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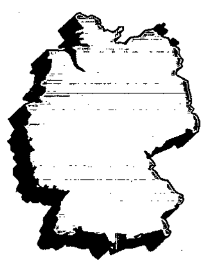
United States and German Bilateral Agreement on Remediation of Hazardous Waste Sites

Interim Status Report

U.S. Environmental Protection Agency
Office of Research and Development
USA



Bundesministerium für Forschung und Technologie
GERMANY

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Interim Status Report

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U.S. Environmental Protection Agency
Office of Research and Development
26 West Martin Luther King Drive
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USA

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Foreword

Environmental contamination is a global situation that requires more reliable, cost-effective cleanup technologies to address common waste problems. Many countries have committed extensive resources to test, develop, and implement technologies to meet complex and ever changing environmental needs. The ongoing challenge for individual countries is how to capitalize on the resources, expertise, and knowledge of other countries that are conducting similar research efforts and effectively transfer the information to those responsible for making decisions and implementing remedial actions.

This research publication is intended to transfer the technological information shared under a bilateral agreement between Germany and the United States. This publication may contribute to finding mutual international solutions for common waste problems.

Over the past 2 years, the U.S. Environmental Protection Agency (EPA) and Germany's *Bundesministerium für Forschung und Technologie* (BMFT) have been actively involved in a bilateral agreement on remediation of hazardous waste sites. This collaboration was initiated to work towards understanding each country's approach to remediating hazardous waste sites and to evaluate the effectiveness of innovative technologies being applied at selected sites within each country. Under the bilateral agreement, 12 innovative technology demonstrations will be evaluated, six in each country. Each technology will be evaluated under the political, regulatory, and social conditions of both partner countries.

The purpose of this interim status report is to describe the background of the bilateral agreement; the progress of innovative technology demonstrations in the United States and Germany; the benefits, accomplishments, and lessons learned under the agreement; and the future of the bilateral agreement.

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Executive Summary

The U.S. Environmental Protection Agency (EPA) and Germany's *Bundesministerium für Forschung und Technologie* (BMFT)[1] are involved in a collaborative effort called the U.S. and German Bilateral Agreement on Remediation of Hazardous Waste Sites. The purpose of this interim status report is to give an overall summary of, and detail the progress and achievements of the bilateral agreement. Specifically, this report will describe the background of the bilateral agreement; the progress of innovative technology demonstrations in the United States and Germany; the benefits, accomplishments, and lessons learned under the agreement; and the future plans of the bilateral agreement.

The bilateral agreement is the result of a research and development joint venture between EPA and BMFT that was established to compare innovative approaches to remediating hazardous waste sites. This comparison was accomplished by exchanging political, regulatory, technical, and business information on new hazardous waste cleanup technologies. The combination of resources of EPA and BMFT allows technologies to be evaluated by both countries and provides an international perspective to solving hazardous waste problems.

The bilateral agreement has two objectives for each partner country: (1) to gain a comprehensive understanding of the other country's approach to remediating hazardous waste sites and (2) to evaluate the effectiveness of innovative technologies being applied at these sites. To achieve these objectives, EPA and BMFT outlined the following specific goals for the bilateral agreement:

- Facilitate an understanding of each country's approach to remediating contaminated sites
- Demonstrate and evaluate innovative remedial technologies
- Compare quality assurance (QA) programs
- Facilitate technology transfer between the two countries

Under the bilateral agreement, 12 innovative technology demonstrations will be evaluated, six in each partner country. Each technology will be evaluated under the political, regulatory, and social conditions of both partner countries.

Of the six U.S. technologies, five technologies are in the EPA Superfund Innovative Technology Evaluation (SITE) Program: (1) SoilTech ATP Systems, Inc. (SoilTech), Anaerobic Thermal Processor (ATP) at the Outboard Marine Corp. site in Waukegan, Illinois; (2) Peroxidation Systems, Inc. (PSI), perox-pure™ advanced oxidation technology at Lawrence Livermore National Laboratory (LLNL) in Tracy, California; (3) Billings and Associates, Inc., Subsurface Volatilization and Ventilation System (SVVS) at the Electro-Voice site in Buchanan, Michigan; (4) Illinois Institute of Technology Research Institute (IITRI) Radio Frequency Soil Decontamination (RFSD) process at

Kelly Air Force Base in San Antonio, Texas; and (5) Western Research Institute (WRI) Contained Recovery of Oily Waste (CROW) at Pennsylvania Power and Light Broadhead Creek site in Stroudsburg, Pennsylvania. The sixth technology is a bioremediation technology that is being implemented under a removal action by EPA Region 5 at the Indiana Wood Preservers, Inc. (IWP) site in Bloomington, Indiana.

Six German remedial projects in the BMFT-Förderschwerpunkt "Modellhafte Sanierung von Altlasten"[2] (Model Remediation Program) were chosen to be demonstrated under the bilateral agreement: (1) Nordac soil washing, Umweltschutz Nord (U-Nord) bioremediation, and thermal treatment at Haynauerstrasse 58, Berlin; (2) soil washing and thermal desorption at Gaswerke München; (3) thermal treatment, soil washing, and bioremediation at Burbacher Hütte, Saarbrücken; (4) soil washing and incineration at Stadtallendorf; (5) soil vapor extraction (SVE) at Kertess, Hannover; and (6) soil washing and chemical extraction at Varta-Süd, Hannover.

Major accomplishments already achieved under the bilateral agreement include initiating or completing work on seven of the twelve innovative technology demonstrations, understanding each partner country's remedial approach and sampling and analysis procedures well enough to prepare effective demonstration plans, identifying current high-profile regulatory issues, implementing both BMFT and EPA QA programs during demonstrations, and introducing innovative technologies to the partner country. Also, both EPA and BMFT have learned to communicate with an international partner in terms of environmental site remediation and innovative technology demonstrations. During the implementation of the bilateral agreement, effective communication has been established on levels ranging from general regulatory policy to the specific technical details of chemical analyses. These accomplishments are especially meaningful given the substantial differences in laboratory practices, regulatory requirements, and implementation practices between the two countries.

In conclusion, the bilateral agreement will continue to enhance each partner country's cleanup capabilities for hazardous waste sites by sharing information on innovative remedial approaches, promoting development of innovative technologies, improving the quality of technology evaluations, and introducing technology developers to international markets. In addition, international partnering such as that under the bilateral agreement has and will continue to allow each country to learn about the partner's environmental regulations, policies, and guidelines. In the future, perhaps as a result of bilateral agreements such as this one, regulations may be standardized on an international level, further encouraging and enabling technology developers to enter international markets and support the much needed remediation of hazardous waste sites around the world.

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1 In English, BMFT is translated as the German Federal Ministry for Research and Technology.

2 In English, Förderschwerpunkt "Modellhafte Sanierung von Altlasten" is translated as Model Remediation of Representative Hazardous Waste Sites Program.

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Tables

Acronyms, Abbreviations, and Symbols

AOX	Adsorbable organic halides
ARAR	Applicable or relevant and appropriate requirements
ATP	Anaerobic Thermal Processor
bgs	Below ground surface
BMFT	*Bundesministerium für Forschung und Technologie* (German Federal Ministry for Research and Technology)
BTEX	Benzene, toluene, ethylbenzene, and xylene
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CHC	Chlorinated hydrocarbon
CROW	Contained Recovery of Oily Waste
DCA	Dichloroethane
DCE	Dichloroethene
DNAPL	Dense nonaqueous phase liquid
dscm	Dry standard cubic meter
EPA	U.S. Environmental Protection Agency
g	Gram
gpm	Gallons per minute
HF	Hydrogen fluoride
IITRI	Illinois Institute of Technology Research Institute
IWP	Indiana Wood Preservers, Inc.
kg	Kilogram
L	Liter
LLNL	Lawrence Livermore National Laboratory
Lpm	Liters per minute
m	Meter
m^2	Square meter
MCL	Maximum contaminant level
mg	Milligram
mm	Millimeter
NCP	National Oil and Hazardous Substances Contingency Plan
ng	Nanogram
NO_x	Nitrogen oxides
NPL	National Priority List
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyl
PCE	Tetrachloroethene
POC	Purgeable organic carbon
ppm	Parts per million
PRP	Potential responsible party
PSI	Peroxidation Systems, Inc.

Acronyms, Abbreviations, and Symbols (continued)

QA	Quality assurance
QAPjP	Quality assurance project plan
QC	Quality control
RCRA	Resource Conservation and Recovery Act
RFSD	Radio Frequency Soil Decontamination
ROD	Record of decision
RREL	Risk Reduction Engineering Laboratory
SACM	Superfund Accelerated Cleanup Model
SARA	Superfund Amendments and Reauthorization Act of 1986
SITE	Superfund Innovative Technology Evaluation
SO_x	Sulphur oxides
SVE	Soil vapor extraction
SVOC	Semivolatile organic compound
SVVS	Subsurface Volatilization and Ventilation System
TC	Total carbon
TCA	Trichloroethane
TCDF	Tetrachlorinated dibenzofurans
TCE	Trichloroethene
TNT	Trinitrotoluene
TOC	Total organic carbon
TOX	Total organic halides
tph	Tons per hour
TRPH	Total recoverable petroleum hydrocarbons
UBA	*Umweltbundesamt* (German Federal Environmental Agency)
UV	Ultraviolet
VOC	Volatile organic compound
WRI	Western Research Institute
μg	Microgram
μm	Micrometer

Acknowledgements

This report and the continued success of the U.S.-German bilateral agreement would not be possible without the diligent efforts of numerous individuals committed to the program. Dr. Wolfram Schött of the *Bundesministerium für Forschung und Technologie* (BMFT) and Donald Sanning of the U.S. Environmental Protection Agency (EPA) are the Bilateral Agreement Program Managers for their respective agencies. This document was prepared under the direction of Robert Olexsey, Director of the Superfund Technology Demonstration Division. Doris King of the EPA Risk Reduction Engineering Laboratory in Cincinnati, Ohio, is the Work Assignment Manager responsible for the preparation of this document. The following EPA technical project managers continue to be key contributors to this project: Paul dePercin, Eugene Harris, Ann Kern, Kim Lisa Kreiton, Norma Lewis, Dr. Ronald Lewis, and Laurel Staley. The following BMFT personnel are key contributors to the bilateral agreement: Dr. Hübenthal (BMFT), Jutta Penning [*Umweltbundesamt* (UBA)], and Hans-Joachim Schmitz (UBA).

Lisa Scola of PRC Environmental Management, Inc. (PRC), and Beate Neuenhofer and Kai Steffens of *Arbeitsgemeinschaft focon-PROBIOTEC* (focon-PROBIOTEC) are the contractor project managers responsible for the development of this document. Key PRC contributors include Carol Adams, Roger Argus, Jeanne Bartel, Eleanor Blomstrom, Gina Bergner, Ed DiDomenico, Rob Foster, Tonia Garbowski, and Mark Walsh. Key focon-PROBIOTEC contributors include Hans-Jürgen Schwefer and Dr. Peter Dreschmann.

Section 1
Introduction

Because waste management and the cleanup of contaminated sites present major problems in every industrialized nation, most countries are searching for innovative solutions to hazardous waste treatment problems. Based on a variety of national and local circumstances, differing standards and techniques have been developed and adopted in various individual countries to solve pressing environmental problems. However, environmental contamination is fast becoming an international problem requiring more than a local or national perspective. Instead, a broad international awareness and continued cooperative international programs are required to find solutions to our global environmental problems. By coordinating a joint understanding of environmental situations in different countries, the interactive transfer of technological information may contribute to finding mutual solutions to common waste problems. This report is a part of the technology transfer initiative.

This interim status report summarizes the progress of a bilateral technology transfer agreement between Germany's *Bundesministerium für Forschung und Technologie* (BMFT) and the U.S. Environmental Protection Agency (EPA). This chapter discusses the program's background, goals, and approach. Chapters 2 and 3 discuss demonstrations of hazardous waste treatment technologies in Germany and the United States. Chapter 4 summarizes the accomplishments and benefits of the bilateral activities already underway, and Chapter 5 discusses the future goals, approach, and activities of the U.S.-German bilateral agreement.

