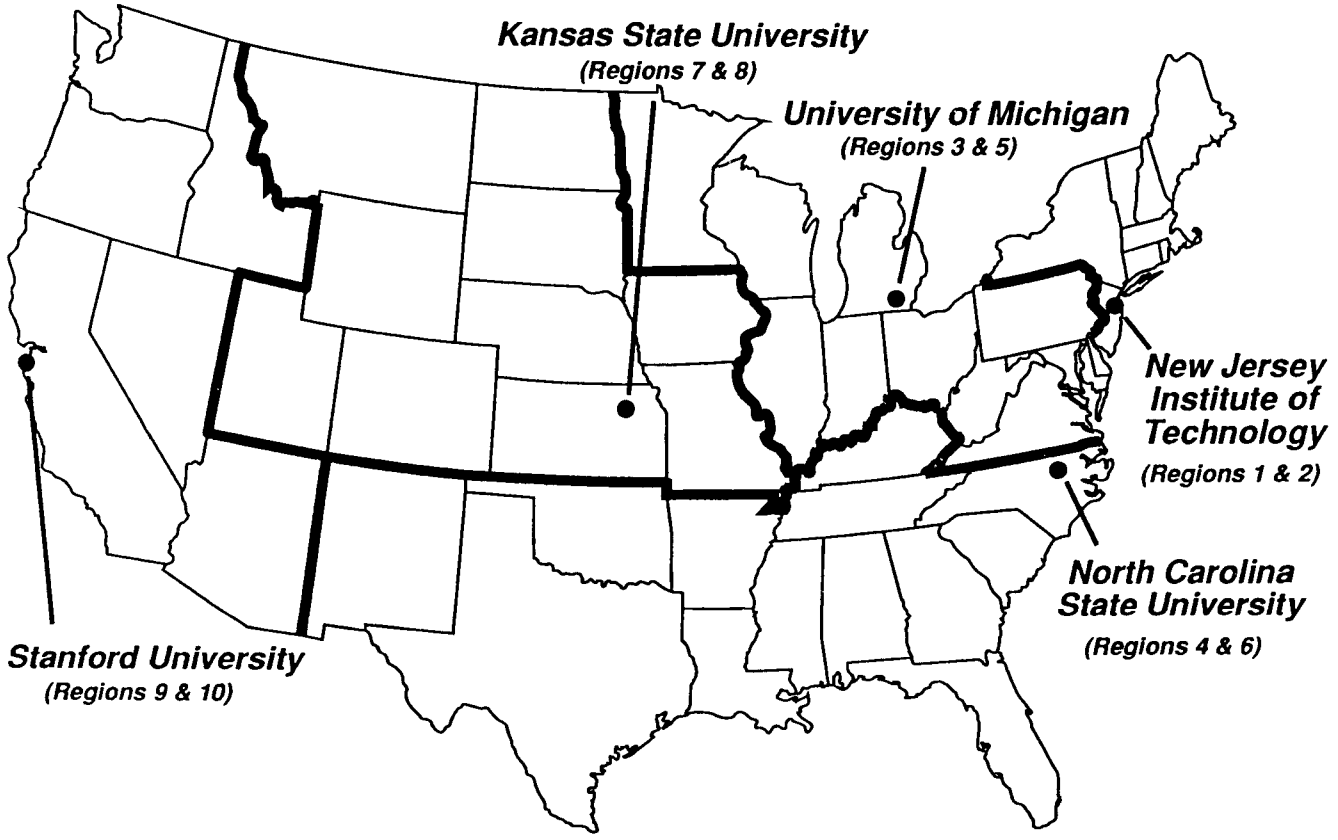


Figure 12. Superfund Hazardous Substance Research Centers

Five separate peer-review panels composed of technical experts from outside the Agency were convened to select the HSRCs for each pair of Regions. The selected universities and their expected research emphases are:

- The New Jersey Institute of Technology will be the lead institution for Regions 1 and 2. Other institutions in the consortium are Massachusetts Institute of Technology, Princeton University, Rutgers University, Stevens Institute of Technology, Tufts University, and the University of Medicine and Dentistry of New Jersey. This Center will emphasize soil and ground-water treatment technologies and thermal destruction of solid wastes.

- The University of Michigan will be the lead institution for Regions 3 and 5. Other institutions in the consortium are Michigan State University and Howard University. This Center will concentrate on bioengineering and the microbial treatment of contaminated aquifers and soils.

- North Carolina State University will be the lead institution for Regions 4 and 6. Other institutions in the consortium are the University of North Carolina and Texas A&M. This Center will emphasize waste minimization.

- Kansas State University will be the lead institution for Regions 7 and 8. Other institutions in the consortium are Montana State University, University of Iowa, University of Missouri, University of Montana, University of Nebraska, and the University of Utah. This Center will feature treatment of metal mining, agricultural, and organic wastes.

- Stanford University will be the lead institution for Regions 9 and 10, with support from Oregon State University. This Center will stress bioremediation.

Each Center has a Science Advisory Committee that will meet twice annually to advise the Center director on areas of research and to review current and proposed research projects for technical soundness, innovation, and relevance to the Center's mission. The committee consists of technically qualified individuals from EPA, academia, industry, and state and local regulatory agencies.

Each Center also has a Training and Technology Transfer Advisory Committee that will meet once a year. The committee includes representatives from OSWER, Regional offices, ORD's Office of Technology Transfer and Regulatory Support, ORD laboratories, industry, and state and local regulatory agencies. All Centers will provide training and technology transfer up to a level of 15 percent of their funds.

Each Center is required to submit an annual report of its progress to EPA, which will include a listing of all peer-reviewed publications and other materials published during the year, training courses given, symposia and workshops sponsored, and any other significant accomplishments. To ensure adequate oversight of the direction and accomplishments of the HSRCs, the Hazardous Waste/Superfund Research Committee will periodically conduct program reviews of each HSRC program.

The Centers will coordinate among themselves as well as with other organizations engaged in similar activities, including the Hazardous Waste Research Center at Louisiana State University (one of eight EPA-sponsored Environmental Research Centers), the Center for Intermedia Transport Research at UCLA, and the National Science Foundation Hazardous Waste Center at UCLA. Coordination of their programs will be guided by the Office of Exploratory Research to ensure efficient development and delivery of appropriate research results and technology and improved training of personnel engaged in the management and handling of hazardous substances. An estimated 100 articles will be published annually in peer-reviewed journals and over 20 training courses will be conducted. Numerous activities will be carried out to transfer technology to the academic community, private sector, state and local agencies, and the public.

University Research Grants

As a part of its long-term research effort, ORD established the research grants program within the Office of Exploratory Research in 1980 and began issuing Superfund-related grants in 1987. The objectives of this program

are to develop an effective means to stimulate university scientists to work on EPA's technical problems, complement existing EPA programs, and provide a stronger creative base for mission-oriented research needed for EPA's regulatory and enforcement programs. This program is an important part of an overall multidisciplinary research program to address health, environmental, and engineering issues associated with hazardous substances.

Researcher-initiated grant applications are received in response to an annual general solicitation and special thematic solicitations called Requests for Applications (RFAs). The RFA is a mechanism by which proposals are solicited for a one-time competition in a narrowly defined, high-priority research area. Grants from both mechanisms are selected on the basis of technical merit, potential relevance to EPA research needs, and contribution to a balanced research program.

The grants selection process uses a dual system of review. *Ad hoc* panels, comprised of at least three scientists or engineers from the relevant field, meet to review each proposal. Applications that pass the scientific panel review are then evaluated by EPA staff for their relevance to EPA's mission. The combined recommendations are ranked and the grants are awarded until available funds are exhausted.

