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Workshop on Innovative Technologies for Treatment of Contaminated Sediments
June 13-14, 1990

Summary Report

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WORKSHOP ON INNOVATIVE TECHNOLOGIES FOR TREATMENT OF CONTAMINATED SEDIMENTS
June 13-14, 1990

SUMMARY REPORT

by

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

This report provides a summary of the presentations and panel discussions from the Workshop on Innovative Technologies for Treatment of Contaminated Sediments, which was conducted on June 13-14, 1990, in Cincinnati, Ohio. The intended audience for this summary comprises those individuals and organizations involved in the remediation of contaminated sediments at sites throughout the United States.

E. Timothy Oppelt, Director
Risk Reduction Engineering Laboratory

ABSTRACT

The Workshop on Innovative Technologies for Treatment of Contaminated Sediments was held in Cincinnati, Ohio, on June 13-14, 1990. Its twofold purpose was 1) to provide interested individuals and organizations with current information on innovative treatment technologies for contaminated sediments, and 2) to provide the Risk Reduction Engineering Laboratory (RREL) staff with an opportunity to increase their understanding of the problems associated with the management of contaminated sediments treatment at various locations throughout the United States.

The workshop was organized into six segments related to policy and technology development. "Setting the Scene" included presentations by representatives from RREL, EPA's Office of Water Regulations and Standards (OWRS), EPA's Great Lakes National Program Office (GLNPO), Environment Canada, and the U.S. Army Corps of Engineers (COE). The succeeding four segments were entitled "Dredged Materials Removal, Pretreatment and Disposal," "Extraction Technologies," "Biological/Chemical Treatment Technologies," and "Other Technologies of Interest." This Workshop Summary Report contains summaries of each presentation and panel discussion. The final segment of the workshop consisted of an open discussion on "Future Direction for Contaminated Sediments Treatment." The questions raised by attendees covered overall approaches to pollution prevention and forthcoming strategies, development of criteria for action and target levels, monitoring requirements, cost/benefit concerns, short-term versus long-term considerations, and characterization of ecosystems. The open discussion is summarized in the final report section.

This document covers the period of April 1990 to July 1990, and work was completed as of September 1990.

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SECTION 1

INTRODUCTION

1.1 Background

The Workshop on Innovative Technologies for Treatment of Contaminated Sediments was held in Cincinnati, Ohio, on June 13-14, 1990. This workshop, which was developed and organized by the Risk Reduction Engineering Laboratory (RREL), was conducted at the request EPA's Office of Water Regulations and Standards (OWRS). Its two-fold purpose was 1) to provide interested individuals and organizations with current information on innovative treatment technologies for contaminated sediments, and 2) to provide RREL staff with an opportunity to improve their understanding of the problems associated with the management of contaminated sediments at various locations throughout the United States. Some of the technologies discussed at the workshop are potential candidates for remediation of contaminated sediments under the Assessment and Remediation of Contaminated Sediments (ARCS) Program, which is sponsored by EPA's Great Lakes National Program Office (GLNPO). Significant contributions to the workshop were also made by GLNPO and the U.S. Army Corps of Engineers (COE).

1.2 Workshop Structure

Individual presentations were made by representatives of the workshop's major contributing organizations, each of whom is recognized as an expert in one or more of the various fields related to innovative treatment technologies or contaminated sediments management. In keeping with the goal of providing workshop attendees with the most up-to-date information available, workshop organizers decided to schedule panel discussions at regular intervals throughout the workshop. The intent of the panel discussions was to encourage a free exchange of information so as to maximize the opportunities to obtain useful information. Section 2 presents a summary of each presentation and a summary of each panel discussion.

Finally, an open discussion was held among all workshop attendees, presenters and organizers. Its primary purpose was to provide a forum for workshop attendees to give feedback to the workshop organizers concerning the attendees' own information requirements for the selection and application of contaminated sediments treatment technologies. Section 3 presents a summary of the open discussion.

1.3 Summary Report Format

This summary report is organized as follows. Section 2 contains summaries of each of the individual presentations and panel discussions. Section 3 provides a summary of the open discussion that was held as the final session of the workshop. Appendix A is the workshop agenda, and Appendix B is a listing of workshop attendees. No formal papers were presented at the workshop. The information contained herein is based on recordings and notes taken throughout the workshop.

SECTION 2

SUMMARY OF PRESENTATIONS AND DISCUSSIONS

2.1 Setting the Scene

2.1.1 Welcome and Challenge to the Participants
John Convery, U.S. EPA, RREL

The scope of the contaminated sediments problem encompasses ecological damage, potential human health risks, and high cleanup costs. A total of 362 toxic chemicals have been identified in the bottom sediment of the Great Lakes. Fish and birds exhibit tangible effects of this pollution in disease, tumors, and deformities, but adequate health and ecological risks have not been quantified. It is estimated that remediation of Great Lakes sediments could cost $10 billion. It would entail treatment of 40 million cubic yards of material at costs ranging from $10 to $1500 per cubic yard.

Sediment/contaminant interaction determinants include the type and amount of clay, cation exchange capacity, organic content, pH, active iron and manganese, oxidation-reduction conditions, and salinity. Generally, fine-grained sediments and organic fractions are the most contaminated because of their greater surface area and their higher organic content. Interstitial water content can approach 90 percent, which necessitates extensive screening or dewatering pretreatment.