1.1 Program Background

In early 1990, the United States and Germany realized the importance of exchanging global solutions to hazardous waste problems, and initiated a research and development joint venture called the United States and German Bilateral Agreement on Remediation of Hazardous Waste Sites. The agreement was established between the two heavily industrialized countries to compare innovative technologies and explore new approaches to remediating hazardous waste sites. This is a collaborative effort between EPA and BMFT. In December 1990, BMFT met with EPA to finalize selecting the innovative technologies to treat hazardous waste at six sites in Germany and at six sites in the United States. In October 1991, EPA and BMFT exchanged detailed reports describing the site background, key individuals and responsible parties, the remedial investigations at the site, the remedial concept and working plan, and the innovative technology to be applied at the site. In October 1991, the summary reports were exchanged between the partner countries. In June 1992, BMFT conducted a technical tour of U.S. sites to correspond with implementing the first bilateral demonstration at the Outboard Marine Corporation Superfund site in Waukegan, Illinois. Since then, several bilateral demonstrations have been completed or are ongoing (see Sections 2 and 3 for further details).

Combining the technical resources of both agencies allows a technology to be evaluated by both countries, and it provides an international perspective on various approaches to solving hazardous waste problems. The bilateral agreement was created to exchange information in three main areas: (1) political, social, and regulatory circumstances that influence environmental policy and remediation decisions; (2) technical details required to adequately compare and evaluate performance and cost data on innovative technologies; and (3) business considerations in performing environmental work in a partner country. These areas are all inter-related, and an understanding of each is essential for an international environmental program such as the bilateral agreement to be effective. For example, a delay in acquiring an operating permit to conduct a technology evaluation is just as much a barrier to progress as having language differences in technical terminology between two countries. Exchanging information on typical procedural and operational practices, particularly regarding the approved methods and approach to remediating contaminated sites, is of particular interest to program participants because it allows results to be obtained more swiftly and more economically.

1.2 Program Goals and Approach

The bilateral agreement has two objectives for each partner country: (1) to gain a comprehensive understanding of the other country's approach to remediating hazardous waste sites and (2) to evaluate the effectiveness of innovative technologies being applied at these sites. To achieve these objectives, EPA and BMFT established the following specific goals for the agreement:

- Facilitate an understanding of each country's approach to remediating contaminated sites
- Demonstrate and evaluate innovative remedial technologies
- Compare quality assurance (QA) programs
- Facilitate technology transfer between the two countries

Table 1 lists the goals and approach of the bilateral agreement. In general, the approach involves sharing comparable information and analytical data from actual hazardous waste sites where innovative treatment technologies have been demonstrated. Data quality became an important enforcement issue to the EPA with the passage of U.S. Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended. Standardized data QA is now becoming a key focus of BMFT because the Agency is currently considering establishing new QA regulatory standards under a proposed Soil Protection Act. The national act would provide Germany with cleanup criteria and standard operating procedures for hazardous waste site remediation. The Soil Protection Act will most likely have similarities to EPA's CERCLA. Brief summaries of the regulatory framework for remediating sites in Germany and the United States are provided in Sections 1.3 and 1.4, respectively.

EPA and BMFT agreed that for a better understanding of each country's efforts to develop treatment technologies, selected demonstration projects should follow the regulations and guidelines of both the host and developer countries as well as the respective political, social, and technical circumstances involved in demonstrating the technology. The purpose of the bilateral agreement is to share information on actual cleanups in each country as if the demonstration had taken place in the other country. For this reason BMFT and EPA selected cleanup technologies from their respective technology evaluation programs: the BMFT Förderschwerpunkt "Modellhafte Sanierung von Altlasten" (Model Remediation Program) and the EPA Superfund Innovative Technology Evaluation (SITE) Program.

Table 1. Bilateral Agreement Goals and Approach

Goal	Approach
❖ Facilitate an understanding of each country's approach to the remediation of contaminated sites	❖ Prepare technical demonstration plans for innovative technologies ❖ Visit the partner country to review demonstration sites and their status ❖ Participate in international remediation symposia
❖ Demonstrate and evaluate innovative remedial technologies	❖ Conduct demonstrations as if they were conducted in partner country
❖ Compare QA programs	❖ Provide QA oversight of project activities
❖ Facilitate technology transfer between the two countries	❖ Observe German facilities conducting technology demonstration activities ❖ Compile and transfer information on innovative technologies ❖ Participate in innovative technology symposia

BMFT's program and the SITE Program were established to further develop state-of-the-art cleanup technologies, demonstrate new technologies, and assess their potential applicability to various hazardous waste sites. Both programs emphasize technologies that (1) restore the site to its natural state, (2) are cost-effective, and (3) minimize impacts on the environment by reducing the amount of process residuals needing further treatment or disposal.

In Germany, support for environmental research and development is central to the federal government's environmental policy. As part of its environmental research program, BMFT awards research grants in the area of environment pollution mitigation. In 1989, BMFT established the Model Remediation Program. The aim of the program is to further develop state of the art technologies, to demonstrate new cleanup technologies, and to assess their applicability to actual hazardous waste sites. BMFT's Model Remediation Program funds practical full-scale demonstrations of physical, chemical, thermal, and biological treatment techniques or combinations of these techniques at applicable hazardous waste sites.

In the United States, the SITE program was established in 1986 to objectively evaluate innovative technologies for remediation of Superfund sites and encourage the advancement of technologies to commercial use. The SITE program is managed by the EPA Risk Reduction Engineering Laboratory (RREL) in Cincinnati, Ohio. The SITE demonstration program works cooperatively with technology developers by conducting field evaluations of emerging and newly available commercial technologies, typically at a Superfund site. In conducting the field evaluation, EPA prepares test plans, conducts field sampling, oversees laboratory analysis, and documents results in published reports. The technology developer is responsible for the mobilization and demobilization of the technology and for operating the technology during the demonstration period.

Six U.S. and six German innovative technologies were selected from the two programs and designated for demonstrations under the bilateral agreement. Table 2 identifies the demonstration sites with corresponding technologies and the types of contamination to be treated. Because the technical approach to remediating hazardous waste sites is subject to different environmental and social factors in each country, the overall usefulness of a particular innovative technology can be determined only if it is evaluated in accordance with the political, social, technical, and regulatory requirements of both countries. Under the bilateral agreement, each technology evaluation is conducted as if the technology was to be used in both countries. For each demonstration, both countries identify critical analytical parameters, measurements, and regulatory restrictions that must be assessed to adequately evaluate the technology under the rules and standards of each country.

When BMFT identifies additional measurement requests not already included in the EPA SITE demonstration plan, BMFT notifies the EPA SITE Technical Project Manager. The project manager and EPA QA staff are responsible for including the additional measures in the SITE demonstration. Because data QA and comparability are important, standard analytical procedures are conducted according to EPA-approved methods and German standard methods, respectively. As such, the data will be comparable, useful, and effective in assessing technology performance and cost at sites in both countries.

When EPA identifies additional measurement requests, the requests are prepared as streamlined SITE demonstration plans. The EPA demonstration plan is prepared in addition to BMFT's sampling and analysis plan. Implementation of the EPA's quality assurance and quality control (QA/QC) measures follow EPA's regulatory guidance. Additional analytical requests are conducted according to standard EPA methods by a German analytical laboratory that was checked in a Technical System Review according to EPA's QA program. In this way, the data can be evaluated at the same level of QA/QC used for the EPA SITE program.

For each demonstration, the country-specific results for both partners will be published in final reports that include regulatory conclusions and technical results. The reports will also include a general evaluation of the approach to site remediation and a discussion of how the technology data may influence or determine future remedial actions at the demonstration site and at other potential hazardous waste sites. Documentation of the data and evaluation of the comparability of analytical methods and results will enable remediation experts to evaluate the potential future applicability of U.S. and German technologies in both countries.

Table 2. U.S. and German Remediation Projects

U.S. Sites	Technologies	Contamination Type
Outboard Marine Corp. Site Waukegan Harbor, IL	Anaerobic thermal treatment	Polychlorinated biphenyls (PCB), oil, grease
Kelly Air Force Base San Antonio, TX	Enhanced soil vacuum extraction by radio frequency heating	Volatile organic compounds (VOC), semivolatile organic compounds (SVOC), total recoverable petroleum hydrocarbons
Electro-Voice Site Buchanan, MI	Enhanced soil vacuum extraction by deep well injection	Xylene, tetrachloroethene, trichloroethene, 1,1-dichloroethene
Lawrence Livermore National Laboratory (LLNL) Tracy, CA	Advanced chemical oxidation	VOCs including trichloroethene, tetrachloroethene
Pennsylvania Power & Light, Broadhead Creek Site, Stroudsburg, PA	Contained recovery of oily waste	Organic liquids, coal tars, polynuclear aromatic hydrocarbons (PAH), phenols
Indiana Wood Preservers Site Bloomington, IN	Bioremediation	VOCs, SVOCs
German Sites	**Technologies**	**Contamination Type**
Haynauerstrasse 58, Berlin	Soil washing, bioremediation, and thermal treatment	Chlorinated hydrocarbons (CHC), monoaromatics, petroleum hydrocarbons, PCBs, polychlorinated dibenzodioxins, polychlorinated dibenzofurans
Gaswerke, München	Soil washing and thermal desorption	PAH, cyanide, lead, aliphatic hydrocarbons
Burbacher Hütte, Saarbrucken	Thermal treatment, soil washing, and bioremediation	Sulfides, cyanide, lead, mercury, phenols, hydrocarbons, monoaromatics, PAHs, ammonia
TNT Site, Stadtallendorf	Soil washing and incineration	Monoaromatics, munitions, trinitrotoluene (TNT) and degradation products, heavy metals, phenols, PAHs, cyanides
Kertess, Hanover	Soil vapor extraction	CHC and degradation products, chlorofluorocarbons, hydrocarbons, monoaromatics
Varta Süd, Hanover	Soil washing and chemical extraction	Lead, antimony, arsenic, cadmium

1.3 Background Information on the German Approach to Remediation of Sites

In the 16 federal states of the Federal Republic of Germany, a total number of 131,488 suspected hazardous waste sites are registered. The estimated number, however, is 240,473 sites that comprises approximately 80,000 sites in the new federal states and approximately 160,000 sites in the original federal states. Based on site registration and ongoing preliminary risk assessments, remedial action was identified for a smaller portion of these sites.

During the development of remedial activities in the past 10 years, various remedial technologies have been developed by German companies or licensed to domestic vendors. These cleanup technologies include thermal treatment, physical-chemical treatment (primarily soil washing and soil venting), and biological treatment. The general trend focuses on combined treatment technologies in soil treatment centers. In August 1993, approximately 45 soil treatment centers were operating in Germany. Biological soil treatment is performed in 33 centers, physical-chemical treatment is performed in 11 centers, and incineration is performed in three centers. The planning phase for 43 additional soil treatment centers is completed; the permitting processes are underway. The overall (available and planned) treatment capacity is estimated to exceed 3 million metric tons per year.

The regulatory enforcement and responsibility for the registration, evaluation, and remediation of hazardous waste sites is delegated to the federal states by the German constitution (§§ 30, 83 and 84). To ensure consistency between state-specific approaches, the Federal Conference of Ministers for the Environment has established a working committee (*Arbeitsgruppe "Altablagerungen und Altlasten" der Länderarbeitsgemeinschaft Abfall*) to define standard criteria for the registration, investigation, evaluation, and monitoring of hazardous waste sites. This working group published a report in 1990 that establishes a technical framework for the remediation process. However, the detailed rules and guidelines are different in each of the federal states. The environmental protection agencies of the federal states as well as independent expert working groups have developed rules and guidelines for the overall remediation process and have developed specific regulations covering all aspects of the remediation process. Additionally, some states have developed criteria for establishing a state-specific priority list.

A German Soil Protection Act (*Bodenschutzgesetz*) is currently being prepared. This act will provide federal, legal framework for the remediation of hazardous waste sites. This act will provide the basis for regulations and technical ordinances. The regulations will deal with cleanup criteria and standard working procedures for site investigation and risk assessment, as well as criteria for a national priorities list. QA during all phases of the remediation process will be of fundamental importance to these regulations. The Soil Protection Act will establish the responsibilities for planning and funding remedial actions and will specify overall goals that must be achieved by the remedial action.