The FY89 general solicitation seeks proposals for research in the following general program areas. Every scientifically meritorious proposal will be considered even if does not fall within these program areas, however, all proposals selected for funding must be relevant to EPA's mission.

- *Environmental Biology.* The major objective of the environmental biology research program is to provide a scientific basis upon which the Agency can make decisions concerning human health effects and risk assessments. The principle concern is to determine whether, and to what extent, exposure to various environmental pollutants contribute to health risks. Areas of interest include models and methodologies for predicting human health effects and risk assessment in human populations.

- *Environmental Health.* The environmental biology research program supports a broad range of research in the areas of risk assessment, ecosystem structure and function, toxicology, biotechnology, and degradation processes. The program seeks information that, in combination with exposure data, allows the prediction of the environmental risk of pollutants on individual organisms, populations, communities, and ecosystems. Areas of interest include risk assessment, ecosystem structure and function, toxicological effect studies on chemical reactions and their rates, and the physics of the movement of pollutants in air, water, and soil. The resulting tools and information will allow the estimation of total exposures needed for risk assessments. Areas of interest in air pollution research include exposure monitoring systems and advanced analytical methods, transport and fate studies, and modeling studies. Areas of interest in research on pollution of fresh, marine, and estuarine waters, soils, ground waters, and sediments include transport and fate studies, monitoring systems, and analytical measurements.

- *Environmental Engineering.* The environmental engineering research program supports fundamental research needed to provide solutions to pollution control problems outside the scope of the Agency's response-directed research program. New, innovative toxic substances control and waste management techniques are sought to provide cost-effective advanced multi-media pollution control technologies. Areas of interest include proof-of-concept research in high-risk, high-potential technical areas, pilot-scale evaluation and cost performance testing of innovative technologies, and fundamental thermal destruction/combustion research leading to less pollutant production and to better incineration of hazardous wastes.

- *Environmental Air/Water Chemistry and Physics.* The environmental air/water chemistry and physics research program supports research leading to the basic scientific tools for establishing the levels at which pollutants occur or might occur in the environment. The program includes projects in analytical chemistry, studies on chemical reactions and their rates, and the physics of the movement of pollutants in air, water, and soil. The resulting tools and information will allow the estimation of total exposures needed for risk assessments. Areas of interest in air pollution research include exposure monitoring systems and advanced analytical methods, transport and fate studies, and modeling studies. Areas of interest in research on pollution of fresh, marine, and estuarine waters, soils, ground waters, and sediments include transport and fate studies, monitoring systems, and analytical measurements.

In addition to the general annual solicitation, when the Agency wants to explore a new research area and existing Agency research efforts are minimal, applications are sought through the more narrowly defined RFAs. These are limited to non-profit research organizations and educational institutions. Five to ten, two-year research agreements are usually awarded.

While a specific research theme has not yet been chosen for the FY89 RFA, it is anticipated that one will be issued in March, 1989. The most probable candidate is *in situ* treatment of hazardous wastes, which was also issued in FY88. The FY88 RFA solicited proposals for the development of innovative cost-effective methods for the *in situ* treatment of hazardous wastes. Treatment includes the degradation of wastes, but not their immobilization. Biological techniques that use genetically engineered microorganisms were not included because special clearances are required. *In situ* technologies must meet the following requirements to be considered for a grant:

- The net result of the technology must be the degradation of contaminants to reduce their toxicity and concentration in soil and ground water. Processes in which the net result is to transfer contaminants between media or to immobilize a contaminant within a single phase are not acceptable.

- Providing the technology meets the first criteria, efforts that improve only a portion of the overall process are acceptable, such as improving mass transfer or the reaction steps that limit a particular process.

- In all technologies to be considered, the soil phase must remain in place, although mechanical devices that promote local mixing of the soil may be incorporated in the process.

- Processes that add chemical and biological agents to the ground water or that remove products of subsurface degradation at the surface are permissible as long as all degradation processes occur on site in the upper surface of the soil, vadose zone, or ground water.

- On-site or pump-and-treat processes where pollutants are treated or removed from contaminated water or air after being brought to the surface are not acceptable.

The proposed research must do more than merely demonstrate a particular technology that is already being applied. Efforts should be made to extend the application to other types of soil or to mixtures of wastes where a technology has previously been successfully demonstrated with single contaminants. Methods for treatment of complex mixed wastes, including those that are relatively insoluble, are of particular interest. *In situ* treatment technologies can include chemical detoxification, electrochemical decomposition, physical methods for subsurface mixing, biotreatment methods, reagent delivery systems, and reaction product recovery systems.

The FY88 *in situ* treatment RFA resulted in the award of eight research grants:

- *Characterizing and Modifying Important Properties of Anion-Exchange Resins for Selective Removal of Toxic Anions.*
- *Enhanced Bioremediation of Hydrophobic Organic Contaminants in Soil/Water Systems through Addition of Solubilizing Agents.*
- *Optimization of In Situ Biodegradability of Subsurface Soil Contaminants.*
- *Promoting In Situ Dechlorination of Aromatic Compounds through Catalysis by Extracellular Enzymes.*
- *Anaerobic Microbial Transformation of Homocyclic and Heterocyclic Aromatic Hydrocarbons, Chlorinated Benzenes, and Mixtures, and the Relevance to Bioreclamation.*
- *In Situ Biodegradation of Hazardous Chemicals Enhanced by Chemical Oxidation.*
- *In Situ Treatment of Trichloroethylene-Contaminated Ground Water.*
- *Lysimeter Control of Aerobic Biodegradation in the Vadose Zone.*

MAJOR DELIVERABLES

Annual reports on Hazardous Substance Research Center and competitive grant research and activities will be prepared at the end of each fiscal year. The publications and other outputs of the HSRCs and grantees will be available through the Office of Exploratory Research and the university researchers.

RESEARCH PLANNING PROCESS AND RESOURCES

Total resources for conducting the Superfund research program in FY89 will be $72.97 million and 102.8 FTEs. Planning and budgeting this research requires extremely close cooperation and working relationships between ORD and OSWER senior managers and technical staff. This need is met through a combination of formal and informal interactions with OSWER and Regional managers and technical staff.

RESEARCH COMMITTEE

The Hazardous Waste/Superfund Research Committee (Figure 13) is an advisory committee to the Assistant Administrator for ORD and is jointly chaired by Office Directors representing both ORD and OSWER. Its role is to direct research activities to meet priority needs of the Superfund program. It is responsible for reviewing the hazardous waste and Superfund research programs, determining whether high-priority research needs are being met, negotiating research approaches to best meet identified needs, and recommending resource allocations to the ORD Assistant Administrator. Three standing subcommittees, Superfund Research, Hazardous Waste Research, and Technology Transfer, are also jointly chaired by ORD and OSWER personnel. The Superfund research program is primarily coordinated by the ORD and OSWER co-chairs of the Superfund Research Subcommittee, although the Hazardous Waste and Technology Transfer Subcommittees are responsible for integrating hazardous waste research and technology transfer programs, respectively, with Superfund research. Designated Regional representatives participate in the Research Committee and Subcommittee planning process through attendance at meetings, teleconferencing and use of the OSWER Electronic Bulletin Board to exchange information.