Dewatering techniques include gravity thickening, plate and frame filter press, centrifugation, vacuum filtration, belt filter press; followed by filtrate treatment. These are pretreatment steps that in no way remediate actual contamination. Remediation technologies include in-place capping, in situ solidification, confined aquatic disposal, solidification, in situ vitrification, supercritical oxidation, chemical dehalogenation, incineration, biodegradation, and solvent extraction.

The International Joint Commission Water Quality Board Sediment Subcommittee has developed recommendations for the initial assessment of contaminated sediment. Methods for such an assessment include physical, chemical, and biological testing. Physical tests include measurements of grain size, water content, organic content, and pH. Chemical tests include measurements for nutrients, metals, total organic carbon, persistent organics, and oxygen-consuming contaminants. Bioassay tests measure the body burden of toxics in benthic invertebrates and bottom-dwelling scavenging fish such as carp. Benthic community diversity is also measured.

The following amounts have been spent by RREL during fiscal year 1990 for soil treatment research that may be applicable to the cleanup of contaminated sediments:

o	On-site technologies	$ 480,000
o	In situ technologies	660,000
o	Superfund Best Demonstrated Available Technology	653,000
o	Combustion technologies	860,000
o	Biosystems	2,101,000
o	SITE Emerging	703,000
o	SITE Demonstration	3,553,000
o	Solidification/stabilization	550,000
o	Release/emissions from underground storage tanks	300,000
	Total	$9,860,000

The goals of this workshop are twofold. The first goal is to develop an understanding of the extent to which contaminated sediments pose an environmental problem. The second is to share information on innovative technologies for the remediation of contaminated sediments.

2.1.2 Overview of EPA Efforts on Contaminated Sediments

Mike Conlon, U.S. EPA, OWRS

Many EPA offices are currently involved in programs that address contaminated sediments. The Office of Research and Development (ORD) is conducting vital research. The Office of Emergency and Remedial Response (OERR), which administers the Superfund program, is working on several National Priority List sites with highly contaminated sediments; OERR also takes emergency action in response to spills that affect sediment. The Great Lakes National Program Office (GLNPO) is administering a 5-year program entitled the ARCS Program to research and develop methods for assessing and remediating contaminated sediments. The Offices of Marine and Estuarine Protection (OMEP) and Wetlands Protection (OWP) and the U.S. Army Corps of Engineers (COE) have jointly managed the disposal of dredged materials for many years. The Office of Water Regulations and Standards (OWRS) is developing chemical-specific sediment criteria and tests that measure the chronic toxicity of sediments to freshwater species.

Since 1988, the Office of Water (OW) has been charged with coordinating EPA activities on contaminated sediment. In response to this mandate in FY 89, OW created the Sediment Steering Committee and the Sediment Technical Committee.

The Sediment Steering Committee is chaired by the Assistant Administrator for Water. Its members include key Office Directors, Deputy Assistant Administrators, and Deputy Regional Administrators throughout the Agency. The Committee's objectives are to develop a management strategy for contaminated sediments, to facilitate resource commitments, to establish policy and interim guidance on sediment management, and to develop a long-term research program. In FY 89, the Steering Committee prepared a program summary report that identified existing Agency activities on contaminated sediments and the need for sediment classification methods. The Committee prepared a Decision Document on current sediment decision-making processes and an Issues Document on impediments to effective sediment management. At a meeting held in January 1990, the Steering Committee decided to commit resources to the development of a comprehensive sediment management strategy. An option selection meeting is scheduled for the Fall of 1990.

The objectives of the Sediment Technical Committee are to coordinate research, technical, and field activities and to identify problem areas. In 1989, the Committee compiled a listing of sediment quality data surveys and a compendium of sediment assessment methods. The compendium is now being reviewed by the Science Advisory Board. The Committee is currently preparing a guidance document on how to remediate contaminated sediments. This year, the Committee will also be responding to the review of the Sediment Classification Methods Compendium by the Science Advisory Board.

Four work groups were formed in February 1990 to assist in the preparation of a sediment management strategy for the Steering Committee. The Assessment and Identification of Risk Work Group is evaluating EPA's options for conducting a national inventory of sediment quality and for using a consistent approach to assessing sediment quality. The Prevention Work Group is examining options on how the NPDES program and pesticides and toxic substances programs might better prevent sediment contamination. The Remediation Work Group is focusing on how EPA programs might choose cleanup targets and make better use of EPA's authority to require such cleanups. The Work Group on Managing Dredged Materials is evaluating EPA's position on 1) the relative roles of economics and environmental protection in dredged materials management; and 2) whether the RCRA hazardous waste tests are applicable to dredged materials.

The work groups have formulated 14 draft issue papers (see Section 3.2). Senior EPA managers will be briefed on these sediment issues in September prior to the Steering Committee's option selection meeting.

2.1.3. *The GLNPO Program and Contaminated Sediments Management*

Paul Horvatin, U.S. EPA, GLNPO

The U.S. EPA Great Lakes National Program Office (GLNPO) is involved with tracking the progress of remediation at 30 of the 42 Great Lakes Areas of Concern (AOCs) located in the United States. Contaminated sediment exists at all 42 sites, and 41 are identified as having serious contaminated sediment problems. Three hundred sixty-two toxic substances have been found in the lake system, and such pollution has largely superseded nutrient loading and eutrophication as the most severe form of degradation. Polychlorinated biphenyls (PCBs), one of the most toxic and bio-accumulative families of compounds, are present in many of the AOCs and have been measured at concentrations of 4300 ppm at Sheboygan Harbor in Wisconsin, and much greater than this at Waukegan Harbor, Illinois.