At present, soil and water treatment plants that will be operated for more than 1 year at one site, must be permitted to the Federal Emissions-Protection Act (*Bundesimmissionsschutzgesetz, BImSchG*). This process can take several years, because detailed documentation of technical and environmental aspects of system operation is required. However, under the Federal Investment-Promotion Act, mobile treatment plants may be operated for up to 1 year at one site under a temporary permit, provided that all technical regulations (including safety, water protection, and construction of buildings) are met. For the remedial action, the party responsible for the damage is also responsible for cleanup. If, for legal or other reasons, the respective party cannot be held responsible, the federal state must finance the remediation.

As mentioned above, site investigation and remediation requirements are different in each federal state. For single steps in the remediation process, standardized procedures are established in technical DIN *(Deutsches Institut für Normung)* standards. These standards are prepared for use by experts and, therefore, allow for method variation within the standardized methods. The level of detail specified in these methods is less than that of comparable U.S. methods. Several thousands of DIN standards cover all fields of technical work and are, therefore, of substantial importance for the remediation of hazardous waste sites. QA requirements are also specified in the DIN standards. However, Germany uses a more general approach to QA and QC in site cleanup activities.

1.4 Background Information on the U.S. Approach to Remediation of Sites

CERCLA as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) provide the statutory basis for the EPA Superfund program. CERCLA was the first national legislation that addressed past hazardous waste disposal violations and SARA provided EPA with power to enforce environmental liability. Under CERCLA, the federal government is given authority and funds for the cleanup of uncontrolled hazardous waste sites and releases.

The National Oil and Hazardous Substances Contingency Plan (NCP) provides a consistent framework for implementing CERCLA and establishes EPA's response policy. The response activities are carried out in EPA's removal, remedial or enforcement programs. The removal program addresses immediate risk, the remedial program addresses longer-term risks and promotes responsible party responses, while the enforcement program solicits responsible party responses and recovers costs associated with abandoned site cleanup. These programs are described in further detail below.

Removal programs are short-term actions designed to protect the public from immediate threats to public health and welfare or the environment. This program involves removals that cost less than $2 million and are less than 1 year in duration, although these limitations can be expanded under certain circumstances. The removal process consists of the following four phases: (1) discovery and notification, (2) evaluation and planning, (3) removal operations, and (4) project close-out. EPA is responsible for determining the urgency of a removal action and funding the removal activities. State governments do not share the cost of removals unless the property is specifically owned by the state.

Most CERCLA sites are cleaned up under a remedial program that is conducted by the federal or state government, or by a responsible party that has made a commitment or settlement to clean up a site, or that has been compelled to do so by a court order. The remedial process includes discovering a potential waste site, conducting a preliminary assessment and visual site inspection, and determining if the site qualifies for EPA's National Priorities List (NPL). The NPL is a ranking of EPA's priority hazardous waste sites. Once on the NPL, a remedial investigation is conducted to collect data and to characterize the waste streams. A feasibility study is performed to develop specific alternatives for the remedy. Remedy selection is based on the following nine criteria: (1) overall protection of human health and the environment; (2) compliance with applicable or relevant and appropriate requirements (ARAR) including federal or sometimes more stringent state environmental laws; (3) long-term effectiveness and permanence; (4) reduction of toxicity, mobility, and volume through treatment; (5) short-term effectiveness; (6) implementability; (7) cost; (8) state acceptance; and (9) community acceptance. The selected remedy and rationale are documented in EPA's Record of Decision (ROD). Finally, the remedial approach is designed and implemented in the remedial design and remedial action phases. When all cleanup requirements are met, the site is delisted from the NPL.

The enforcement program compels those responsible for an environmental release to pay for or conduct the response to the release, or both. All responsible party (RP) cleanups are overseen by EPA. Enforcement actions consist of issuing direct administrative orders, negotiating out of court settlements, or litigating in court to compel RPs to conduct cleanup activities. If the RPs cannot be identified quickly enough or do not settle, EPA can proceed with a response action and later reclaim up to three times the cleanup cost through a cost recovery action. The enforcement program works in conjunction with the removal and remedial programs to meet emergency responses and site cleanup goals for the Superfund program.

QA/QC is an essential part of the entire process within the Superfund program. Strict quality assurance requirements ensure that sampling procedures and analysis data are verifiable and legally defensible. For example, detailed QA project plans (QAPjP) are prepared prior to project startup and rigorously followed during project implementation. EPA's QA consists of four categories. Category I requires the most stringent quality assurance plan because the data must be legally and scientifically defensible. Category II is used to compare data sets with other similar projects and is used to generate data for regulatory or policy decisions. Category III is used to perform feasibility studies or preliminary assessments and Category IV is used to assess suppositions between data sets.

Section 2
Progress of U.S. Demonstration Activities

Of the six U.S. technologies, five are being evaluated under the EPA SITE program: (1) SoilTech ATP, Inc., Anaerobic Thermal Processor (ATP); (2) Peroxidation Systems, Inc. (PSI), perox-pure™ advanced oxidation technology; (3) Billings and Associates, Inc., Subsurface Volatilization and Ventilation System (SVVS); (4) Illinois Institute of Technology Research Institute (IITRI) Radio Frequency Soil Decontamination (RFSD), and (5) Western Research Institute (WRI) Contained Recovery of Oily Waste (CROW). The sixth technology is a bioremediation removal action being implemented by EPA Region 5.

This chapter discusses each of the six U.S. technologies being evaluated under the bilateral agreement. For each technology, the subsections below provide a process description, demonstration objectives and approach, and progress to date and future activities. Appendix A lists appropriate contact names and addresses for each technology.

2.1 Soiltech ATP Systems, Inc.—Anaerobic Thermal Processor

The ATP technology, developed and licensed by SoilTech, thermally desorbs organics such as polychlorinated biphenyls (PCB) from soils, sludges, and liquids. The thermal separation ATP system was used to remove PCBs from contaminated soils and sediment at the Outboard Marine Corporation (OMC) Superfund site in Waukegan, Illinois. EPA conducted the technology demonstration in June 1992 during full-scale remediation of the site.

2.1.1 Process Description

The ATP processor consists of two rotating drums with four internal thermal zones: the preheat, retort, combustion, and cooling zones. The unit is designed to operate at temperatures of 400 to 1,000 °F (200 to 540 °C) in the preheat zone; 900 to 1,300 °F (480 to 700 °C) in the retort zone; 1,200 to 1,450 °F (650 to 790 °C) in the combustion zone; and 500 to 800 °F (260 to 430 °C) in the cooling zone.

Contaminated soil first enters the preheat zone where water and volatile organic compounds (VOC) are vaporized. Hot, granular solids exiting the preheat zone pass through a sand seal and enter the retort zone. The higher temperatures in the retort zone cause (1) vaporization of heavy oils and (2) thermal cracking of hydrocarbons, which forms coke and low molecular weight gases. The coked solids then pass through a second sand seal into the combustion zone. Solids are then either recycled to the retort zone to provide heat, or sent to the cooling zone located in a space between the two rotating drums. Treated soils exiting the cooling zone are quenched with scrubber water and are then transported by conveyor to storage and final disposition.

Water vapor, vaporized contaminants, low molecular weight gases, and a small amount of particulates are removed by vacuum from the preheat and retort zones of the processor. Removed water vapor and vaporized contaminants are then condensed in a direct-contact cooling system that separates the organic and water phases. Recovered water is sent to an on-site treatment system, and the condensed organic phase is stored for off-site disposal. Light organic vapors that are not condensed are fed by a blower directly into the combustion zone of the processor. Flue gas from the combustion zone is first treated in a cyclone and baghouse to remove particulates and then in a carbon adsorption system to remove trace organics prior to discharge to the atmosphere.

2.1.2 Demonstration Objectives and Approach

For the SITE program, EPA identified four technology demonstration objectives and the approach to achieving each objective for the SoilTech ATP:

- To assess the technology's ability to remove PCBs from soil and sediment at the OMC Superfund site, EPA collected samples entering and exiting the processor. The evaluation of these samples determined the system's treatment efficiency and ability to meet site-specific cleanup levels. EPA also collected stack gas samples to determine the ATP's destruction and removal efficiency.

- To determine whether PCBs are transformed to dioxins or furans at the elevated temperatures within the system, EPA collected solid, liquid, oil, and stack gas samples from various internal process streams and discharge streams.

- To document the operating conditions of the SoilTech ATP during the demonstration, several key operating parameters were recorded, including process temperatures and soil feed rate. These data provided a better understanding of the effect of these parameters on the contaminant concentration in treated soil.

- To develop capital and operating costs for the ATP technology that can be readily used in the Superfund decision-making process, EPA obtained capital and operating cost data from this demonstration and from previous bench-, pilot-, and full-scale demonstrations conducted by SoilTech.

For the bilateral agreement, BMFT requested the following additional measurements:

- To determine the system's ability to comply with German regulations and performance standards regarding contaminant concentrations in pretreatment and posttreatment soil, EPA performed additional sampling based on BMFT's request.

- To determine if the air emissions could meet German air quality standards, EPA collected additional samples for metals in the flue gas fines and for particulate metals, sulphur oxides (SO_X), nitrogen oxides (NO_X), and hydrogen fluoride (HF) in stack gases.

2.1.3 Progress To Date and Future Activities

The SoilTech ATP technology was demonstrated in June 1992. During the SITE demonstration, approximately 253 tons (230 metric tons) of PCB-contaminated soils and sediments were treated during four test runs. The ATP was run under two operating conditions. Three replicate 8-hour test runs were first conducted under the operating conditions used to remediate the site. After the third replicate test run, SoilTech discontinued the addition of sodium bicarbonate to the ATP system; the sodium bicarbonate had been added to reduce PCB emissions from the stack. A fourth 4-hour test run was then conducted.

Tentative findings of the ATP SITE demonstration are presented below. BMFT is currently assessing the results from additional measurements:

- PCB concentrations were reduced from an average of 9,761 parts per million (ppm) in contaminated soil and sediment to an average of 2 ppm in treated solids.

- About 0.117 milligrams (mg) of PCBs was discharged from the ATP system's stack per kilogram (kg) of PCBs fed to the ATP. This PCB concentration in stack gas corresponds to a removal efficiency of greater than 99.99 percent.

- Most PCBs removed from the contaminated soil and sediment were accumulated in vapor scrubber oils.

- No polychlorinated dibenzodioxins were detected in the stack gas from the ATP. Tetrachlorinated dibenzofurans (TCDF) were found in contaminated soil and sediment at 88 nanograms per gram (ng/g), in treated solids at 6 ng/g, and in stack gas at 0.08 nanograms per dry standard cubic meter (dscm).

- No significant differences in PCB removal efficiency or formation of thermal transformation by-products can be attributed to the addition of sodium bicarbonate to the ATP system's combustion zone.

- Levels of leachable VOCs, semivolatile organic compounds (SVOC), and metals in treated solids were below Resource Conservation and Recovery Act (RCRA) toxicity characteristic standards.

- The stack gas contained low levels of particulate metals, SO_x, NO_x, and HF.

- No operational problems affecting the ATP's ability to treat contaminated soil and sediment were observed.

- For the OMC Superfund site, soil treatment costs were approximately $155 per ton. The regulatory support, mobilization, startup, and demobilization costs for SoilTech's 10-ton-per-hour (tph) unit totalled about $1,400,000 for the OMC site.

The draft SITE program *Technology Evaluation Report* was issued in Fall 1993, and the final SITE program *Applications Analysis Report* is anticipated to be published in Winter 1993. The results of the demonstration have been provided to BMFT for comparison to German regulations and performance standards and will be documented in a final report. Appendix A lists contact personnel for the ATP technology at EPA and at SoilTech.

2.2 Peroxidation Systems, Inc.—perox-pure™ Advanced Oxidation Technology

The perox-pure™ advanced oxidation technology, developed by PSI of Tucson, Arizona, was demonstrated under the EPA SITE program at Lawrence Livermore National Laboratory (LLNL), Site 300, in Tracy, California, over a 3-week period in September 1992. Principal groundwater contaminants at Site 300 include trichloroethene (TCE) and tetrachloroethene (PCE), which were present at concentrations of approximately 1,000 and 100 micrograms per liter (µg/L), respectively.

2.2.1 Process Description

The perox-pure™ advanced oxidation technology is designed to destroy dissolved organic contaminants in water. The technology uses ultraviolet (UV) radiation and hydrogen peroxide to oxidize organic compounds present in water at parts per million levels or less. According to the developer, this treatment technology produces no air emissions and generates no sludge or spent media that require further processing, handling, or disposal. Ideally, end products include only water, carbon dioxide, halides (for example, chloride), and in some cases, organic acids. The technology uses medium-pressure, mercury-vapor lamps to generate UV radiation. The principal oxidants in the system, hydroxyl radicals, are produced by direct photolysis of hydrogen peroxide at UV wavelengths.