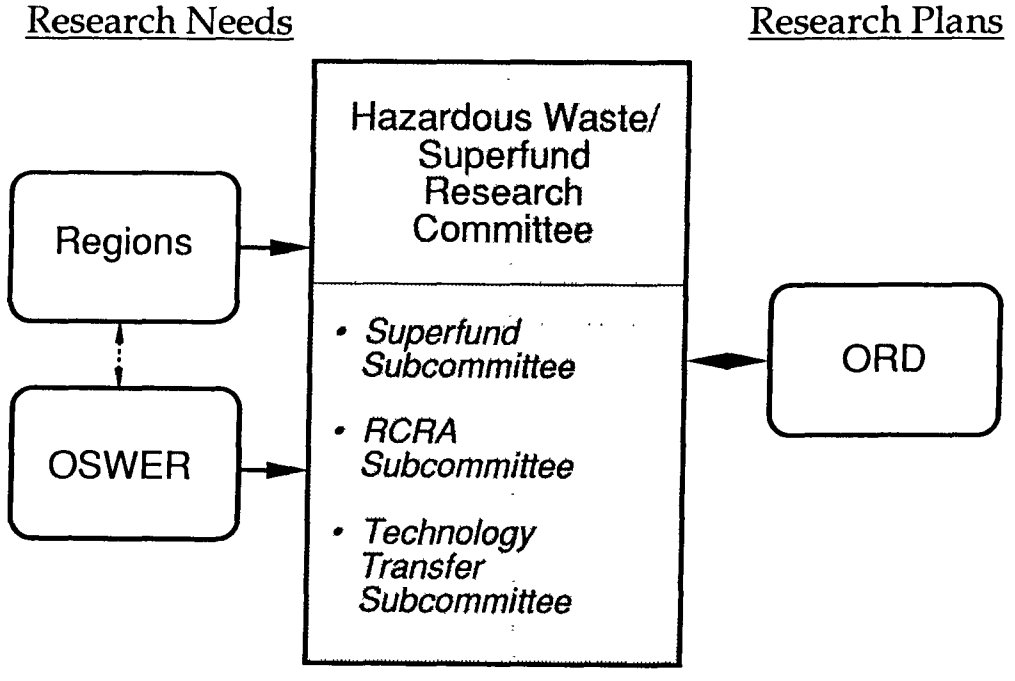


Figure 13. Hazardous Waste/Superfund Research Committee

Work groups composed of ORD, OSWER, and Regional representatives under each Subcommittee negotiate research priorities and programs at the staff level and narrow down those issues that must be brought before the Subcommittees or the full Committee for decisions that often involve tradeoffs from one research area to another, higher-priority area. Historically, the work group organization paralleled the research budget issues. However, this is not required, and the Superfund Subcommittee restructured its work groups early in FY88 to enhance cross-office communications.

The Research Committee, Subcommittees, and work groups provide the organizational structure, senior management oversight, and technical expertise to manage year-round coordination of Superfund research. ORD's Superfund research programs are guided by a combination of an annual, formal, Research Committee process and informal input from OSWER and the Regions throughout the year. The Superfund work groups have the day-to-day responsibility to ensure that program office priorities are factored into research plans; extramural resource allocations reflect priorities; research results are conveyed to the program and Regional offices in a timely manner; technical issues between ORD offices, laboratories, and Program offices are resolved expeditiously; and ongoing research projects reflect expectations and priorities. Generally, technical issues and priorities are resolved at the work group level. Potential deviations from Committee agreements approved by the Subcommittee co-chairs are submitted in writing to the Committee co-chairs for approval. The applicable ORD office directors and ORD's Office of Research Program Management (ORPM) are also involved.

The Technology Transfer Subcommittee is responsible for recommending priorities for technology transfer activities funded through the Committee, which include integrated technology transfer programs for Superfund, hazardous waste, enforcement, and underground storage tanks. Within the constraints placed on the use of Trust Fund monies, the Technology Transfer Subcommittee encourages activities that address several program needs using the same resources. In addition, the Technology Transfer Subcommittee serves as an advisory body to OSWER, setting priorities for program office resources. Since the Technology Transfer Subcommittee has representatives from most of the ten EPA Regions, it provides an excellent vehicle for directly addressing Regional needs.

CONTINUING OVERSIGHT

To ensure continuing oversight by senior managers and quality technical analyses used in decision making, EPA has expanded its formal and informal research program reviews. The Research Committee conducts three to four research program reviews each year that include ORD representatives to inform senior OSWER managers of the progress of the research program. ORD conducts laboratory reviews each year encompassing the entire ORD research program to ensure headquarters review of research progress and to foster improved communication between laboratory and headquarters technical staff. Special mid-year research program reviews are conducted by the Technology Transfer and Superfund Research Subcommittees, including both ORD and OERR managers, for high-priority program areas such as health and risk research, technical support, and ground-water research. In addition to these internal EPA reviews, ORD offices and laboratories invite peer reviews by scientists and engineers from universities and other federal agencies to ensure the scientific credibility of its research projects.

The Science Advisory Board (SAB), established by the *Environmental Research, Development, and Demonstration Authorization Act Amendments of 1978*, is the principal independent advisory board used by EPA's Administrator to obtain outside advice on the scientific aspects of important public health and environmental issues.

Many ORD programs have been referred to the SAB for scientific review, and the Board has been instrumental in shaping specific research programs and initiatives that support major Agency decisions.

RESEARCH PROJECT TRACKING

OSWER needs to be informed of progress and interim results of ongoing research to plan its own regulatory and enforcement agenda and to ensure that field office staffs have the most current information available. In response to this need, ORD and OERR instituted a joint *Superfund Research Program Tracking System* in 1987. Its key elements are the development of a project database, identification of ORD contacts, and the involvement of OSWER project monitors—technical staff responsible for regularly reviewing progress of the Superfund research projects. The tracking system presents OSWER with the opportunity to exert some influence on the direction and progress of research.

Information on the scope of program activities and specific deliverables is provided to OSWER at the beginning of each fiscal year. OERR managers provide comments on whether these documents reflect the research agreed to in Research Committee deliberations. ORD provides quarterly reports to OSWER to indicate the status of activities and deliverables. The Quarterly Reports include at least one interim milestone in the current year for all deliverables listed for completion in subsequent years. Quarterly Reports also explicitly state the completion and delivery dates of any products due during the reporting period. ORD's Program Coordination Staff has primary responsibility for coordinating the compilation of status reports and making sure the reports are prepared in an accurate manner and delivered in a timely fashion. The ORD Superfund Subcommittee work group members ensure that any significant redirections in schedules, products, or resources that ORD must consider during the year are immediately communicated to OSWER and coordinated as they occur.

OSWER's project monitors are responsible for keeping abreast of the status of activities in the Superfund research program for the program office. The project monitors are in continued contact with ORD Program Element Coordinators and selected laboratory personnel to discuss the research and suggest additional products that would ensure greater program support. OSWER project monitors brief OERR's Deputy Director on significant activities and any problems that have been brought to their attention, which allows ORD and OSWER senior management to negotiate problems as they arise.

The success of the system depends on the quality and completeness of the reports, oversight and monitoring of the tracking process, and good follow-up by ORD offices when issues arise within the research program. Senior managers of the Superfund program rely heavily on this process to maintain an awareness of the content of the Superfund research program and its progress.

SUMMARY OF RESOURCES

ORD resources for FY89 Superfund research are summarized in the following four figures. Figures 15 and 16 present the total dollars and FTEs planned within ORD's eight broad technical issues (unshaded areas in Figure 14). The total dollars include Research and Development (R&D) resources and Salaries and Equipment (S&E) resources. Figures 17 and 18 present the total dollars and FTEs planned within ORD's four major research program areas (shaded areas in Figure 14). Figure 19 presents a historical overview of ORD research funding within the eight technical issues over the period 1981 through 1989.