Both the Great Lakes Water Quality Agreement (GLWQA) and the Clean Water Act Amendments of 1987 direct GLNPO to assume a leading role on the Great Lakes contaminated sediment issue. Annex 14 of GLWQA gives GLNPO the following directions:

- To identify the nature and extent of sediment pollution in the Great Lakes ecosystem.
- To develop methods to evaluate the impact of polluted sediment.
- To develop and demonstrate remediative technologies.

The 1987 Clean Water Act Amendments authorized GLNPO to initiate the Assessment and Remediation of Contaminated Sediments (ARCS) Program. The ARCS Program is a 5-year study and demonstration project at five priority AOCs.

Another GLNPO activity is assisting States in developing Remedial Action Plans (RAPs) for AOCs. In addition, GLNPO conducts harbor and estuary sediment sampling to identify problem areas and pollution sources.

A future plan involves sediment sampling away from nearshore areas of the Great Lakes. This will facilitate mass balance modeling and allow development of Lakewide Management Plans as required by GLWQA and the 1987 Clean Water Act Amendments. This work is coordinated with the U.S. EPA Office of Research and Development Laboratories in Duluth, Minnesota, and Grosse Ile, Michigan.

Other new initiatives focus on:

- The importance of contaminated sediments to the overall problem of toxic pollutants in the Great Lakes.

- The significance of pollutant contributions made or potentially made by ground water that is discharged to the Great Lakes.

- The significance of pollutants deposited in the Great Lakes from the atmosphere.

- The development of a Geographic Information System to integrate existing data bases and to provide for analyses of multimedia information in Great Lakes problems.

2.1.4 The Canadian Experience With Contaminated Sediments

Ian Orchard, Environment Canada

There are 17 Areas of Concern (AOCs) designated for cleanup in Canada--12 are solely under Canadian jurisdiction and 5 are jointly managed by Canada and the United States. The Ontario Region office of the Environmental Protection Division of Environment Canada has the lead from the federal government in matters relating to contaminated sediment. Whereas eight U.S. States border the Great Lakes, only one Canadian province (Ontario) borders the system. This facilitates a streamlining of efforts toward remediation and prevention. The Ontario Region office's Ports, Harbors, and Dredging Program addresses contaminated sediments.

Two documents, the Great Lakes Water Quality Agreement (GLWQA) and the Canada-Ontario Agreement (COA), guide Canada's policy on contaminated sediment. The GLWQA is a 1978 U.S./Canada agreement to which 1987 amendments, including Annex 14, were added. Annex 14 requires specific actions and deadlines regarding contaminated sediment management. The Canada-Ontario Agreement facilitates and coordinates Canada's efforts toward honoring its commitments under GLWQA.

In 1986, the COA Polluted Sediment Committee was formed. One committee goal is the development of a standardized assessment procedure that incorporates not only traditional bulk physical and chemical criteria, but also biological criteria. Another goal is the establishment of an action threshold for cleanup. The committee also develops numerical criteria guidelines for sediment assessment. Finally, the committee evaluates options for contaminated sediment management and remediation, including source abatement and sediment treatment technologies. The Assessment, Remediation and Objectives, and Dredging Work Groups carry out these efforts. The COA Polluted Sediment Committee is linked with the U.S. EPA's Assessment and Remediation of Contaminated Sediments Management Advisory Committee and its technical work groups for the purposes of technology transfer and information exchange.

The Great Lakes Action Plan (GLAP) was announced by Canada in 1988 and funded in 1989. Six federal departments participate in the program, which involves the preparation of Remedial Action Plans (RAPs) for the 17 priority AOCs. An important component of GLAP is the Cleanup Fund, a $55 million, 4-year program for RAP implementation in which pollutant sources fall under federal jurisdiction. This federal appropriation may not directly fund capital and operating costs of municipal infrastructures unless it is consistent with the Federal Water Policy. It can, however, co-fund the development and testing of technologies for municipal and industrial section use.

Certain criteria dictate the eligibility of projects for funding by the Cleanup Fund. Projects must support the development and implementation of remedial measures for the 17 AOCs. They must also demonstrate the need for federal participation. Agencies requesting funding must themselves commit substantial resources to the project, and funding partnerships will be sought from federal, provincial, and municipal governments and from the private sector. Further criteria include the project's capacity to reduce pollutant loading, certainty of the project's technical merit, its benefit to the entire Great Lakes Basin ecosystem, and its capacity to restore the beneficial use of or to delist the AOC.

2.1.5 ARCS Engineering/Technology Work Group Status

Stephen Yaksich, U.S. Army Corps of Engineers

The Engineering/Technology (E/T) Work Group is one of four work groups established under the Assessment and Remediation of Contaminated Sediments (ARCS) Program. The ARCS Program is a 5-year demonstration project (1988 to 1992) created by the 1987 Amendments to the Clean Water Act in response to the contaminated sediment problem in the Great Lakes. The E/T Work Group evaluates sediment removal and remediation technologies by conducting bench- and pilot-scale demonstrations. Five Priority Consideration Areas were specified for study in the 1987 Act: Ashtabula River, Ohio; Buffalo River, New York; Grand Calumet River and Indiana Harbor in Indiana; Saginaw Bay, Michigan; and Sheboygan Harbor, Wisconsin. The E/T Work Group efforts are concentrated on those sites.

The E/T Work Group has four defined objectives. The first is to evaluate existing technologies. Evaluative criteria include effectiveness, technical feasibility, the estimated costs, and the level of contaminant loss associated with the technology. The second objective is to demonstrate the effectiveness of the available proven technologies by using bench-scale tests and pilot-scale tests at two or more Areas of Concern (AOCs). The Work Group's third objective is to develop remediative options for the five Priority Consideration Areas. The fourth objective is to develop remediation guidance and methodology to conform to legal and public policy, to characterize material in terms of treatability, and to identify the best technologies for specific sites.