The perox-pure™ advanced oxidation treatment system (Model SSB-30) used for the SITE technology demonstration was assembled from the following portable, skid-mounted components: an advanced oxidation unit, a hydrogen peroxide feed module, an acid feed module, a base feed module, a UV lamp drive, and a control panel. The advanced oxidation unit consists of six reactors in series with one 5-kilowatt UV lamp located in each reactor; the unit has a total volume of 15 gallons (57 liters). The UV lamp is mounted inside a UV-transmissive quartz tube in the center of each reactor so that water flows through the space between the reactor walls and the quartz tube. Circular wipers mounted on the quartz tubes periodically remove any solids that have accumulated on the tubes. The buildup of such solids impairs UV transmission.

2.2.2 Demonstration Objectives and Approach

For the SITE program, EPA identified the following primary objectives and approaches for the SITE technology demonstration:

- To determine the ability of the perox-pure™ system to remove VOCs from groundwater at the LLNL site under different operating conditions, EPA performed 14 test runs and calculated removal efficiencies for VOCs under different operating conditions.

- To determine whether treated groundwater met applicable disposal requirements at the 95 percent confidence level, EPA calculated 95 percent upper confidence limits for effluent VOC concentrations and compared them with California drinking water action levels and federal maximum contaminant levels.

- To gather information necessary to estimate treatment costs, including process chemical dosages and utility requirements, EPA documented capital, operation, and maintenance costs using a 12-category cost model.

For the bilateral agreement, BMFT requested the following additional measures:

- Monitor the discharge of wastewater to the municipal sewer
- Analyze the total organic halides (TOX) and adsorbable organic halides (AOX) in treated water
- Collect and analyze samples of influent to Reactor 1 and treatment system effluent for acute toxicity to freshwater organisms
- Collect and analyze hydrogen peroxide, acid, and base solutions to verify concentrations.

Groundwater from a shallow aquifer at the LLNL site was selected as the waste stream for evaluating the perox-pure™ advanced oxidation system. About 40,000 gallons (150,000 liters) of groundwater contaminated with VOCs was treated during the demonstration. Groundwater was pumped from two wells into a 7,500-gallon (28,000-liter) bladder tank to minimize variability in influent characteristics and loss of volatiles. In addition, cartridge filters were used to remove suspended solids greater than 3 micrometers (μm) in size from the groundwater before it entered the tank.

2.2.3 Progress to Date and Future Activities

The technology demonstration was conducted in three phases. Phase 1 consisted of eight runs of raw groundwater, Phase 2 consisted of four runs of spiked groundwater, and Phase 3 consisted of two runs of spiked groundwater to evaluate the effectiveness of quartz tube cleaning. These phases are described below.

During Phase 1, principal operating parameters for the perox-pure™ system, such as hydrogen peroxide dose, influent pH, and flow rate (which determines the hydraulic retention time), were varied to observe treatment system performance under different operating conditions. Preferred operating conditions (those under which effluent VOC concentrations would be reduced to below target levels for spiked groundwater used in Phases 2 and 3) were then determined for the system.

Phase 2 involved spiked groundwater and reproducibility tests. Groundwater was spiked with about 200 to 300 μg/L each of chloroform; 1,1-dichloroethane (DCA); and 1,1,1-trichloroethane (TCA). These compounds were chosen because they are difficult to oxidize and because they were not present in the groundwater at high concentrations. This phase was also designed to evaluate the reproducibility of treatment system performance at the preferred operating conditions determined in Phase 1.

During Phase 3, the effectiveness of the quartz tube wipers was evaluated during two runs using spiked groundwater. One run used quartz tubes scaled with solids, and one used cleaned quartz tubes.

During the demonstration, samples were collected at several locations, including treatment system influent; effluent from Reactors 1, 2, and 3; and treatment system effluent. Samples were analyzed for VOCs, SVOCs, total organic carbon (TOC), total carbon (TC), purgeable organic carbon (POC), TOX, AOX, metals, pH, alkalinity, turbidity, temperature, specific conductance, hydrogen peroxide residual concentrations, and hardness.

A summary of key U.S. findings of the technology demonstration are listed below. BMFT is currently assessing the results.

- For the spiked groundwater, PSI determined the following preferred operating conditions: (1) influent hydrogen peroxide level of 40 mg/L; (2) hydrogen peroxide level of 25 mg/L in the influent to Reactors 2 through 6; (3) an influent pH of 5.0; and (4) a flow rate of 10 gallons per minute (gpm) or 38 liters per minute (Lpm). At these conditions, effluent TCE, PCE, and DCA levels were generally below detection limit (5 μg/L), and effluent chloroform and TCA levels ranged from 15 to 30 μg/L. The average removal efficiencies for TCE, PCE, chloroform, DCA, and TCA were about 99.7, 97.1, 93.1, 98.3, and 81.8 percent, respectively.
- For unspiked groundwater, effluent TCE and PCE levels were generally below the detection limit (1 μg/L), with corresponding removal efficiencies of about 99.9 and 99.7 percent. Effluent TCA levels ranged from 1.4 to 6.7 μg/L, with corresponding removal efficiencies ranging from 35 to 84 percent.

- The perox-pure™ system effluent met State of California drinking water action levels and federal drinking water maximum contaminant levels (MCL) for TCE, PCE, chloroform, DCA, and TCA at the 95 percent confidence level.

- The quartz tube wipers were effective in keeping the tubes clean, and they appeared to reduce the adverse effect scaling has on contaminant removal efficiencies.

- Economic data indicate that groundwater remediation costs for a 50-gpm (190-Lpm) perox-pure™ system could range from about $7 to $11 per 1,000 gallons (or 3,800 liters) of liquid treated, depending on contaminated groundwater characteristics. Treatment costs directly related to the perox-pure™ system could account for about $3 to $5 per 1,000 gallons (or 3,800 liters) of the remediation costs.

- Bioassay tests showed that the perox-pure™ system effluent was acutely toxic to freshwater organisms, even though the influent was not toxic. Comparison of effluent toxicity data with that of hydrogen peroxide residual concentrations in the effluent (10.5 mg/L) indicated that the effluent toxicity may be due to hydrogen peroxide residual rather than perox-pure™ treatment by-products. Additional studies are needed to draw any conclusion regarding effluent toxicity.

- TOX removal efficiencies ranged from 93 to 99 percent. AOX removal efficiencies ranged from 95 to 99 percent.

- During reproducibility runs for spiked groundwater, the system achieved average removal efficiencies of 38 percent and about 93 percent for TOC and POC, respectively.

- The temperature of groundwater increased at a rate of 12 °F (6.3 °C) per minute of UV exposure in the perox-pure™ system. Because the oxidation unit is exposed to the surrounding environment, the temperature increase may vary depending on the ambient temperature or other atmospheric conditions.

The *Applications Analysis Report*, the *Technology Evaluation Report*, and the *Technology Demonstration Summary* were available by October 1993. The results of the demonstration have been provided to the BMFT for comparison to German regulations and performance standards and will be published in a final report. Appendix A lists contact personnel for the perox-pure™ technology at EPA and at PSI.

2.3 Billings and Associates, Inc.—Subsurface Volatilization and Ventilation System

The SVVS technology was developed by Billings and Associates, Inc., of Albuquerque, New Mexico. It is operated by Billings and under license to Brown & Root Environmental, Inc. The demonstration site is located in Buchanan, Michigan, on the property of Electro-Voice, Inc., a manufacturer of electronic audio equipment. Previous painting facilities at the site discharged solvent wastes into a dry well, consisting of a bed of gravel and other porous material covered with soil. This waste disposal practice was halted many years ago, but the paint and solvent wastes remain in the subsurface soils and groundwater. PCE; TCE; dichloroethene (DCE); and benzene, toluene, ethylbenzene, and xylenes (BTEX) are the main contaminants of concern in the glacial till soil and groundwater.

2.3.1 Process Description

The SVVS technology consists of multiple drilled wells that either inject into or withdraw air from the subsurface soils and groundwater. Air is injected into the groundwater to use the aquifer as a sparging system for distributing injected air. Injection and withdrawal rates are about one to two orders of magnitude less than rates for similar soil vacuum extraction systems. The purpose of SVVS is to oxygenate contaminated soil to achieve in situ bioremediation. Because some vacuum extraction necessarily occurs, on-surface bioremediation units are placed on withdrawal lines to eliminate air contamination. The SVVS technology can be used in combination with injected nutrients to speed remediation, and bioaugmentation with natural, indigenous bacterial populations is frequently included as part of the SVVS treatment. Drilled wells backfilled with a porous sand, known as "sand chimneys," may also be installed to facilitate pneumatic activity in the subsurface.

2.3.2 Demonstration Objectives and Approach

The primary objective of the EPA SITE demonstration was to evaluate the developer's claim that the SVVS technology achieved a 30 percent reduction in select VOCs in the vadose zone over a 12-month period. To accomplish this objective, total concentrations of the select VOCs in the matrix will be compared before system startup and after 12 months of operation.

For the bilateral agreement, BMFT requested that the demonstration determine if degradation of contaminants generates dead-end products with higher toxicity than the initial contaminants. This will be accomplished by measuring the concentrations of potential toxic degradation byproducts, such as vinyl chloride, both before and after treatment to prove that treatment does not increase concentrations of these byproducts.

2.3.3 Progress To Date and Future Activities

The SVVS technology was installed during fall and winter 1992; the demonstration officially started in mid-March 1993. The full site cleanup is expected to require approximately 5 years. Because the long time needed for complete treatment was not practical for the SITE demonstration, a 1-year demonstration period was agreed upon to evaluate the technology developer's claim that the SVVS can reduce total contamination by 30 percent. Approximately 120 subsurface soil samples were collected to determine initial contaminant and background concentrations at the site. Throughout the 12-month demonstration, the withdrawal air stream will be monitored for oxygen, carbon dioxide, and contaminant levels, and groundwater will be monitored regularly.

An in situ respirometry or "shut down" test was conducted just before initiating the 12-month evaluation period; an additional shut down test will be conducted again at the end of the period to estimate the level of biological activity in the subsurface. Just before the test, the soils had been fully oxygenated and bacterial populations were thought to be fully established. Three background wells located away from the contaminated area were also injected with air to oxygenate the soil. The test wells and background wells were then shut down, and oxygen and carbon dioxide levels were monitored for 48 hours.

In wells where bioremediation was occurring, oxygen levels dropped and carbon dioxide levels increased rapidly. However, bioremediation appears to be limited at some site locations due to lack of carbon substrate. At these locations, oxygen and carbon dioxide levels did not change significantly. Evidence of high levels of biological activity in SVVS wells with corresponding low levels of biological activity in background wells will help support the claim that in situ bioremediation of the contaminants is occurring.

Soil samples were collected before beginning the project in March 1993. However, due to time limitations, no useful vinyl chloride data was generated using the requested German analytical method. Nevertheless, both EPA and BMFT gained a more thorough and useful understanding of the differences between U.S. and German sampling and analytical techniques. Data for VOCs, including vinyl chloride, will be available from the U.S. analytical methods implemented. The experience gained through this demonstration effort may allow similar situations to be streamlined in the future to provide complete comparable analyses for both partners.

The SVVS will continue to operate throughout the 12-month period, and will be evaluated in March 1994 to determine whether or not the 30 percent contaminant removal goal was met. Periodic monitoring of groundwater and withdrawal air may indicate if progress slows or increases before final sampling to be conducted in 1994.

Appendix A lists contact personnel for the SVVS technology at EPA and at Billings.

2.4 Illinois Institute of Technology Research Institute—Radio Frequency Heating

The IITRI and Haliburton NUS developed the Radio Frequency Soil Decontamination (RFSD) technology, an enhanced SVE method that uses electromagnetic radiation to heat soil in situ. RFSD treatment enhances the recovery of VOCs and SVOCs from the vadose zone. The RFSD technology is currently being demonstrated at Kelly Air Force Base in San Antonio, Texas. Approximately 188 cubic yards (140 cubic meters) of contaminated soil was treated over a period of 10 weeks. The principal contaminants of concern include toluene, chlorobenzene, ethylbenzene, tetrachloroethane, and various phenolic compounds and polycyclic aromatic hydrocarbons (PAH). Other contaminants present include PCBs and total recoverable petroleum hydrocarbons (TRPH).