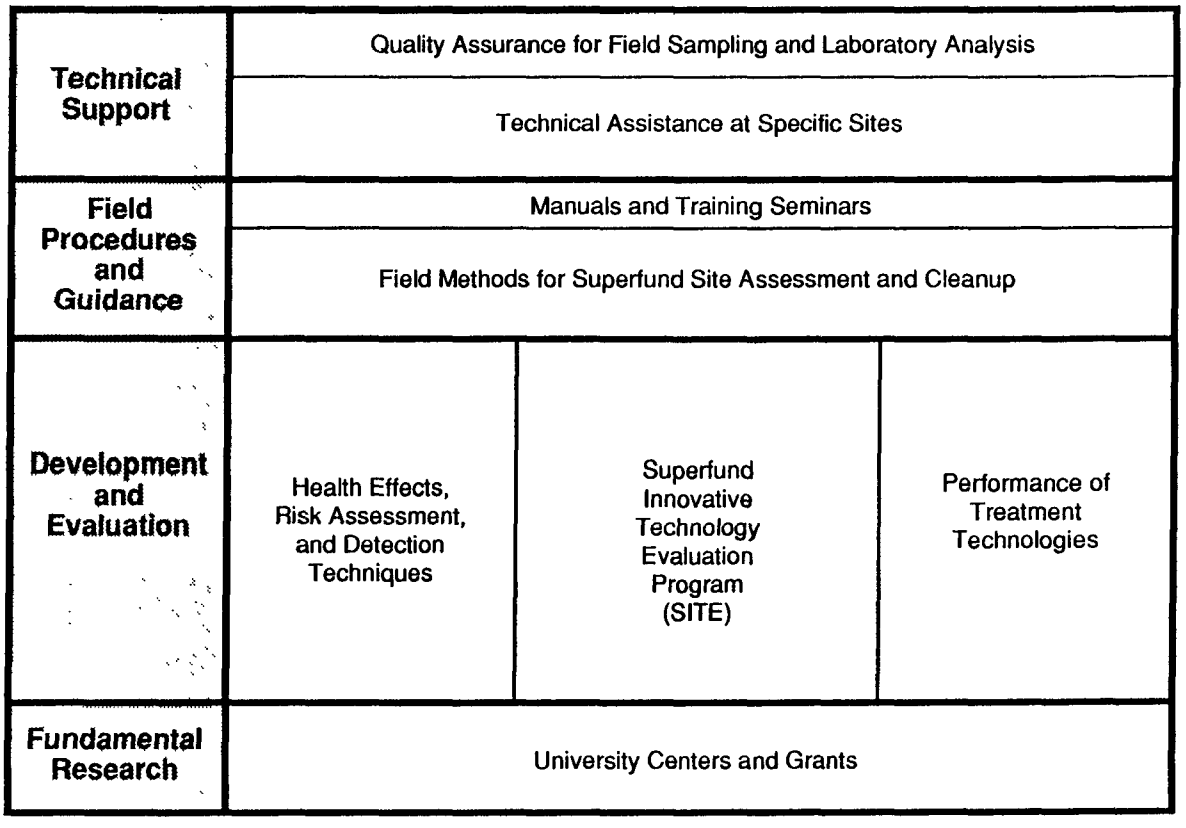


Figure 14. Overview of ORD Superfund research program (reproduced from Introduction).

RESOURCE CHANGES FOR FY90

Administrator William K. Reilly commissioned an internal *Management Review of the Superfund Program*, which was completed within three months of his confirmation in the Spring of 1989. This "90-Day Study" sets forth a comprehensive, long-term strategy for the Superfund program. Several key findings and recommendations deal with pressing needs for enhanced technical information and support to EPA field personnel—primarily Remedial Project Managers. While many of these needs were already recognized by Superfund and ORD management, and some initiatives were underway to respond to them, this review accelerated some of the initiatives from the FY91 planning year into FY90.

A key role for ORD's support to the Superfund program is hands-on, site-specific technical assistance and consulting. In response to the Administrator's "90-Day Study", ORD's Superfund research program received a one-time, above-base enhancement of $1.1 million to be obligated during FY90 and FY91, and a permanent increase of 25.5 FTEs (plus the associated salary and benefits resources). These enhancements were allocated as follows:

- Accelerated or enhanced research on bioassessment protocols and biodegradation and assistance to EPA Regions on a number of ecological risk assessments ($0.7 million).

- Accelerated work on expert systems designed to assist Regional field personnel and managers in making technical decisions. There will also be a companion program to the SITE effort to evaluate actual cleanup projects that have used treatment technologies in novel ways ($4.9 million).

- A Superfund Technical Assistance Remedial Technology (START) program to provide engineering and technical assistance to Regions on selected highly complex sites on a continuing basis. In addition, ORD will conduct waste-treatability studies for Regions on request in order to evaluate the effectiveness and efficiency of alternative remedial approaches ($3.7 million plus 15 FTEs).

- Health effects assessments, reportable quantity methods and adjustments for newly listed substances, hazardous substances, chronic toxicity, and carcinogenicity of lead compounds ($0.3 million).

- Inexpensive, rapid field-portable screening and sampling equipment and methods development, and evaluation of promising commercial systems for conversion to Superfund requirements ($0.8 million).

- A Superfund Technical Liaison Program is placing an ORD scientist on the staff of each Regional program to ensure continuous coordination with laboratories and assistance to Regions in identifying ORD expertise for assistance in the field ($0.7 million plus three FTEs).

- The Superfund Technical Support Centers at four ORD laboratories have received 7.5 additional FTEs for on-going technical assistance activities.

Aside from these special enhancements, ORD base resources for FY90 are essentially equivalent to FY89. However, there are three significant differences between the FY89 budget and the FY90 base budget presented in Figures 15-18 :

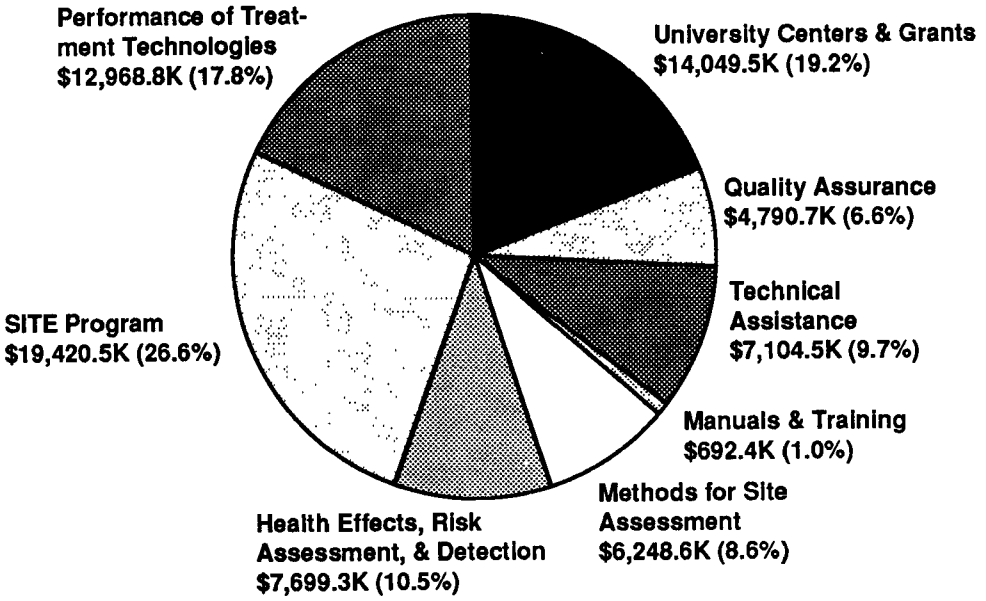
- The Safety Procedures and Equipment program, within Field Procedures and Guidance, is being phased out. EPA and Superfund contractors obtain equipment from commercial vendors who meet existing standards. With the development and promulgation of clothing and equipment standards, EPA believes that the continued development and innovation of equipment is best left to the private sector and to federal or state agencies that regulate worker safety. Approximately $700 thousand is being redirected from this topic to fund start-up costs for the Environmental Test and Evaluation Center ("E-TEC"; formerly the Test and Evaluation Facility).