Table 1 presents the technology demonstration status at the Priority Consideration Areas.

TABLE 1. PRIORITY CONSIDERATION AREAS TECHNOLOGY STATUS SUMMARY

Technology	Ashtabula River	Buffalo River	Grand Calumet/ Indiana Harbor	Saginaw Bay	Sheboygan River
Solidification/stabilization		Bench	Bench		
Inorganic treatment/recovery	Bench		Bench	Bench	
Bioremediation	Bench	Bench			Bench, Pilot
KPEG Nucleophillic Substitution	Bench		Bench		Bench
BEST Extraction Process		Bench	Bench	Bench	
CF Systems Solvent Extraction			Bench	Bench	
Incineration			Bench		
Low-Temp. Thermal Stripping	Bench				
Wet Air Oxidation		Bench	Bench		
Eco-Logic Destruction Process					Bench
In Situ Stabilization					Bench, Pilot
Acetone Extraction (ART International)					Bench
Aqueous Surfactant Extraction					Bench
Taciuk Thermal Extraction					Bench
Sediment Dewatering Methods					Bench

Bench-scale demonstrations have been underway since fiscal year 1989 and will continue through fiscal year 1991. Pilot-scale demonstrations will run from fiscal year 1991 through fiscal year 1992. Technology workshops will be held in fiscal years 1990, 1991, and 1992.

Concept plans for the Buffalo and Saginaw Priority Consideration Areas are being prepared during fiscal year 1990. In fiscal year 1991, plans for the final three Priority Consideration Areas will be developed, and data for all five sites will be collected. Options for final remediation of the five areas will be developed in fiscal year 1992.

2.1.6 *SITE Program Overview*

Robert Olexsey, U.S. EPA, RREL

The Superfund Amendments and Reauthorization Act of 1986 (SARA) established the Superfund Innovative Technology Evaluation (SITE) Program. The SITE Program's objectives are as follows:

- To accelerate the development, demonstration, and use of new or innovative treatment technologies.
- To demonstrate and evaluate new, innovative measurement and monitoring technologies.

The SITE Demonstration Program generates performance and cost data on innovative technologies, which facilitates their use as options for hazardous waste remediation. Innovative technologies are fully developed methods whose routine use is precluded by a lack of data from field-scale testing.

The SITE Emerging Technologies Program supports bench- and pilot-scale testing of promising but unproven alternative technologies. Other SITE components include the Monitoring and Measurement Technologies Program and the Technology Transfer Program.

A number of technologies with potential applicability to contaminated sediments are currently in the SITE Demonstration and Emerging Technology Programs. These include bioremediation, physical/chemical treatment, solidification/stabilization, and thermal treatment.

2.1.7 *Panel Discussion: Setting the Scene*

Moderator: Alden Christianson, U.S. EPA, RREL

Members of this panel included John Convery and Robert Olexsey of the U.S. EPA's Risk Reduction Engineering Laboratory (RREL), Mike Conlon of the U.S. EPA's Office of Water Regulations and Standards (OWRS), Paul Horvatin of the U.S. EPA's Great Lakes National Program Office (GLNPO), Ian Orchard of Environment Canada, and Steve Yaksich of the U.S. Army Corps of Engineers (COE). Panel members discussed the availability of information and data concerning contaminated sediments and remediation technologies. Also discussed were goals and targets for remediation efforts.

A draft compendium of treatment technologies is currently under review by the U.S. EPA Science Advisory Board. A literature survey was completed by the Waterways Experiment Station of the Army Corps that reviews sediment remediation technologies for the Great Lakes. The Assessment and Remediation of Contaminated

Sediments (ARCS) Program has compiled actual chemical and biological data in addition to modeling data. Area case histories are also available.

In response to the questions regarding how much money should be spent on contaminated sediment remediation and what target goals should be established, the feasibility of choosing discrete numbers was questioned because such numbers will not be applicable to all situations. This question is now before the Science Advisory Board.

The wide diversity of site-specific conditions was noted. For example, in some lakes PCBs are bound to bottom sediment, whereas those in others may not. In the latter case, PCBs would tend to bioaccumulate because the lake has smaller amounts of sediment. Contaminant concentrations in excess of 50 ppm require special sediment disposal, but this is not an action number. It was noted that the presence of metals in sediment requires confinement because most remediation technologies do not treat metals.

The International Joint Commission (IJC) determines what constitutes an Area of Concern (AOC). The AOC evaluation incorporates an ecosystem approach that uses biological data on fauna from benthic invertebrates to eagles. The need to reemphasize bioaccumulative compounds in evaluation options was stressed.

With regard to the identification of sites for study under the EPA's Superfund Innovative Technology Evaluation (SITE) Program, one possible method involves canvassing regions for voluntary suitable sites. Another prospect would be to coordinate efforts between SITE and ARCS.

2.2 Dredged Materials Removal, Pretreatment, and Disposal

2.2.1 Dredging and Pretreatment Operations for Contaminated Sediments

Steve Garbaciak, U.S. Army Corps of Engineers

Nationally, the U.S. Army Corps of Engineers dredges 365 million yd^3 of sediment each year. This accounts for 71 percent of all dredging conducted in U.S. waterways. In the Great Lakes region, the Corps dredges an annual volume of 4 million yd^3 of sediment.