2.4.1 Process Description

The RFSD technology consists of a radio frequency power source and an electrode array. The electrode array contains a row of exciter electrodes within two rows of grounded electrodes. Electromagnetic energy generated at 6.78 megahertz slowly heats the soil to 302 °F (150 °C). Heated soil vapors are extracted from the treatment area and decontaminated through the use of condensation, refrigeration, and gas and liquid separation. Treated soil gas is then passed through a flare prior to discharge to the atmosphere, combusting any noncondensable VOCs that remain. To prevent the entrainment of ambient air into the soil gas extraction system and to minimize fugitive emissions, a vapor barrier is used to cover the treatment area.

2.4.2 Demonstration Objectives and Approach

The primary objective of the EPA SITE demonstration is to evaluate whether the RFSD technology can achieve 90 percent removal for SVOCs and TRPHs and 95 percent removal for VOCs. Analytical data obtained from soil samples taken before and after treatment will be used to determine whether the anticipated removal efficiencies were achieved.

Secondary objectives for the demonstration will include (1) measuring the degree of removal for other soil contaminants and (2) determining whether the contaminants within the treatment zone are migrating laterally into zones outside of the treatment area.

For the bilateral agreement, BMFT requested additional measurements to determine the removal efficiency for selected VOCs and SVOCs. VOC and SVOC removal rates are critical parameters for BMFT. With the exception of analyses for TRPH, U.S. analytical methods will be used to determine BMFT's critical parameters. For TRPH, six pretreatment and six posttreatment samples will be analyzed using the German analytical method for TRPH. Analyses requested by BMFT are being performed in parallel to the EPA-approved analyses to determine the TRPH removal efficiency and to assess the similarities and differences of the U.S. and German methods.

2.4.3 Progress To Date and Future Activities

Pretest soil sampling was completed in early April 1993. In situ soil heating and concurrent extraction of soil vapors was initiated soon after sampling and was completed in June 1993.

Posttest sampling is scheduled to begin as soon as the soil cools to 122 °F (50 °C); this final sampling involves drilling additional boreholes in the test area to collect subsurface soil samples. Information will also be gathered regarding energy consumption and other operational parameters so that a cost estimate for the RFSD technology can be developed.

Appendix A lists contact personnel for the RFSD technology at EPA and at IITRI.

2.5 Western Research Institute—Contained Recovery of Oily Waste

The CROW process will be demonstrated at the Pennsylvania Power and Light manufactured gas site at the Broadhead Creek Superfund site in Stroudsburg, Pennsylvania. The horizontal and vertical extent of coal-tar contamination has been assessed during a remedial investigation and a predesign investigation. A discrete phase of coal tar that is heavier than water was detected in on-site monitoring wells; this coal-tar phase is the target waste for the CROW process demonstration. Site conditions that may impact the CROW process demonstration include the presence of cobbles and boulders in the aquifer matrix as well as the presence of discrete phases of organic liquids that are lighter than water.

2.5.1 Process Description

The CROW process developed by WRI uses (1) a series of injection and recovery wells and (2) hot water and steam to reduce the concentration of oily wastes in subsurface soils and underlying bedrock. The wells sweep the oily waste accumulation with hot water. Low quality steam is injected below the deepest level of contamination with organic liquids. After the steam condenses, rising hot water dislodges and sweeps buoyant organic liquids upward into more permeable regions. Hot water is injected above impermeable barriers to heat and mobilize the main accumulations of oily wastes. Heating the oily wastes reduces both the density and viscosity of the organic liquid phase. Mobilized oily wastes can then be recovered by hot-water displacement.

After organic liquids are mobilized, hot-water injection and product recovery rates are controlled to sweep accumulated oily wastes to the recovery wells. Oily wastes are contained vertically by controlling temperatures during the hot-water displacement. Downward penetration of oily wastes is reversed by thermal expansion of the organic liquids to a density that is less then the surrounding hot water. Flotation of the heated organic liquid phase is limited by injecting cooler water above oily waste accumulations. When the organic liquid phase contacts the cooler water, it contracts and becomes denser than the surrounding water. Two factors maintain cooler water temperatures above the oily waste accumulation: (1) operating the displacement process in the laminar flow regime and (2) natural conductive heat loss to the ground surface.

2.5.2 Demonstration Objectives and Approach

The EPA SITE demonstration will evaluate the technology's ability to meet the site cleanup goal set in the Record of Decision (ROD). The ROD mandates a 60 to 70 percent reduction in the coal tar concentration, which is currently 100 percent pore volume saturation. The CROW process demonstration will attempt to remediate a 150- by 200-foot (45- by 60-meter) area until the required cleanup levels are achieved. The SITE demonstration will be used to evaluate the following:

- Removal efficiency for dense nonaqueous phase liquids (DNAPL)
- Potential for contaminant migration
- Integrity of the cold water cap
- Rate of contaminant recovery

EPA will prepare a SITE Program QAPjP that will specify project objectives and describe sampling, analysis, and QA/QC requirements for the demonstration. After review of the QAPjP, the BMFT may request additional measurements that may include sampling, analysis, and QA/QC activities required to evaluate the CROW technology under German regulations.

2.5.3 Progress To Date and Future Activities

The demonstration has been delayed to complete additional site investigation activities. A draft system design plan will be submitted to EPA Region 3 by December 1993. The demonstration is tentatively scheduled to begin in February 1994.

Appendix A lists contact personnel for the CROW technology at EPA and at WRI.

2.6 EPA Region 5—Bioremediation Removal Action

EPA Region 5 is currently conducting a bioremediation removal action at the Indiana Wood Preservers, Inc. (IWP), site in Bloomington, Indiana. From 1976 to 1987, IWP operated as a wood-treating facility. A solution of creosote and coal tar was used to preserve railroad ties. Process residues were collected in a transfer pit and discharged into either the on-site creek or one of two holding ponds. Sludges from the transfer pit were removed and deposited in a waste pile on site. Contaminated sawdust was also disposed of in the pile. Principal contaminants of concern at the site include PAHs and phenols.

2.6.1 Process Description

The bioremediation technology is designed to biodegrade chlorinated and nonchlorinated organic contaminants. The technology employs aerobic bacteria that use the contaminants as their carbon source. Microbiological activity in soil treatment biopiles will be monitored to verify that the colonies are forming units and that the proper levels of heterotrophs, ammonia, phosphate, and moisture are present.

2.6.2 Demonstration Objectives and Approach

The objective of this EPA Region 5 emergency removal action was to reduce PAH and phenol contamination to below applicable regulatory limits. The monitoring plan at the IWP site includes assessing physical, chemical, and biological parameters, and it requires daily, weekly, and monthly sampling and analysis. After baseline tests are conducted, the monitoring will include daily checks of physical characteristics such as moisture content, temperature, and percent oxygen. Weekly monitoring will include determining chemical parameters (such as nitrogen and phosphate levels), as well as additional physical parameters (such as moisture content at the core of the soil treatment biopile). Monthly monitoring will include determining ash content, PAH and nitrogen levels, and microbiological activity.

BMFT requested additional information and monitoring so that the demonstration would comply with German regulations and laws. The objective of the additional monitoring program is to identify the source of contaminant reduction, that is, whether degradation or volatilization dominate. This will be determined by evaluating the degradation of PAHs and phenols in contaminated soil; monitoring the microbiological activity in contaminated soil; determining the concentration of extractable organic halides, petroleum hydrocarbons, BTEX, and heavy metals in the soil; and monitoring process water, air, and meteorological parameters that might influence contaminant degradation or emissions.

2.6.3 Progress To Date and Future Activities

The soil treatment biopiles are constructed and the long-term monitoring of the biopiles is nearing completion. Because the removal action is almost complete, project plans for further testing of the bioremediation technology are not entirely feasible. At the completion of the removal action, the soil treatment biopiles will be dismantled and spread across a designated area. Because of the short time frame and the nature of an emergency removal, implementing the additional monitoring measurements requested by BMFT was not possible.

No further action has been planned at the site under the bilateral agreement. EPA is actively locating another site that will allow an evaluation of another bioremediation technology incorporating the German request for additional measures.

Appendix A lists the EPA contact person for the bioremediation technology.

Section 3
Progress of German Demonstration Activities

Under the bilateral agreement, BMFT selected six German sites under its Model Remediation Program for the demonstration of innovative technologies: (1) Haynauerstrasse 58, Berlin; (2) Gaswerke München; (3) Burbacher Hütte, Saarbrücken; (4) Stadtallendorf site; (5) Kertess, Hannover; and (6) Varta-Süd, Hannover. The BMFT-headed Model Remediation Program focuses on the remedial approach to a given site and therefore, the following site descriptions will discuss the potential application for one or more innovative technologies at the site. Reports have been prepared for all six sites to inform EPA of each project's background and status. Project summaries for each site are presented below. Appendix A lists appropriate contact names and addresses for each technology demonstration.

3.1 Haynauerstrasse 58, Berlin

The 3,100-square-meter (m^2) Haynauerstrasse 58 site is located in the southern part of Berlin. A spent chemical, solvents, and waste oil recycling facility previously operated at the site. As a result of chemical storage and processing practices between 1952 and 1986, site soil and groundwater are contaminated with a variety of organic contaminants. Primary contaminants of concern include chlorinated hydrocarbons (CHC), aromatic hydrocarbons, petroleum hydrocarbons, and PCBs. In addition, the debris from abandoned site buildings had been contaminated with dioxins and furans.

The remediation concept for the Haynauerstrasse site includes the following treatment technologies:

- SVE at a depth of 7 to 12 meters (m) (23.1 to 39 feet) below ground surface (bgs)
- Soil excavation to a depth of 7 m (23.1 feet) bgs (approximately 42,000 metric tons or 46,300 tons) and backfilling with clean soil
- Off-site treatment of contaminated soil by microbiological degradation and soil washing
- Off-site rotary kiln treatment of dioxin- and furan-contaminated debris
- Pump-and-treat groundwater remediation

A SVE system was put in operation at the site in 1990. The first of three excavation phases was conducted from fall 1991 to August 1992. About 9,500 metric tons (10,500 tons) of soil were excavated and replaced with clean soil; approximately 6,700 metric tons (7,400 tons) of excavated soil were treated by soil washing, and 1,600 metric tons (1,750 tons) were treated microbiologically. The second excavation phase was initiated in November 1992 and will be completed in August 1993. Soil from the second excavation phase is expected to be treated by the Nordac soil washing process and the Umweltschutz Nord (U-Nord) bioremediation process (see Sections 3.1.1 and 3.1.2). The third and final excavation phase is expected to be initiated in fall 1993. Dioxin- and furan-contaminated debris from the site was treated in a rotary kiln during spring 1993. Groundwater remediation is expected to start in fall 1993.

The U-Nord bioremediation system and the Nordac soil washing technology were the primary technologies to be evaluated under the bilateral agreement. Both of the technologies are discussed in detail below.

3.1.1 Umweltschutz Nord (U-Nord) Soil Treatment Technology

The U-Nord soil treatment technology is a full-scale commercial system that consists of two main components, a Terranox bioreactor and a biopile. These two operating components are batch processes and are operated in sequence.

3.1.1.1 Process Description

The Terranox bioreactor is a horizontal encapsulated system. It has a modular design and consists of a variable number of interconnected tank segments with covers. For the demonstration, the bioreactor will have a total length of about 40 meters (129 feet) and a width of 2.5 meters (8.1 feet). The bioreactor is initially operated for about 7 days in an anaerobic mode to enhance dehalogenation of chlorinated compounds. The system is then aerated for about 3 days to initiate aerobic biodegradation and to strip any volatile compounds. The system can treat approximately 80 cubic meters (105 cubic yards) per batch.

After loading the bioreactor with contaminated soil for anaerobic treatment, a mix of water and nutrients is added to the continuously stirred reactor. The pH and temperature of the soil in the reactor, as well as water and nutrient levels, are controlled as necessary. Three longitudinal mixing shafts can be moved along the length of the bioreactor to agitate the soil continuously and intensively. Air emissions from the bioreactor are controlled by an activated carbon filter.