- The resources for University Centers and Grants in FY89 ($14,049,500) include a $5 million carryover from FY88 for the Superfund Hazardous Substance Research Centers. This carryover is not reflected in the FY90 President's budget, which therefore shows a reduction for University Centers and Grants.

- Small increases in Expert Systems and Field Sampling Quality Assurance, accomplished by an internal reallocation of funds, which do not affect resource totals.

Actual funding levels for ORD research are dependent upon Congressional appropriations. As this document was completed, representatives from ORD and OSWER were reviewing priorities and preparing recommendations to ORD's Assistant Administrator to carry forward through FY91, and identifying gaps and issues to initiate planning for FY92. This document will be updated and revised over the following year to address these subsequent years of Superfund research.

Total FY89 = $72,974,300



Total FY90 = $78,282,800

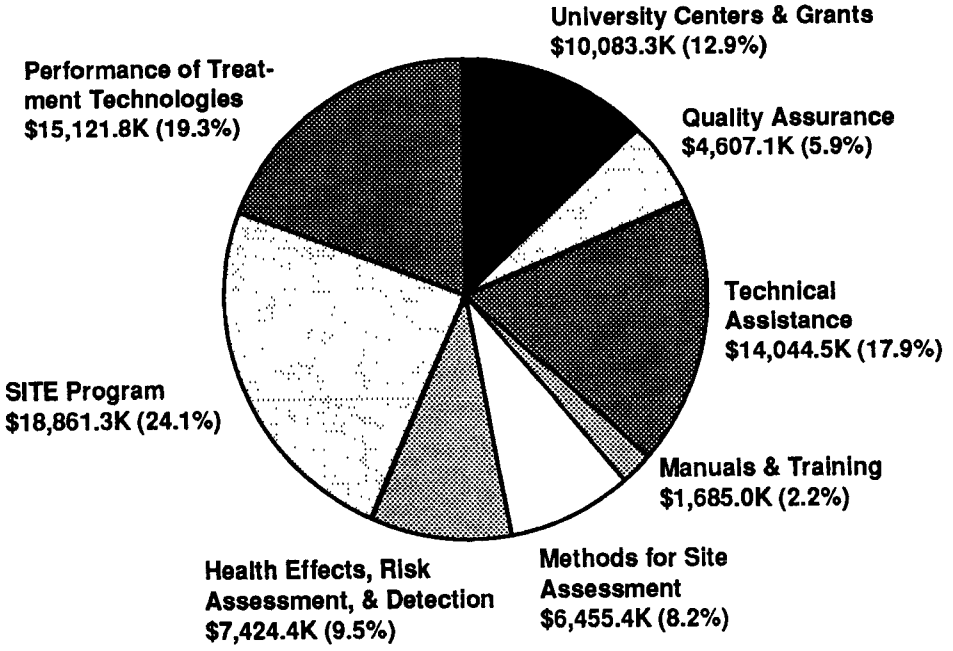


Figure 15. ORD Superfund Research Budget for FY89 and FY90 Total Dollars (Thousands)

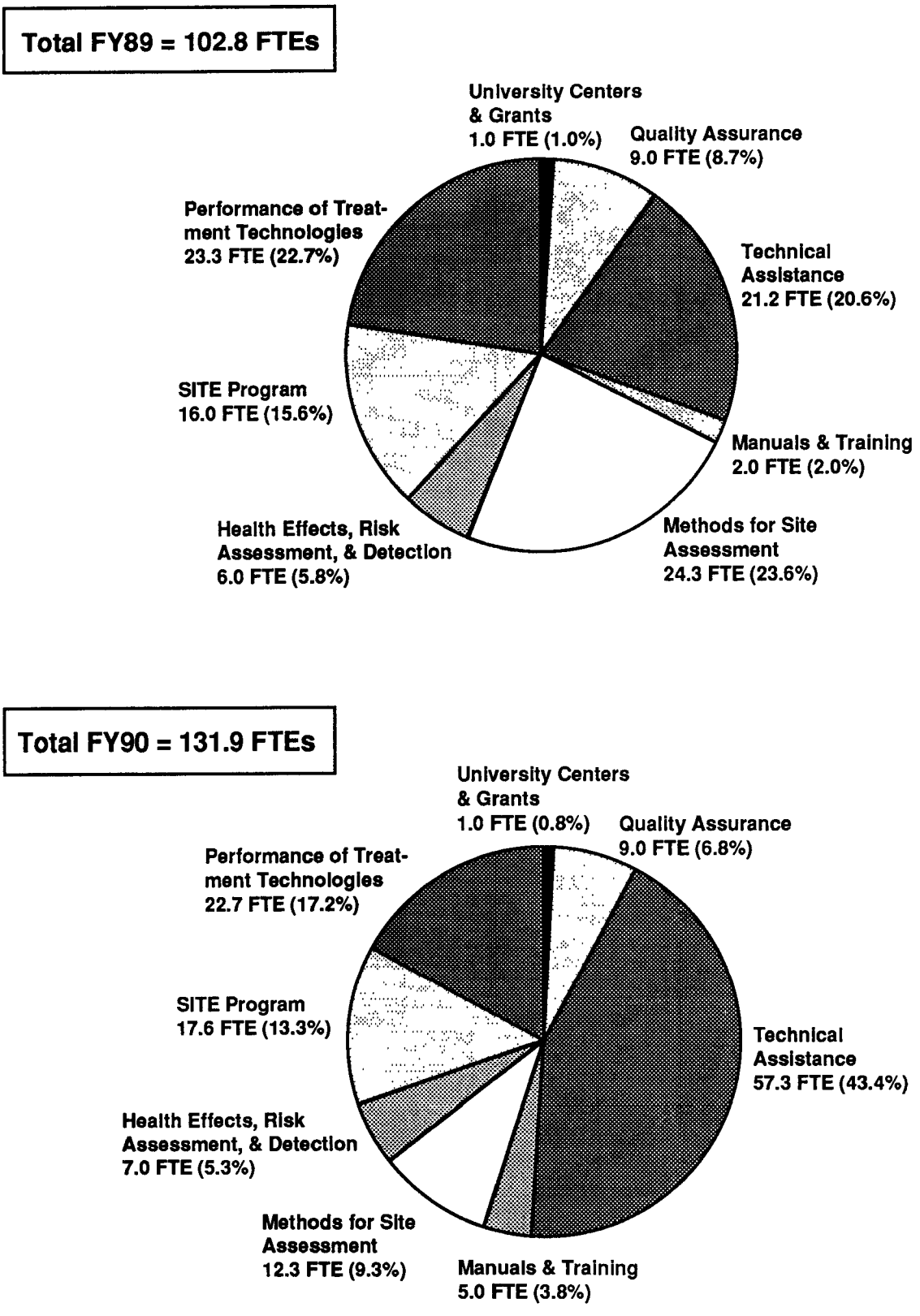
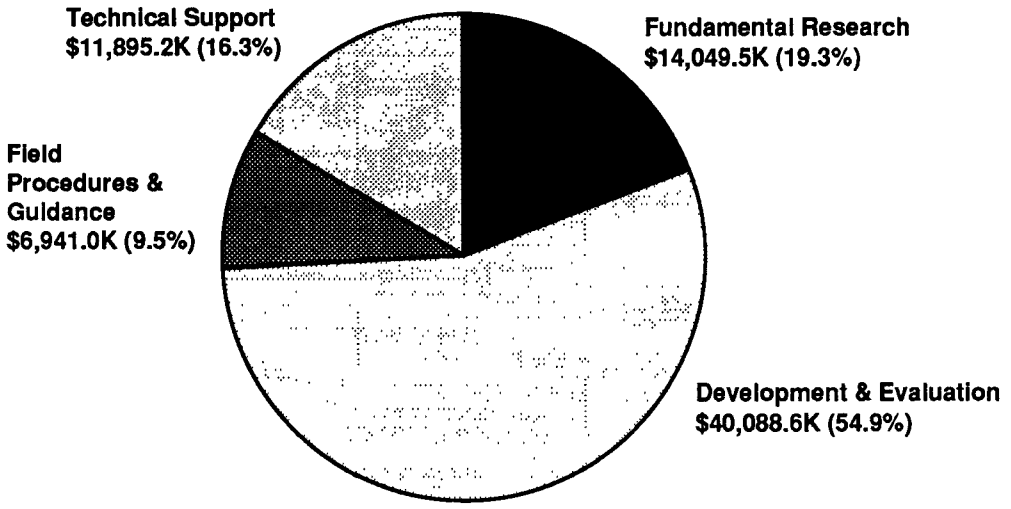