The two primary methods of dredging are mechanical and hydraulic. Each has its own equipment, uses, advantages, and disadvantages.

Four types of mechanical dredges are commonly used:

- Dipper--used for digging new harbors, not for use in removing contaminated sediments.

- Bucket ladder--used mainly in the mining industry, not applicable to removing contaminated sediment.
- Dragline--also used mainly in the mining industry.
- Clamshell--used extensively in the Great Lakes and has applicability to removing contaminated sediments.

Advantages of mechanical dredges for sediment removal include the following:

- Excavation can proceed at the sediment's in situ water content; no additional water needs to be added for pumping.
- The dredge is highly maneuverable in confined waterways.
- No depth limitations exist for the clamshell dredge.
- All types of debris can be removed.
- Good dredging accuracy can be attained.

Some of the disadvantages of using mechanical dredges for removing contaminated sediment are as follows:

- If proper precautions are not taken, large amounts of sediment can be resuspended into the water column.
- The dredged material must be rehandled at the disposal site.
- Production capacity is generally low.

The three main types of hydraulic dredges are as follows:

- Plain suction
- Cutterhead--a modification of the plain suction dredge, used to break up consolidated material.
- Dustpan--used in fast-flowing rivers.

Hydraulic dredge ships can be designed either to contain the dredge material (hopper ships) or to pipe the material directly to the disposal site.

The advantages of a hydraulic dredge include the following:

- Resuspension of bottom material is limited.
- Dredged material can be piped directly to the disposal area, which eliminates the need for rehandling.
- Production capacity is generally high.

Like mechanical dredges, hydraulic dredges also have certain disadvantages as tools for the removal of contaminated sediments:

- The large volumes of water that are removed with the sediment must be

treated prior to their disposal or release.
- The pipeline is often a significant obstruction to navigational traffic.
- Most debris cannot be removed hydraulically.
- Nonhopper dredges cannot be operated in rough water.

The Corps uses several methods to reduce the environmental impacts of dredging. A fully enclosed clamshell bucket can reduce the amount of resuspension caused by a mechanical dredge by as much as 30 to 70 percent. Barriers such as silt curtains can be used to contain turbidity within the excavation area. Experienced dredge operators can significantly decrease the amount of sediment that is resuspended.

In the selection of a dredge type for the removal of contaminated sediments, four factors should be considered:

- Volume--The volume of material to be removed will determine the scale of operations and the time frame available for removal.
- Location--This factor is especially important in the Great Lakes. Obstacles (such as bridges and shallow water), areal layout of the harbor, and distance to the disposal area are all of interest.
- Material--Consolidated sediments, large amounts of debris, and the contaminants of concern can have an impact on dredge selection.
- Pretreatment--Requirements of the sediment treatment technology (such as drying, sorting, etc.) also must be considered.

2.2.2 Material Handling Research at RREL

Richard Griffiths, U.S. EPA, RREL

In the past, little research has been done at the Risk Reduction Engineering Laboratory (RREL) concerning material handling. Material handling is of prime concern at Superfund sites, however, and research in this area is therefore expanding. One issue concerns controlling air emissions from dust and chemicals in the soil during excavation at Superfund sites. Other issues include the possible excavation of explosives and the intractable behavior of some soils (bridging, swelling, abrasion). Contractors face problems with the handling of materials in continuous or semi-continuous flow processes because of inadequate feed systems. For example, the size of materials may cause them to become jammed in hoppers. Inasmuch as many treatments (e.g., incineration) require low water content, another issue has to do with dewatering of dredged slurries.

One area of research at RREL covers particle measurements. A variety of measurements are possible, especially on solids that can flow. Although smaller size particles are expected to flow, many do not. The research at RREL is attempting to increase the understanding of the properties and handling methods of materials speincrease the understanding of the properties and handling methods of materials specific to Superfund sites to assist contractors at Superfund sites to foresee problems and to choose the appropriate solutions. Measurement parameters that are being considered are mass/weight, volume/flow rate, permeability, porosity, and particle size distribution. The research at RREL will focus specifically on chemical composition, frictional properties, compressive properties, and physical properties such as pH and cation exchange capacity.

Current projects include a broad survey of material handling methods, the development of reactive foams, and the creation of a material properties data base geared toward the handling of these materials. The survey will detail problems encountered at Superfund sites and the equipment available to move materials. Reactive foams blanket the ground to suppress air emissions, and research is targeted to neutralize or precipitate contaminants with these foams. Material properties scheduled for inclusion in the data base are frictional properties, compressive properties, agglomeration tendencies, swelling tendencies, and slurry transport.

2.2.3 Disposal of Dredged Material: Current Practice

Steve Garbaciak, U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers performs maintenance dredging of sediments at navigation projects authorized under River and Harbor Acts. Most dredging equipment can remove sediments much faster than these materials can be treated; therefore, the sediments must be stored prior to treatment. The Corps has had considerable experience in storing dredged material.

Disposal alternatives for dredged material consist of restricted and unrestricted options. Unrestricted alternatives include open-water dumping, upland deposition, and beneficial uses. Restricted alternatives include capping, contained aquatic disposal, and confined disposal. Nationally, only 5 percent of the Corps' dredged material requires restricted disposal options (unsuitable for open water disposal) compared with 50 percent in the Great Lakes area.

Level bottom capping entails making a discrete mound of material with no lateral confinement. Contained aquatic disposal entails lateral confinement. A hole is dug especially for the dredged material, and a lateral cap is placed on the material. For confined disposal, three alternatives exist: upland confined disposal facility (CDF), in-water CDF, and a commercial landfill.