After anaerobic treatment, the partially treated soil is transferred to a biopile to allow for additional biodegradation of slowly degradable hydrocarbons. The duration of the second treatment phase may be varied depending on contaminant content and cleanup requirements. The biopiles are typically 60 meters (198 feet) long, 10 meters (33 feet) wide, and 1.5 to 2 meters (4.8 to 6.6 feet) high. The total volume is about 1,200 cubic meters (1,600 cubic yards). In addition, biopiles may contain soil from a number of different sites. For the demonstration, the biopile will be only 3 to 4 meters (9.9 to 13.2 feet) long to evaluate the degradation of contaminants in one segregated Terranox treatment batch. The biopiles are operated without an irrigation system; however, approximately once each month the biopiles are turned over for aeration. During this turning process nutrients and water can be added to the soil, if required.

3.1.1.2 Demonstration Objectives and Approach

The EPA SITE program has prepared a demonstration plan for the U-Nord soil treatment system to serve as the EPA request for additional measurements. The primary objective of the U-Nord process demonstration of the U-Nord process is to measure the technology's reduction efficiency for selected aromatic hydrocarbons, CHCs, total petroleum hydrocarbons, and PCBs at a confidence level of 95 percent. The effectiveness of the U-Nord process will be measured by sampling soil before and after treatment. Secondary objectives include determining contaminant reductions at various stages of the treatment process, documenting key nonproprietary system operating parameters and untreated soil characteristics, assessing the presence of toxic biodegradation by-products, documenting remediation costs, and determining whether applicable soil treatment limits are met.

3.1.1.3 Progress To Date and Future Activities

In February 1993, a U.S. technical representative visited the U-Nord facility and the Haynauerstrasse site to discuss the approach and objectives of the demonstration. The discussions helped to improve the understanding of the demonstration from both the German and U.S. perspectives. As a result of the discussions, comments from the vendor and the German technical support consultant were incorporated into the demonstration plan.

Recent analyses of soil excavated for the U-Nord demonstration indicated lower contaminant concentrations than expected. The lower concentrations may preclude the use of soil from the Haynauerstrasse site for the demonstration. Other sources of contaminated soil for the technology demonstration are currently being investigated. As a result, the schedule for the technology demonstration may be delayed until early 1994.

Appendix A lists contact personnel for the U-Nord soil treatment system.

3.1.2 Nordac Soil Washing Technology

The Nordac soil washing technology is a full-scale, commercial treatment system that was developed to remove organic and inorganic contaminants from soil. This high-pressure soil washing system is designed to separate out fine-grained soil and clean coarse-grained soil. In some cases, fine-grained soil may have a higher contaminant concentration (due to its greater surface area to volume ratio) and may require additional treatment prior to disposal. The Nordac system is fully automated and can process up to 1,000 metric tons (1,100 tons) of soil per day. For the Haynauerstrasse site, only 300 metric tons (330 tons) per day will be processed due to the large fine-grained fraction of the soil.

3.1.2.1 Process Description

Feed soil is initially screened by size, and materials with a diameter greater then 50 millimeters (mm) (2 inches) are mechanically crushed. The soil is then transported to a homogenization unit, where it is mixed with recycled process water using a plough-blade mixer to create a pumpable slurry.

The soil-water slurry is transported to a water jet and baffle chamber, where it undergoes high-pressure spraying with recycled process water. In the chamber, the slurry passes through a series of three high-pressure water jets. The water jets are configured in a circular array of nozzles producing a cone-shaped water jet. The soil particles are drawn through the focal point of the water jet to remove some contaminants adhered to the soil particles. The water jet also produces a partial vacuum that draws in a large volume of air. The vacuum's stripping effect releases volatile substances from the soil particles; the volatile substances are then drawn into the process air.

The slurry is then blasted into a steel wall to break up soil particles. This action is intended to reduce contaminant concentrations in the coarse-grained portion of the soil to below regulatory cleanup levels. The soil-water slurry generated in the jet and baffle chamber is then separated into three fractions (lightweight, coarse-grained, and fine-grained soil-water slurry) using a multi-step separating process.

Coarse-grained material that meets regulatory cleanup requirements will be used in road construction. Fine-grained materials will be either incinerated, landfilled, or treated by bioremediation. Process water is treated and recycled, and air emissions are treated to meet regulatory requirements prior to release.

3.1.2.2 Demonstration Objectives and Approach

The EPA identified the following objectives for this demonstration:

- To measure the reduction efficiency of selected aromatic hydrocarbons, CHCs, total petroleum hydrocarbons, and PCBs at a confidence level of 95 percent

- To determine the percent reduction of soil mass requiring additional treatment to meet applicable cleanup criteria

These objectives will be accomplished by sampling the soil before and after treatment and by determining the mass of soil treated and the mass of soil requiring additional treatment. Secondary objectives include documenting residual stream characteristics, documenting wastewater characteristics, documenting remediation costs, and determining whether soil cleanup criteria are met.

The EPA SITE program drafted a streamlined demonstration plan (QAPjP) for the Nordac system demonstration that is currently undergoing internal review. The demonstration plan is designed to collect information that allows for a U.S. evaluation using U.S. standard methods.

3.1.2.3 Progress To Date and Future Activities

In February 1993, a U.S. technical representative visited the full-scale Nordac treatment facility to discuss the approach and objectives of the demonstration plan. This meeting helped improve the understanding of the demonstration approach and project objectives. In addition, discussions with the administrative and laboratory personnel at the German laboratory, Institut Fresenius, improved the laboratory's understanding of EPA QA/QC requirements. In March 1993, a contracted U.S. EPA QA auditor visited Germany and provided support to German laboratory personnel responsible for implementing U.S. sampling and analysis methods.

Analyses of soil excavated for the Nordac demonstration have shown lower concentrations of contaminants than expected. The low concentrations may preclude the use of soil from the Haynauerstrasse site for the demonstration. Other sources of contaminated soil for the technology demonstration are currently being investigated. As a result, the schedule for the technology demonstration may be delayed until spring 1994.

Appendix A lists contact personnel for the Nordac soil treatment system.

3.2 Gaswerke München

The Gaswerke München site is a former coal gasification and gas distribution facility in Munich. The remediation of this site is being coordinated by an interdisciplinary working group comprised of the site owner, city and state regulatory agencies, and various technical consultants. The site is about 325,000 m^2 (81 acres) in size and is located about 1 kilometer (0.6 mile) northeast of the city center. Various site investigations have revealed that both soil and groundwater are contaminated with PAHs and that the top-most layer of soil is also contaminated with lead. In addition, slightly elevated concentrations of aliphatic hydrocarbons and cyanides were found throughout the site, with some higher concentrations in limited areas. One of the contamination hot spots covers an area of about 4,000 m^2 (1 acre) and consists of approximately 50,000 metric tons (55,000 tons) of gravelly sediment. This hot spot was found to pose a substantial potential for release to groundwater and will be remediated in the initial phase of the overall site remediation.

Treatability studies of various technologies, including soil washing and thermal desorption, have been conducted at the site. During the soil washing treatability study, the QA approach implemented included elements of the EPA QA/QC process; for example, chain of custody was used to track samples. Ultimately, thermal desorption was selected for treatment of contaminated soils. Desorption of volatile contaminants will be accomplished by heating contaminated soils in a reactor vessel, followed by off-gas treatment using condensers and conventional filter systems. The reactor unit of the selected technology may either be heated directly by steam or by indirect heating methods. In addition, the reactor may be operated under a vacuum to enhance contaminant volatilization.

Because of delays in completing the treatability study, the site remediation schedule has been modified. Soils to be treated have been excavated and are stored in an interim on-site storage facility. Proposals from technology developers for on-site treatment were received in July 1993. It is anticipated that soil treatment will begin in 1994.

Appendix A lists contact personnel for the Gaswerke München demonstration.

3.3 Burbacher Hütte, Saarbrücken

The Burbacher Hütte site is a former steel factory located in Saarbrücken. During times of peak productivity, the facility had a maximum size of about 600,000 m^2 (150 acres). At present, only about one third of the facility (200,000 m^2 or 50 acres) is in use.

The steelworks formerly consisted of different individual production plants (for example, coke factories, benzene works, and a gas generation plant). The individual production units caused specific contamination at different on-site locations. The primary contaminants of concern at the site include aromatic hydrocarbons, PAHs, phenols, heavy metals, sulfides, and cyanides. Additionally, ammonium has been detected at elevated concentrations at several locations on the site.

In 1991 and 1992, full-scale bioremediation, soil washing, and incineration pilot tests were performed using soil from the site. At present, the results of these pilot tests are under evaluation as part of a remedial feasibility study. It is anticipated that the remediation concept for cleanup of the site will consist of a combination of these technologies for the individual groups of contaminants. The remedial feasibility study report identifying the selected technologies is expected to be issued in 1994.

Appendix A lists contact personnel for the Burbacher Hütte demonstration.

3.4 Stadtallendorf Ammunition and Explosive Factory Site

The former ammunition and explosives factory at Stadtallendorf is located about 100 kilometers (62 miles) north of Frankfurt. The production area of the site covered about 4.2 square kilometers (1.6 square miles). From 1941 until 1945, the facility was used for the production of trinitrotoluene (TNT) and other explosives. During operation, the facility produced about 126,000 metric tons (140,000 tons) of TNT and 27,000 metric tons (30,000 tons) of other explosives. After World War II, the U.S. Army used the site as a storage facility for ammunition and equipment. In the period between 1946 and 1949 almost all production plants were demolished. Today, the Stadtallendorf site is a mixed use area that includes residential areas, industrial sites, and the former ammunition and explosives factory.

Between 1941 and 1945, unsafe production methods, uncontrolled waste disposal, and insufficient wastewater treatment contaminated the site with the following substances:

- Explosives (for example, TNT)
- Raw materials used in explosives production (for example, toluene, mono- and dinitro-toluenes)

- Degradation products of explosives (for example, dinitro-aminotoluenes)

- Miscellaneous pollutants (for example, phenols, aromatic hydrocarbons, PAHs, cyanides, and heavy metals)

The anticipated remedial technology for soil decontamination is a combination of soil washing and high-temperature incineration of highly contaminated soil washing residues. For soil decontamination, the cleanup target has been defined as 1 mg/kg for total explosive-related contaminants.

At present, a detailed remedial investigation of selected residential areas is underway to evaluate the site-specific risks associated with the contaminants. The results of this investigation will provide the basis for the remedial concept. After negotiations with the state authorities, the remedial design phase is expected to begin by the end of 1993, and remedial action is expected to start in 1996.

Appendix A lists contact personnel for the Stadallendorf demonstration.

3.5 Kertess, Hannover

This project involves the remediation of an industrial facility that stored and handled organic solvents, detergents, aromatic hydrocarbons, and halogenated hydrocarbons from 1946 until 1985. The site covers about 10,000 m^2 (2.5 acres) and is located in the southern part of Hannover. Primary contaminants at the site include chlorinated and aromatic solvents. These contaminants are present in the vadose zone and groundwater and are found as DNAPL at the bottom of the uppermost aquifer.

3.5.1 Process Description

In 1976, a groundwater extraction and treatment system was installed at the site. However, due to the poor efficiency of the pump-and-treat system, the project management was reorganized, and other remediation concepts were investigated. The remediation technologies intended for use at the site include DNAPL extraction, excavation of contaminated soil from the saturated zone in combination with physical groundwater barriers, and SVE in the vadose zone. Research efforts focus on DNAPL extraction because it is a common problem at hazardous waste sites.

BMFT and EPA anticipate demonstrating the vadose zone remediation technology under the bilateral agreement. The technology, developed by Herbst Umwelttechnik GmbH of Berlin, employs a three-step process:

Step 1—Extraction of soil gas from the vadose zone
Step 2—Fluid absorption of volatile contaminants
Step 3—Vinyl chloride removal in a bioreactor

After extracting soil gas from the vadose zone, the process employs a recirculating carrier fluid to absorb volatile contaminants, with the exception of vinyl chloride. The contaminant-laden fluid then passes through a desorption unit where contaminants are thermally volatilized. The process off-gas is treated by conventional means, and the clean carrier fluid is recycled.

Soil gas carrying vinyl chloride passes through a bioreactor vessel filled with microbe-bearing granules. The microbes are supplemented with a nutrient solution, and the bioreactor operating parameters are kept stable by a feed-gas conditioner. Long-term tests have shown that the reactor bed does not need to be replaced over long periods of operation.