Figure 16. ORD Superfund Research FTEs for FY89 and FY90

Total FY89 = $72,974,300



Total FY90 = $78,282,800

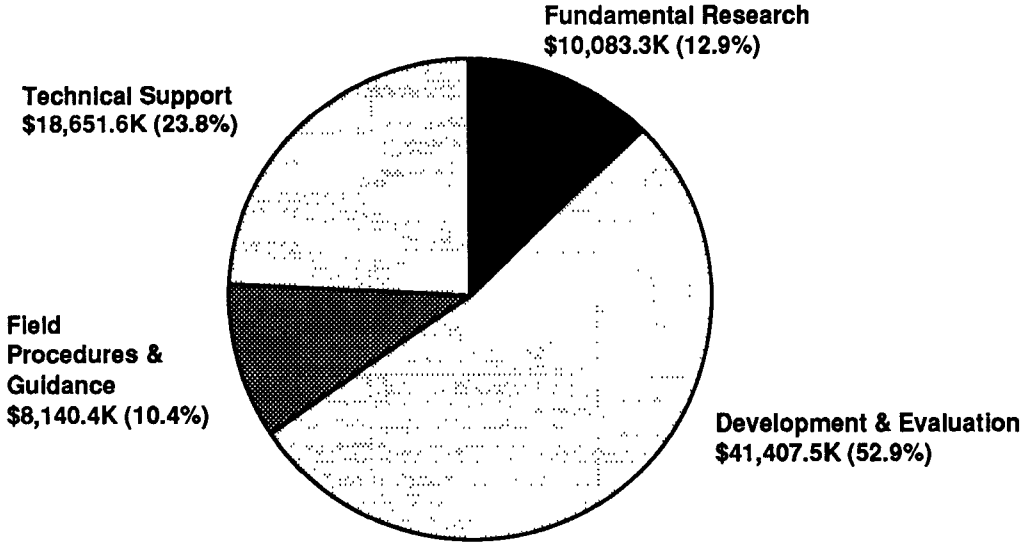


Figure 17. ORD Superfund Program Budget for FY89 & FY90 Total Dollars (S&E and R&D)