In the late 1960s, open-water disposal of contaminated dredged material was deemed undesirable, which resulted in a diked disposal program that began in 1970. As part of this program, CDF considerations include siting, design, construction, operation, monitoring, and maintenance/construction. Items to consider in the siting of a CDF are the physical aspects (size, proximity to a navigable waterway); the design/construction (geology, hydrology); and the environment (current use of area, environmental value, environmental effects). In the design of a CDF, contaminant pathways must be identified, specific lab tests that the Corps developed for dredged material must be conducted, needs for controls must be evaluated, and an appropriate design must be selected. Some examples of controls for effluent contamination are filtration and polymer flocculation. Controls for ground-water contamination are clay and synthetic liners; controls for air contamination are capping, vegetative cover, and pond management. More than 40 confined disposal facilities have been constructed throughout the Great Lakes.

2.2.4 Research on In Situ Techniques and Their Application in Confined Treatment Facilities

Mike Roulier, U.S. EPA, RREL

The EPA's Superfund research program is currently developing methods for in situ treatment of contaminated soils. This work is motivated by the high cost of managing large volumes of soil with relatively low levels of contamination and by the need to comply with the Superfund Amendments and Reauthorization Act (SARA) and the Resource Conservation and Recovery Act (RCRA).

Major developments in the field have been in biodegradation, stabilization/solidification (S/S), and removal of contaminants. Both biodegradation and S/S are limited by the problem of delivering materials to subsurface soils and achieving uniform mixing. Stabilization/solidification has been used to treat inorganic contamination, but controversy exists over whether S/S processes are chemical processes that result in the formation of new low-solubility compounds or whether they merely retard the release of contaminants through physical processes.

There have been only a few instances of in situ treatment based on aqueous solution chemistry. The contaminants treated have been primarily low-solubility organic compounds, because organic compounds with high aqueous solubility or vapor pressure are transported out of soil by natural processes or are easily removed in water or the vapor phase for above-ground treatment.

For many low-solubility organics, equilibrium thermodynamics indicate that the aqueous liquid phase will contain greater amounts of organic contaminants than will an equal volume of the gas phase. The rates of transfer from the solid to the liquid phase, however, are often slow relative to the rates of transfer into the gas phase. Also, because of the relative densities and viscosities, it is easier to move large volumes of gas through the subsurface than to move equal volumes of liquid. This combination of greater convective flow and more rapid phase transfer makes gas-phase removal an efficient process for many organic compounds, particularly in partially saturated vadose zones, where it is difficult to remove water. For these reasons, it may be useful to examine gas-phase removal for treatment of contaminated sediments.

Several in situ methods for heating soils are being examined. These include injection of steam or hot air, use of radiofrequency fields (similar to microwaves), direct current resistance heating, and passive solar heating. Soil heating coupled with surface collection has been used for gas-phase removal of volatile and semi-volatile organic compounds. Soil heating also appears useful for improving biodegradation rates and for favoring specific classes of organisms.

Currently available in situ technologies do not have any application to treatment of sediments until they have been placed in confined disposal facilities (CDFs) and dewatered. The in situ technologies that are most applicable are (1) soil heating in conjunction with either gas-phase removal or biodegradation and, (2) stabilization/solidification. Soil heating in conjunction with gas-phase removal and S/S has been performed under field conditions; biodegradation has been conducted under field conditions but has not yet been tested with temperature enhancement. None of these technologies have been applied to CDFs but the conditions under which they have been used are sufficiently similar to those in CDFs that there is a high probability for successful application.

2.2.5 *Panel Discussion: Dredged Materials Removal, Pretreatment, and Disposal*

Moderator: John Martin , U.S. EPA, RREL

Members of this panel include Steve Garbaciak of the U.S. Army Corps of Engineers (COE) and Richard Griffiths and Mike Roulier of the U.S. EPA's Risk Reduction Engineering Laboratory (RREL).

A number of questions were posed related to dredging and CDF design. Panelists noted the important control factor of operator experience in dredging. The control of contaminant volatilization during dredging is very difficult. The best approach seems to be to control emissions at the excavation face, either with foam sprays or with water. In situ quick-set stabilization is still a theoretical technology, and no measures of electrokinetic soil treatment efficiency exist in the United States as they do in Europe. Subaqueous capping is feasible where there are preexisting pits (e.g., in New York Harbor). Liners were installed in CDFs in the Chicago area at the request of the State of Illinois.

Other questions pertained to CDF permits, criteria, and monitoring. For the construction of a CDF, the Corps must comply with all Federal environmental laws, including Sections 404 and 401 of the Clean Water Act. Most Corps dredging is conducted by private contractors who must follow specifications developed by the Corps for individual dredging contracts. The EPA and Corps have jointly prepared guidelines for the evaluation of dredged materials under Section 103 and 404 authorities. These guidelines are used for evaluating disposal alternatives. The 1977 EPA Region V Guidelines have been used on the Great Lakes, and the Corps uses bulk chemical and biological testing. Anthracite-sand has proven to be a good filter medium, whereas the fabric filters originally used tend to become clogged with fine particles. No detectable losses of contaminants from CDFs have been ascertained by ground-water or uptake-bag monitoring or by material balance tests. The prospect of the levels of organics in CDFs decreasing with time has not been studied from an organic decay perspective. Only uptake of organics through the food chain has been examined.

An EPA Region V attendee noted that continuous monitoring showed no increase in sediment resuspension underneath silt curtains at depths ranging from 2 to 6 feet at the Sheboygan River site in Wisconsin.