3.5.2 Objectives

The technology demonstration is intended to focus on the innovative second and third steps of this soil gas treatment technology. These process steps have been designed specifically to remove vinyl chloride from the extracted soil gas stream. If effective, the system would avoid consumption of large amounts of activated carbon to remove vinyl chloride as in traditional treatment systems.

3.5.3 Future

Remediation equipment is scheduled for installation at the Kertess site in September 1993, and operation is planned to begin in December 1993. At present, BMFT is compiling detailed process descriptions and regulatory treatment requirements to provide a basis for a SITE demonstration QAPjP that will serve as the EPA request for additional measurements.

Appendix A lists contact personnel for the Kertess demonstration.

3.6 Varta-Süd, Hannover

The Varta-Süd site is located northwest of Hannover adjacent to the site of a battery factory that operated from 1938 to 1989. The site covers about 45,000 m^2 (11 acres). Site investigations have revealed lead, antimony, and cadmium contamination in on-site soil, with the highest contaminant levels in sediment samples from a creek that received wastewater discharges from the battery factory. Slag, debris and other residues from smelting and coal firing are also distributed randomly over the site. In addition to heavy metal contamination in on-site soils, PAH contamination of unknown origin has been detected in the southeastern portion of the site. Groundwater at the site is not significantly contaminated with heavy metals.

Treatability studies with a variety of treatment technologies, including high-pressure soil washing and chemical extraction, have been completed. The results of a risk assessment are currently being evaluated, guiding decisions on remedial action.

Appendix A lists contact personnel for the Varta-Süd demonstration.

Section 4
Summary of Bilateral Agreement Goals, Accomplishments, and Benefits

With three planned technology demonstrations completed, one technology undergoing quarterly sampling, and another technology currently going into the field, a review of benefits and accomplishments at this point in the program provides interim documentation of the limited successes of the bilateral agreement. This section summarizes the partner countries' accomplishments during the first 2 years of the bilateral agreement, lessons learned that have improved the program's efficiency in achieving its goals, and lessons learned that will allow future activities to focus directly on the main interests of the partner countries.

This section summarizes the bilateral agreement goals and lists separately the benefits and accomplishments gained by each partner. Each partner prepared their portion of this section and it was reviewed by the other partner. Also, the benefits and accomplishments are listed under the goals in which they were achieved. While the goals are the same for each partner, the benefits are realized in different ways.

4.1 Summary of U.S. Accomplishments and Benefits

Table 3 lists specific U.S. goals, accomplishments, and benefits for each of the four bilateral agreement program goals. The specific goals and accomplishments are discussed in detail below.

4.1.1 Understand German Remedial Approaches

By preparing technology demonstration plans and QAPjPs and by coordinating demonstration activities, U.S. representatives have learned a great deal about how remedial activities are conducted in Germany. In addition, U.S. representatives have gained a better understanding of German political and social issues. Of specific benefit is the identification of current high-visibility environmental issues in Germany. Two such issues are the potential presence of vinyl chloride as a degradation product of chlorinated solvents and the heightened regulatory attention paid to atmospheric emissions from all remedial processes.

German remedial programs are currently implemented on a regional basis under the jurisdiction of individual states. Remedial requirements are based primarily on preestablished contaminant cleanup criteria that specify MCLs in treated material. In addition, German remedial activities under the BMFT Model Remediation Program are typically overseen by project steering committees that include regulatory and scientific experts. These experts provide advice to regulators and other key personnel for use in determining compliance requirements for remediation projects. In Germany, the regulators, responsible parties, and contractors work closely to evaluate and select technically feasible, cost-effective remedial solutions.

U.S. representatives visited Germany to meet with regulators, survey hazardous waste sitesincluded in the bilateral agreement, and meet with technology developers and technical experts to discuss the implementation of German technology demonstrations. Meetings conducted during these visits allowed U.S. representatives to discuss the intent and scope of activities required to demonstrate an innovative technology according to EPA protocols under conditions in Germany.

4.1.2 Demonstrate Innovative Remedial Technologies

Five technology demonstrations have either been initiated or completed under the bilateral agreement. Of these five demonstrations in the United States, four are completed and one technology is undergoing quarterly sampling activities. The demonstrations have introduced technology developers to foreign regulatory requirements and monitoring techniques and have introduced the international regulatory, consulting, and industrial community to new technologies. Demonstrations in the

Table 3. U.S. Accomplishments of Bilateral Activities

Goals	Accomplishments
❖ Facilitate an understanding of each country's approach to the remediation of contaminated sites	❖ Gained understanding of German remedial approach by preparing demonstration plans and QA project plans ❖ Identified current high-profile German regulatory issues ❖ Learned how German remedial programs are implemented on a regional basis under state jurisdiction ❖ Gained an understanding of Germany's capabilities in conducting technology demonstrations
❖ Demonstrate innovative remedial technologies	❖ Three completed, and one long-term monitoring ❖ Conducted demonstrations as part of full-scale remediation activities ❖ Developed understanding of German sampling and analysis procedures
❖ Compare QA programs	❖ Implemented German QA programs during demonstrations ❖ Observed and implemented German analytical procedures ❖ Disseminated U.S. QA/QC guidelines to Germany
❖ Facilitate technology transfer	❖ Introduced U.S. innovative technologies to Germany ❖ Participated in international symposia to exchange information on innovative technologies ❖ Introduced German technology evaluation procedures and environmental regulations to developers

United States have included radio frequency heating, oxidation by ultraviolet light and hydrogen peroxide, vapor extraction, and anaerobic thermal processing; in Germany, demonstration plans have been prepared for high-pressure soil washing and enhanced bioremediation.

Full-scale remediation demonstrations have provided an opportunity for U.S. and German technical representatives to observe the roles of responsible parties, regulators, developers, and consultants during innovative technology implementation. Understanding the roles and scope of authority of key participants in the remedial process has been instrumental in the efficient performance of bilateral program activities. At times, however, political and cost considerations have hampered demonstration activities, resulting in delays and other difficulties. Most of the difficulties resulted from combining a demonstration with full-scale remedial activities. The lesson learned from this is that conducting technology demonstrations as independent treatability studies may be more efficient, albeit in some cases more expensive, than conducting the demonstration in concert with a full-scale site remediation.

Similarities and differences exist between German and U.S. technology monitoring techniques. The differences have been one of the main hurdles to overcome in designing the technology demonstrations. From experience gained under the bilateral agreement, U.S. representatives have gained an understanding of German monitoring capabilities and have used that understanding in designing plans for German demonstrations. However, implementing each country's monitoring requirements is difficult even under the best circumstances, because most monitoring techniques rely heavily on the experience of the technical staff performing the measurements. Even with highly trained technical staff, learning new techniques and obtaining high quality data are difficult. U.S. representatives have learned that direct communication between technical staff from both countries is the best method to overcome this hurdle.

4.1.3 Compare Quality Assurance Programs

Demonstrations in Germany and the United States have required implementing QA programs specific to each country's requirements. EPA has prepared detailed QAPjPs identifying project objectives, QA objectives, and procedures for collecting data of known and documented quality for the evaluation of demonstrated technologies.

These QAPjPs have served as a primary vehicle for dissemination of the U.S. QA procedures. U.S. representatives have assisted German technical experts in understanding the basis and intent of the U.S. QA/QC requirements, analytical method requirements, and interpretation of QC results. In addition, U.S. representatives held conference calls and attended meetings with German regulators, technology developers, consultants, and analytical laboratories to discuss and evaluate QA/QC requirements associated with technology demonstrations. A large portion of this interaction involved discussing the scope and intent of the rigorous U.S. QA/QC requirements.

In preparing and implementing technology demonstrations, German and U.S. technical representatives observed and implemented each partner's analytical methods. This hands-on experience provided a basis of comparison of the similarities and differences of the German analytical techniques and QA/QC procedures with EPA-approved methods. During the course of the demonstrations, two sets of data were generated: one set of data derived by U.S. procedures, and one set derived by German methods. A review of the data could be a potential first step toward achieving performance-based method requirements for international environmental studies.

Prompted in part by U.S. QA/QC procedures disseminated under this program, German technical representatives are currently revising regulatory QA/QC guidelines to provide objective documentation of data quality. Germany's revision of QA/QC guidelines signifies the importance of QA as a key element in technology demonstrations as well as remedial activities in general. U.S. procedures are often consulted as an example for data quality documentation in the international arena.

4.1.4 Facilitate Technology Transfer

U.S. and German regulators, responsible parties, and consultants have been introduced to new, innovative technologies in both countries. This introduction will allow environmental decision makers to select the appropriate technology for site remediation from a broader base of alternatives. Completed demonstrations provide technically sound performance and cost information for comparison of innovative versus traditional technology options.

Participation in international remediation symposia has played a major role in transferring information on technologies demonstrated under the bilateral agreement as well as the overall EPA SITE program. Under the bilateral agreement, U.S. representatives participated in symposia in Berlin, Germany; San Francisco, California; and Budapest, Hungary. Each of these symposia were well attended by the international regulatory and industrial community and provided an opportunity to discuss the technical details of the latest developments in the environmental field. Participation in the various technical sessions and workshops allowed U.S. technical and regulatory representatives to directly discuss pertinent issues with their international counterparts. Participation in these three international symposiums resulted in numerous requests for additional information and yielded interest from international environmental experts.

U.S. and German technology developers have been introduced to each other's technology evaluation approaches, and both countries will perform an evaluation of the selected technologies. By including developers in the demonstration process, the developers learn about performance and cost requirements of the partner country. Understanding these requirements is one important element required to break into international environmental markets. To this end, the bilateral agreement has provided a significant new market opportunity for these technology developers.

4.2 Summary of German Accomplishments and Benefits

Table 4 lists specific German accomplishments and benefits for each of the four bilateral agreement program goals. The specific goals, accomplishments, and benefits are discussed below.

4.2.1 Understand U.S. Remedial Approaches

German technical representatives studied information from actual site remediation projects to compare the U.S. approach to remedial activities with German procedures. Technical meetings and exchange of regulatory documents and work plans were instrumental in performing this study. After studying the formal, detailed U.S. methods required for every specific remedial project activity, German representatives concluded that the process can result in a greater amount of time to implement remedial actions. For

Table 4. German Accomplishments of Bilateral Activities

Goals	Accomplishments
❖ Facilitate an understanding of each country's approach to the remediation of contaminated sites	❖ Gained understanding of U.S. remedial approaches based on exchange of regulatory documents and work plans and through technical meetings ❖ Gained greater insight into the basis for and substance of EPA regulatory programs for remediation of hazardous waste sites ❖ Identified the role and jurisdiction of the following remedial project participants: federal and state regulators, responsible parties, and contractors ❖ Gained an understanding of the role of the cleanup technology developer, contractor, and regulatory agencies during full-scale remediation projects
❖ Demonstrate innovative remedial technologies	❖ Initiated two technology demonstrations ❖ Developed an understanding of U.S. sampling and analysis procedures ❖ Conducted demonstrations as part of full-scale remediation activities ❖ Studied regulatory requirements for data collection
❖ Compare QA programs	❖ Implemented U.S. QA programs during demonstrations ❖ Discussed and evaluated QA/QC issues ❖ Observed and implemented U.S. analytical procedures ❖ Generated data by U.S. and German methods to allow a comparison of analytical procedures
❖ Facilitate technology transfer	❖ Introduced German innovative technologies to the United States ❖ Generated parallel performance data to allow an evaluation of U.S. analytical methods ❖ Promoted innovative technology development by establishing direct lines of international communication ❖ Participated in international symposia to exchange information on innovative technologies

the purposes of developing German regulations further, German representatives considered streamlining the formalized U.S. processes to adapt it for German use.

German representatives studied the organizational responsibilities of federal and state authorities, responsible parties, and contractors involved in remedial projects and compared their findings with comparable environmental regulations in the partner countries. The effects different approaches may have on the progress of remedial projects will be evaluated and discussed in the final report on the bilateral agreement.

The relationship between technology developers, cleanup contractors, and regulatory agencies was studied during full-scale U.S. remedial projects to assess the efficiency of the U.S. remedial approach. By studying these relationships during innovative technology demonstrations, German technical representatives gained an understanding of the roles of the respective parties during remedial actions.

4.2.2 Demonstrate Innovative Remedial Technologies

German technical representatives accomplished the following while demonstrating innovative technologies.