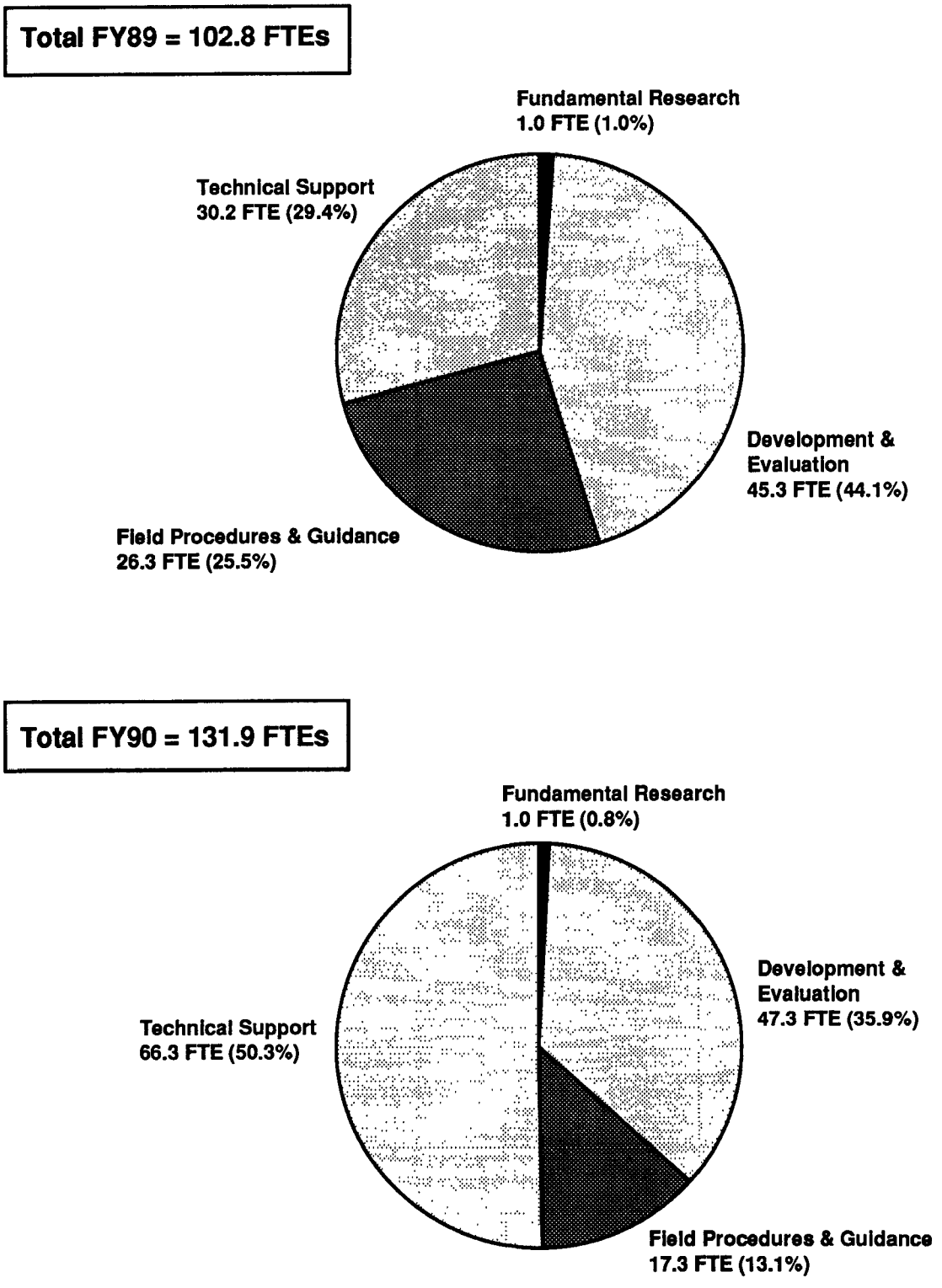


Figure 18. ORD Superfund Program FTEs for FY89 & FY90

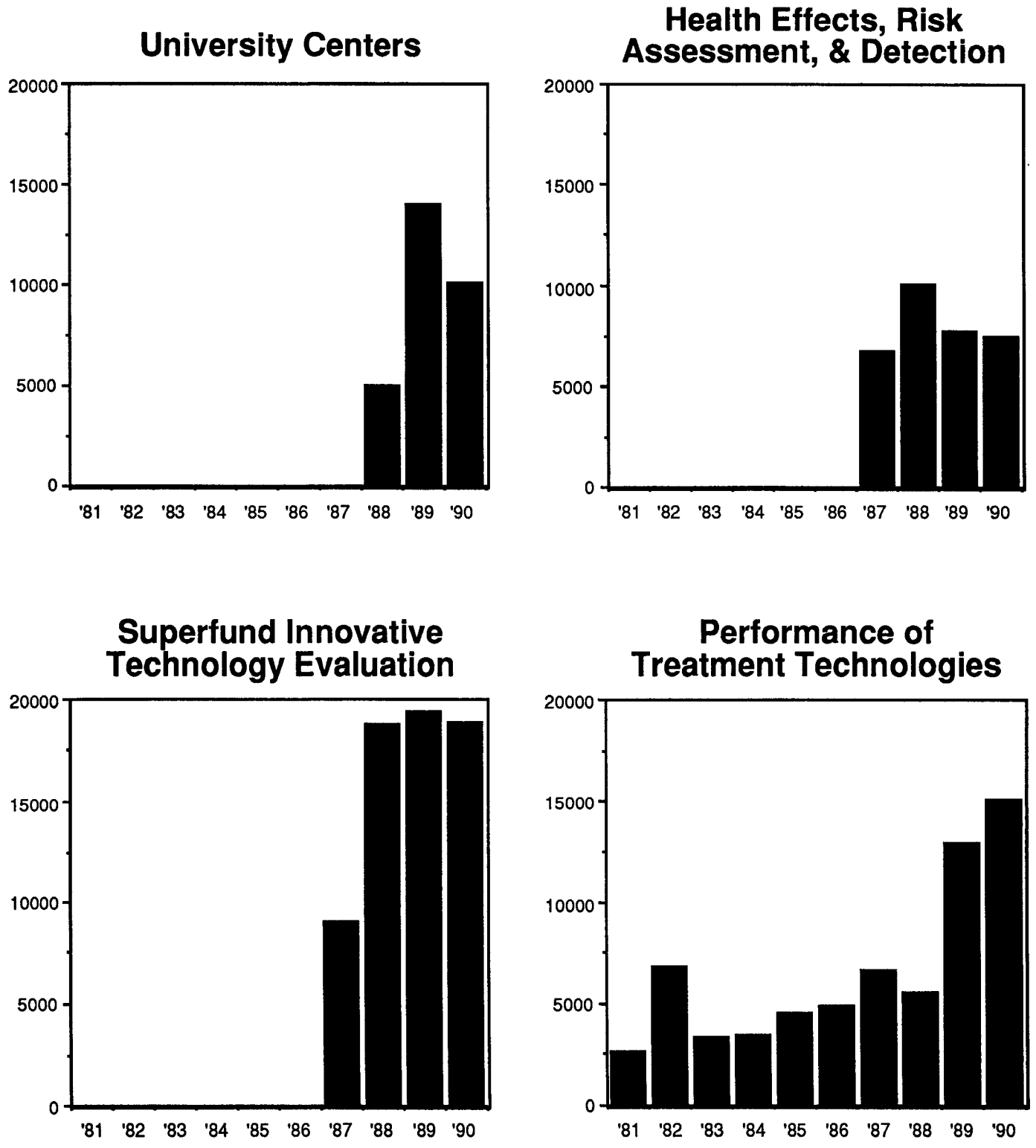


Figure 19. Annual Superfund Research Budget in thousands of dollars for 1981-1990

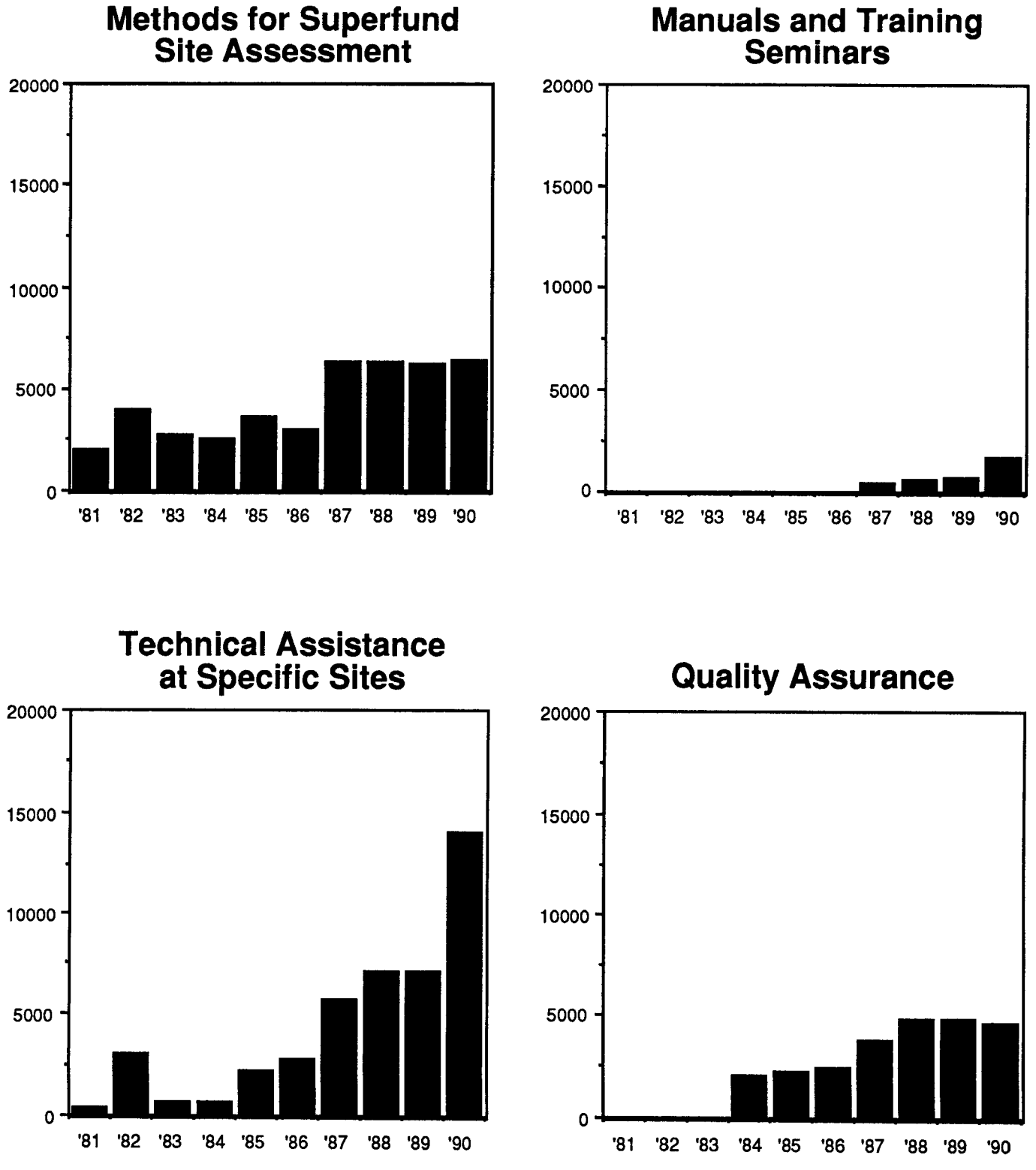


Figure 19. Continued. Annual Superfund Research Budget in thousands of dollars for 1981-1990