2.3 Extraction Technologies

2.3.1 Review of Removal, Containment, and Treatment Technologies for Remediation of Contaminated Sediments in the Great Lakes

Daniel Averett, U.S. Army Corps of Engineers

Treatment technologies that might be applicable for the remediation of contaminated sediments and should be considered for demonstration under the ARCS Program were identified. Among the characteristics of dredged material that make treatment difficult are high water content, mixture of contaminants, wide range of physical characteristics, low concentrations of contaminants, and large volumes of material.

The Corps has categorized the treatment options into alternatives, components for the alternatives, technologies, and process options. Alternatives to the remediation of contaminated soil are removal and treatment, removal and containment, in situ treatment, in situ containment, or no action. Several components should be considered for those alternatives that require removal of contaminated sediments, including transport of dredged material, disposal of dredged material/residues, and effluent treatment. Factors to be considered in an evaluation of the various technologies are the state of development of a particular process (bench-scale vs. pilot-scale), availability, effectiveness, implementability, and cost. The Corps uses the numerical rating system from the Superfund program to evaluate effectiveness, implementability, and cost of different technologies.

Treatment technologies for remediation of contaminated sediments include biological, chemical, extraction, immobilization, radiant energy, and thermal technologies. Based on its expertise, the Corps reviewed and selected the best technologies in each category. At this stage of evaluation, the Corps deleted from consideration all technologies that were in the early stages of development. The recommended biological process options are aerobic bioreclamation, anaerobic bioreclamation, bioreactors, and composting. These process options are good if the dredged material contains organic constituents/contaminants. The recommended chemical technologies are chelation, nucleophilic substitution, and oxidation of organics. Recommended extraction technologies include acid leaching, Basic Extraction Sludge

Treatment (BEST), CF Systems--propane, Harmon Environmental Services soil washing, and the use of surfactants. The suggested immobilization technologies are chloranan encapsulation, in situ immobilization, lime-based pozzolan immobilization, portland cement-based immobilization, and sorption. Several thermal treatment technologies were recommended, including fluidized-bed incineration, low-temperature thermal stripping, circulating bed combustion, rotary kiln incineration, and wet air oxidation. One problem connected with thermal treatment, however, is the high water content of the dredged material. A pretreatment process such as dewatering may be required. No radiant energy treatment technologies were recommended by the Corps.

2.3.2 *Extraction Technology Research at RREL*

Richard Griffiths, U.S. EPA, RREL

The EPA's Risk Reduction Engineering Laboratory (RREL) has begun to compartmentalize its research by assigning research on specific areas of technology to separate organizational elements of the Lab. The Releases Control Branch in Edison, New Jersey, has been directed to orient its research programs toward processes for extracting contaminants from soil.

The Extraction Technology program has three major subparts: applied research, small-scale experimentation, and pilot-scale experimentation. The applied research will focus on the details of molecule-to-particle bonding, particle-to-particle bonding, avoiding redeposition, and treatment of sidestreams and residues. Specific projects include a concentrated effort under the EPA's Visiting Scientist Program to study the surface chemistry of bonding, experiments to study the kinetics of deposition, and a Research Forum (i.e., workshop) that concentrates on the nature of the problem of separating contaminants from soil.

The small-scale experimentation emphasizes conducting a large number of simple experiments to develop a data base on the range of effectiveness of various extraction processes. Inexpensive, wide-ranging experiments will be conducted to examine the effects of soil type, contaminant type, extractant, pH, temperature, and various physical enhancements. For this to work, the RREL must first identify and select simplified analytical procedures. The analytical procedures currently specified for regulatory purposes take too long to perform and are too expensive.

Nitric acid treatment is currently popular among researchers as a candidate method for extracting metals from soil. We have found, however, that this process tends to create several highly undesirable byproducts (such as nitrogen tetroxide) and produces end products that are not amenable to further treatment. We are considering a more thorough evaluation of acetic acid for lead extraction because it will be safer to use on a large scale, will not produce undesirable byproducts, and is expected to produce tractable end products.

RREL is also beginning to experiment with several components of humic acid in the hope of turning what is now a problem--the tendency of organics to bind tightly to humic materials--into a solution. Other projects will examine various physical enhancements to extraction, such as ultrasonics, low-frequency acoustics, temperature, and surfactants.

Pilot-scale experimentation centers around an apparatus referred to as the Volume Reduction Unit (VRU). The VRU is actually an assembly of several subunits designed to do particle size classification, low-temperature desorption, soil washing, and process-water treatment. One purpose of the VRU is to demonstrate the results of small-scale experiments on larger scale. It is a flexible system which will be used to evaluate various parameters that affect extraction and to conduct process-specific treatability studies for evaluating effectiveness, costs, and support requirements.

2.3.3 Low Energy Solvent Extraction

John Martin, U.S. EPA, RREL

The Low Energy Extraction Process (LEEP) is being developed in conjunction with Enviro-Sciences, Inc., by Applied Remediation Technologies (ART). The LEEP technology uses an organic solvent to extract pollutants from a variety of waste matrices. The organic pollutants are first removed from the solid matrix by a hydrophilic, water-leaching solvent and then concentrated in a hydrophobic, water-immiscible, stripping solvent. The leaching solvent can be recycled; however, the stripping solvent must be disposed of.