- Initiated two innovative technology demonstrations

- Developed an understanding of U.S. sampling and analysis procedures

- Conducted demonstrations as part of full-scale remediation activities

- Studied regulatory requirements for data collection

Comprehensive demonstration plans have been written for two technology demonstrations with one technology currently being mobilized for field activity. Collecting additional data using EPA standard monitoring methods during projects in both countries facilitated the exchange of technical information. For demonstrations conducted in Germany, the EPA request for additional measures is compiled after consultation with various technical experts and governmental agencies. However, in some cases, SITE program technology demonstrations conducted in the United States were implemented too rapidly to comprehensively evaluate the U.S. demonstration plans and develop additional measures based on German regulations. The short demonstration time frame resulted in a reduced level of detail in German requests for additional measures.

BMFT evaluated EPA-approved procedures for collecting and analyzing samples and for monitoring system operating parameters to determine similarities and differences and advantages or disadvantages compared to German procedures. Implementing foreign methods in field and laboratory work allowed German technical staff to gain experience implementing U.S. procedures under realistic conditions, while having technical support from U.S. experts. This understanding of U.S. procedures for technology demonstrations will allow more efficient future demonstrations.

In Germany, emphasis was placed on the implementation and evaluation of technologies in full-scale remedial projects. Assessing an innovative technology in a full-scale demonstration allows an evaluation of the technology's capabilities, flexibility, and cost in a competitive situation. However, full-scale demonstrations generally focus on technologies that have already found access to the commercial market. In similar, future technology transfer programs, the standard EPA approach to technology demonstrations with a formal, unbiased framework will likely be incorporated to some degree in German technology demonstration procedures. BMFT's original intention was to demonstrate technologies under competitive marketplace conditions; however, this approach may have complicated the technology demonstrations because of a lack of flexibility during the planning process. Demonstration projects on a pilot- or limited commercial-scale were generally found to be easier to implement.

German technical personnel reviewed regulatory requirements for data collection during field implementation. The process of planning, reviewing, and implementing monitoring procedures and the associated elements of a QA program are of special interest to Germany, because it is currently developing a national Soil Protection Act. The evaluation of different approaches allows BMFT representatives to assess the responsibilities of technology developers and regulatory agencies for maintaining data quality.

4.2.3 Compare Quality Assurance Programs

German technical representatives accomplished the following while comparing the programs:

- Implemented U.S. QA programs during demonstrations

- Discussed and evaluated QA/QC issues

- Observed and implemented U.S. analytical procedures

- Generated data by U.S. and German methods to allow a comparison of analytical procedures

Demonstrations in Germany and in the United States have required implementing QA/QC procedures specific to each country's regulatory, technical, and political requirements. Adhering to both countries' QA/QC requirements allows direct use of the demonstration results in the other country; it also allowed the U.S. QA approach to be studied and evaluated under practical conditions. The EPA approach to QA/QC in site remediation may substantially influence the development of new QA/QC policies and guidelines in Germany.

Each country's approach to QA was discussed during conference calls and technical meetings. These direct lines of communication enabled experts to gain insight into the possible advantages and disadvantages of the U.S.

procedures. For example, one advantage of U.S. QA/QC requirements is that they provide useful information in determining and documenting data quality.

BMFT and EPA have participated in implementing the other country's analytical methods, and both agencies can compare the effectiveness and cost of various methods while having the full technical support of the partner's laboratory personnel. Although the basic sampling and analysis equipment used in both countries is very similar, difficulties can be encountered in finding laboratories able to perform each partner's analytical methods. Eventually, each partner identified laboratories able to perform analyses.

By compiling two sets of analytical data, EPA and BMFT will be able to determine the similarities and differences of U.S. and German analytical procedures. The comparison, performed with substantial support of both U.S. and German experts, will enable technology developers and potential clients to gain a better understanding of the international remediation market. This understanding of procedures will be useful to technology developers, analytical laboratories, regulators, and responsible parties in assessing the applicability of foreign technologies in their country.

4.2.4 Facilitate Technology Transfer

German technical representatives accomplished the following to facilitate technology transfer.

- Introduced German innovative technologies to the United States
- Generated parallel performance data to allow an evaluation of U.S. analytical methods
- Promoted innovative technology development by establishing direct lines of international communication
- Participated in international symposia to exchange information on innovative technologies

German technology developers have been introduced to the U.S. remediation technology marketplace. The technology information and demonstration results will be published for public distribution in the final report of this program and at international site remediation conferences.

Parallel sets of performance data will be reported and the differences in analytical methods will be evaluated. Information on similarities and differences of analytical results is of fundamental importance to evaluate the possibility of cooperative marketing and research with the United States.

Innovative technology development was promoted by establishing direct lines of international communication. Understanding remediation requirements is fundamental to sharing technical ideas and distributing experiences for the development of innovative technologies.

German technical representatives participated in numerous international symposia on innovative remedial technologies. At symposia, meetings, and conferences throughout the world, the international community expressed great interest in the status of remedial technology development. Symposia participants were particularly interested in system performance during technology demonstrations and in the results of full-scale remediation activities.

Section 5
Reassessment of Program Goals and Approach

With approximately five of the field demonstrations completed, the bilateral program is in the midst of developing substantial performance and cost information from the U.S. and German technology evaluations. This information will provide useful knowledge with which each partner country can improve its remedial programs. The compilation of information may also inform potential technology users in the United States and Germany about the applicability of new technologies and introduce technology developers to each other's evaluation criteria and environmental regulations. Nevertheless, based on lessons learned in the first 2 years of the bilateral agreement, the U.S. and German representatives believe that a logical reassessment and streamlining of the program is warranted. Program goals and refinement to the approach for the bilateral agreement were jointly prepared by the partners and are presented in Table 5. The identified changes in the program approach do not represent a departure from the original program goals but rather a more refined focus.

REVISED PROGRAM GOAL: Facilitate an understanding of remediation approaches

This goal has been refined to focus on summarizing and transferring information on the remedial process, particularly that part of the process associated with the selection of innovative technologies as remediation solutions. Emphasis will be placed on the U.S. Superfund Accelerated Cleanup Model (SACM), the German Soil Protection Act currently under development, and the nine remedy selection criteria that the United States and Germany require for feasibility studies:

- Overall protection of human health and the environment
- Compliance with applicable or relevant and appropriate requirements (ARAR)
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, and volume through treatment
- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance

The revised approach to achieving this goal will include incorporating data from pertinent sites where innovative technologies were selected to remediate hazardous waste sites. The approach will also include promoting the exchange of technical staff to gain a firsthand understanding of the remedial approach, selection, and implementation of innovative technologies. This exchange may involve both regulatory and technical specialists who would visit the partner country to directly participate in remedial programs involving innovative technologies and demonstrations of innovative technologies.

REVISED PROGRAM GOAL: Demonstrate innovative remedial technologies

This goal remains the same as the original goal. The program will continue completing the balance of the "as if" innovative technology demonstrations in the developer's country, but all activities conducted to achieve this goal will continue to focus on innovative technologies. The host country will provide regulatory, engineering, QA, and sampling and analysis support necessary to demonstrate the innovative technology. As in the past, QA will be an important component of the technology evaluation. The approach will continue to include preparing QAPjPs and requests for additional measurements as if the demonstrations are being performed in the partner country.

The actual technology demonstrations will be conducted in each partner country. General steps toward this end include the following: technology selection; site selection; and demonstration planning, implementation (including coordinating international staff and equipment logistics), and reporting. Streamlined demonstration plans

Table 5. Bilateral Agreement Program Goals and Approach

Original Program Goals and Approach			*Revised Program Goals and Approach*	
Streamlined Goals	Approach	Refinement	Streamlined Goals	Approach
Facilitate an understanding of each country's approach to the remediation of contaminated sites	❖ Prepare technical demonstration plans for innovative technologies ❖ Visit the partner country to review demonstration sites and their status ❖ Participate in international remediation symposia	Focus on summarizing and transferring information on the process associated with selecting an innovative technology as the remedial solution and incorporating the SACM, the German Soil Protection Act and the nine remedial selection criteria	Facilitate an understanding of remediation approaches	❖ Compile, summarize, and transfer information on selected approaches for specific innovative technologies and hazardous waste sites ❖ Promote the exchange of technical staff to gain firsthand understanding of partner country's remedial and technology selection approach
Demonstrate innovative remedial technologies	❖ Conduct demonstrations as if they were conducted in partner country	Continue and emphasize "as if" approach	Demonstrate innovative remedial technologies	❖ Conduct additional demonstrations as if they were conducted in partner country ❖ Maintain innovative technology focus rather than contaminated site focus ❖ Provide direct assistance in implementing demonstration activities and QA requirements
Compare QA programs	❖ Provide QA oversight of project activities ❖ Audit German facilities conducting technology demonstration activities	Eliminated as a separate primary goal by incorporating QA under other primary goals	Incorporate QA under other primary goals	❖ Participate in international symposia to gain additional information about QA program
Facilitate technology transfer	❖ Compile and transfer information on innovative technologies ❖ Participate in innovative technology symposia	Focus on the international audience	Facilitate international technology exchange	❖ Prepare international technology transfer publications ❖ Offer international training courses on innovative technology remedial approaches ❖ Participate in international symposia

and requests for additional measurements will be prepared, as necessary, for all demonstrations conducted as if they were in the partner country. New technologies will be identified to complete the balance of the 12 "as if" demonstrations within the original scope of the program. A reserve list of technologies will also be identified as replacement candidates for the program if one of the selected technologies drops out. The program will continue to maintain its focus on innovative technologies, not contaminated sites.

REVISED PROGRAM GOAL: Facilitate international technology exchange

This goal has been refined to more directly address an international audience beyond the two partner countries. Continued participation in international site remediation symposia will also be a key element in facilitating the international technology exchange. The ultimate goal of increased international technology exchange is to create business opportunities for innovative technology developers from each country. In addition, towards the conclusion of the bilateral agreement, an international seminar on "lessons learned" may be held to discuss innovative technology remedial approaches in the partner countries. The seminar will provide current information on innovative remedial approaches and present difficulties encountered in implementing innovative technologies for full-scale site cleanup. The direct interaction provided by the seminar will facilitate technology exchange between the partner countries.

Comparing QA programs is no longer listed as a separate program goal, because transferring QA program information is still and has always been a function of understanding site remediation approaches and demonstrating innovative remedial technologies. Because the revised program goals depend heavily on reliable QA programs, this previous program goal has been incorporated by practice into the activities required for the remaining three goals.

The revised program goals and approach better reflect the primary interests of the partner countries and improve the framework for effectively collecting and disseminating performance and cost information on innovative technologies to an international audience. This framework will facilitate the proper evaluation of and promote the use of innovative technologies for the benefit of the international community, with increasing future benefits to both partner countries.

The revised program goals are directed toward enhancing both partner countries' cleanup capabilities for hazardous waste sites by sharing information on innovative remedial approaches, promoting development of innovative technologies, improving the quality of technology evaluations, and introducing technology developers to international markets. In addition, international partnering such as under this bilateral agreement allows each country to learn about the partner's environmental regulations, policies, and guidelines. This understanding may influence the evolution of remedial regulations in each country and may help to standardize remedial processes on an international level, further encouraging and enabling technology developers to enter international markets.

In conclusion, one of the major program accomplishments of the bilateral agreement to date is that technical professionals in both Germany and the United States have improved their ability to communicate with an international partner in terms of environmental site remediation and innovative technology demonstrations. This is a significant accomplishment given the substantial and numerous differences in regulatory requirements, remedial approaches, and implementation practices between the two countries. During the course of the bilateral agreement, effective communication has been established on levels ranging from general regulatory policy questions to the specific technical details of chemical analyses. Program participants found that direct personal communication between technical experts was the most effective way to overcome technical differences and communication gaps. The breadth of understanding gained under this bilateral agreement is essential for effective international environmental cooperation now and in the future. Establishing good communication between environmental professionals in both partner countries heightens the agreement's effectiveness. Each partner country's hazardous waste cleanup capabilities have been enhanced by sharing information on innovative remedial approaches, promoting development of innovative technologies, improving the quality of technology evaluations, and introducing technology developers to international markets. By learning how to communicate on such a fundamental level, U.S. and German representatives have developed the skills needed to achieve the long-term goals of the bilateral program.

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