APPENDIX - OFFICE OF RESEARCH AND DEVELOPMENT ORGANIZATION

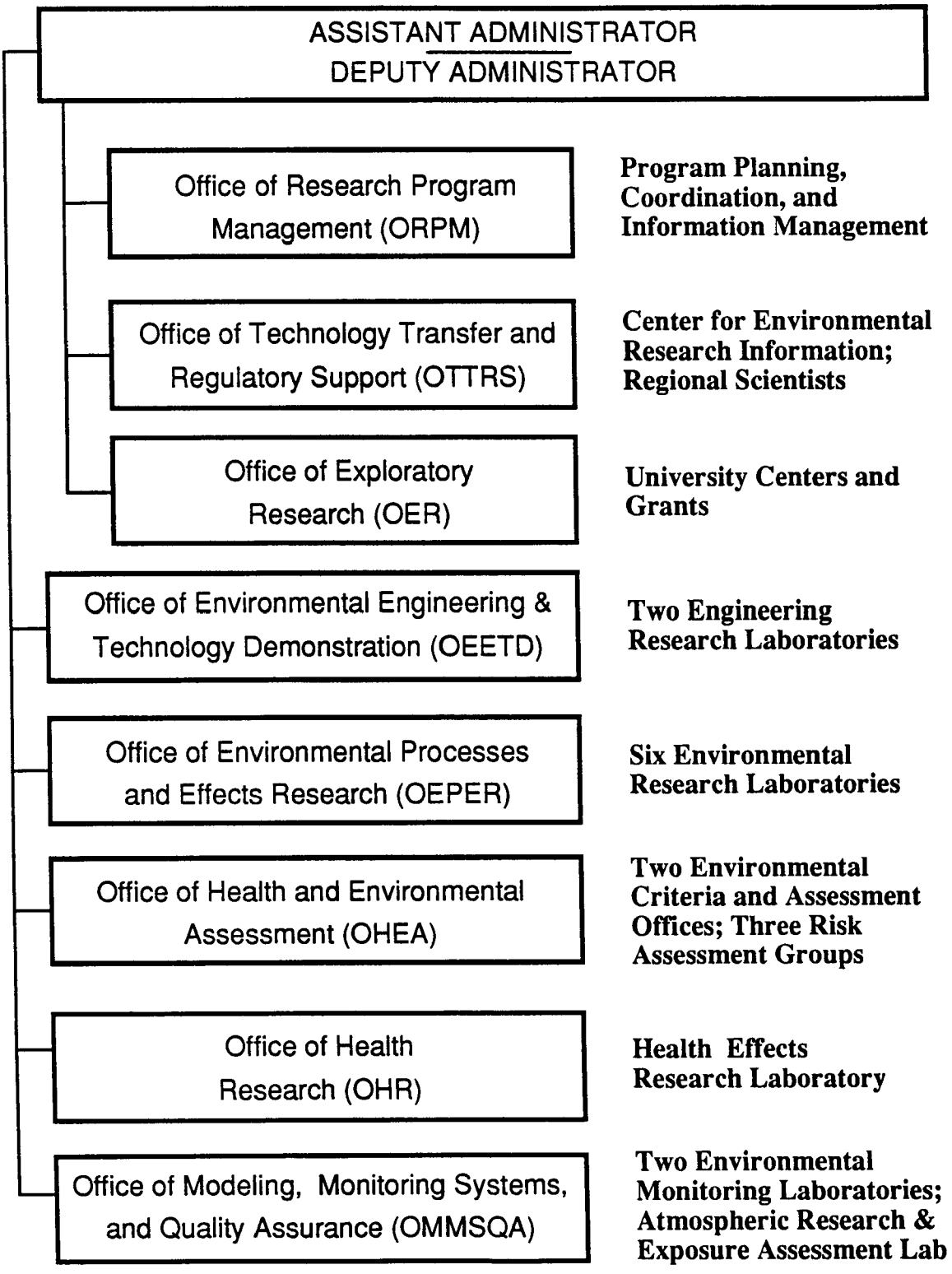


Figure 20. Office of Research and Development Organization

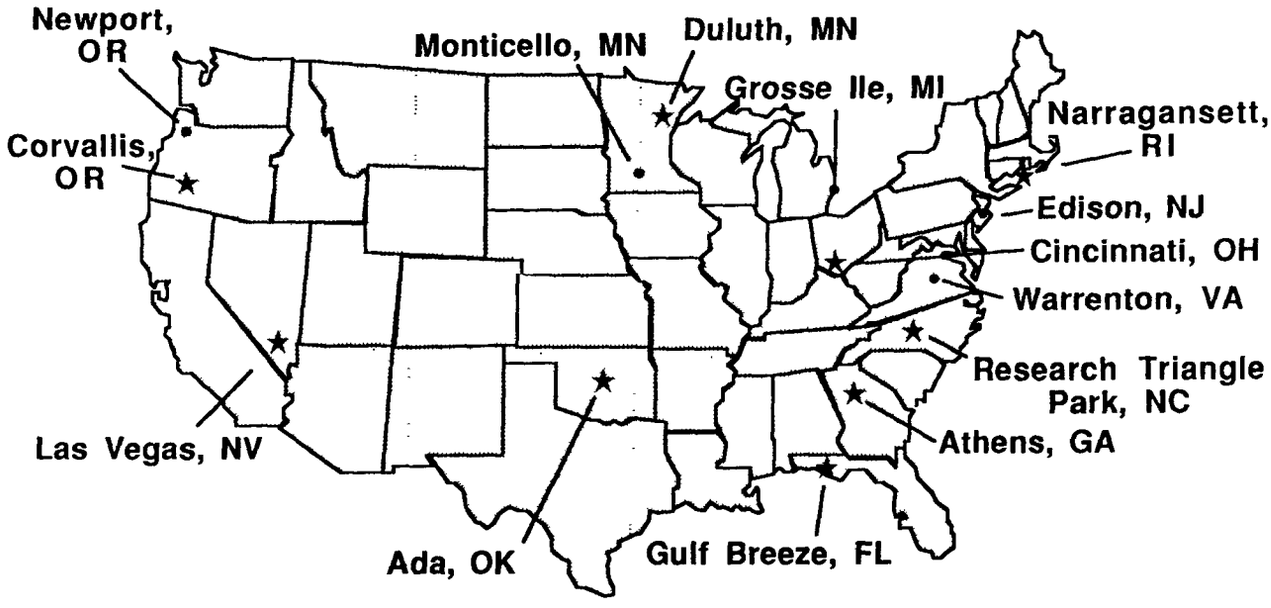


Figure 21. Location of ORD Laboratories (★) and Field Stations (•)

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