The LEEP technology, which can treat PCBs and other organics in soils, sludges, and sediments, consists of the following steps:

- Prescreening to remove debris and rinsing of the coarse fraction
- Absorption treatment of rinse water
- Leaching treatment of contaminated fines
- Drying of treated solids
- Liquid/liquid extraction treatment of contaminated leaching solvent
- Recovery of leaching solvent
- Disposal of contaminated stripping solvent

Applied Remediation Technologies has conducted bench-scale testing of the LEEP technology at Waukegan Harbor. Sediments containing ~3200 ppm of PCBs have been treated to a level of 1 ppm. The investigators have focused on studying mass transfer rates and using different leaching solvents (acetone, isopropanol, and methanol). A pilot-scale unit capable of treating 30 to 50 tons/hour is planned.

The advantages of this treatment technology are as follows:

- Converts a high-volume solid waste stream to a low-volume liquid waste stream.
- Operates at ambient conditions.
- Involves simple process and equipment.
- Has low energy requirements.

Limitations include:

- The stripping solvent effluent requires further treatment.
- Leaching solvent is contaminant-specific.

2.3.4 Solvent Extraction Using the BEST Process

Mark Meckes, U.S. EPA, RREL

The Basic Extraction Sludge Treatment (BEST) technology is being developed for hazardous waste treatment by the Resources Conservation Company of Bellevue, Washington. The basic components of the BEST unit are a washer/dryer, a decanter, a solvent evaporator, and a water stripper.

The types of wastes that can be treated by the BEST technology include oily sludges and organics-contaminated soils and sediments. The waste is treated with the solvent triethylamine to separate oil from water and solids. Upon extraction the process produces the following:

- An incinerable waste oil fraction
- A dry, pathogen-free, solid fraction
- A water fraction that can be discharged to a publicly owned treatment works (POTW)

This technology reduces the total volume of hazardous wastes but does not destroy any hazardous constituents in the waste.

A full-scale demonstration unit was used at the General Refining Site in Savannah, Georgia. A 100 tons/day unit was used to treat PCB-contaminated oily sludges. A high degree of separation was achieved. Problems with the unit included leakage of the triethylamine and pumpability of the waste.

Treatment costs for the BEST technology depend on the waste volume and range from $400/yd^3 for 1000 yd^3 of waste to less than $150/yd^3 for 20,000 yd^3 of waste.

2.3.5 *Liquefied Gas Extraction Using the CF Systems Process*
Laurel Staley, U.S. EPA, RREL

CF Systems Corporation has developed an organic extraction process and demonstrated it at the New Bedford Harbor Superfund Site in New Bedford, Massachusetts. This process uses propane and butane at conditions near the critical point. These conditions are used because a liquid approaching its critical point is able to dissolve large amounts of organic substances. It also behaves as a gas, which allows high rates of extraction. The properties of critical fluids make them particularly useful for removing organic contaminants from soils.

Appropriate waste streams for this technology are pumpable streams containing 10 to 25 percent organics (e.g., harbor waste). Highly water-soluble compounds, highly polar organics, low-concentration organics, and heavy metals are not readily treatable by this process.

Potential applications of a liquified gas extraction system are for the extraction and separation of organics from pit sludges, for separation and recycling of valuable oils, and as a volume reduction step prior to incineration. Results of the demonstration tests at New Bedford showed that PCBs were successfully extracted; however, extraction of PCBs is difficult to prove at low levels.

Residue generation from this process can be significant. The demonstration tests began with 3 drums of contaminated sediment, but produced 57 drums of residues. Six drums contained toluene; 6, toluene/rinse water; 2, fuel/residue; 15, sediments; 8, sediments/rinse water; and 20 decontamination water. For reduction of the volume of residue generated, waste minimization must be considered. Treatment costs range from \$150 yd^3 for material containing less than 1000 ppm halogenated organics to \$400/yd^3 for material containing more than 1000 ppm.

2.3.6 *Panel Discussion: Extraction Technologies*
Moderator: Jonathan Herrmann, U.S. EPA, RREL

Members of this panel included Daniel Averett of the U.S. Army Corps of Engineers, and Richard Griffiths, John Martin, Mark Meckes, and Laurel Staley, all of the U.S. EPA's Risk Reduction Engineering Laboratory (RREL). Panel members responded primarily to questions about the technologies they had presented previously.

The Low Energy Extraction Process (LEEP) is a countercurrent process that was designed specifically for treating contaminated sediments. It is currently being used on sediments at a site on the Hudson River. One problem associated with this particular sediment is its unusually small particle size, which causes it to exhibit poor settling even after several days. When LEEP is used for treatment, fines are carried over into the solvent because of the small particle size of the sediment. Handling this kind of sediment requires careful control of feed rates. The LEEP process has been used to treat sediments with water contents below 50 percent. In fact, researchers are currently attempting to treat sediments that are 30 percent water.

The LEEP process, which is designed to be mobile, will ultimately be able to process 30 to 50 tons per hour. Mobility of treatment processes is viewed as desirable under the SITE program because the entire process can be contained on site, thus eliminating the need for transporting the hazardous waste to a second location. Concern about the extensive use of solvent is obviated by the solvent recovery and reuse inherent to the LEEP process. The system is designed to comply with National Fire Prevention Association (NFPA) code specifications.

Particle size fractionation studies have not yet been conducted on the Basic Extraction Sludge Treatment (BEST) process; therefore, the level of fines that can be handled by the process is not known. Treatability studies are needed to determine this information. Another item requiring additional study is the use of the flammable liquid triethylamine in the BEST process. During a treatment demonstration, triethylamine leaked through the centrifuge seal and was released to the atmosphere. Operators were required to wear a self-contained breathing apparatus. This problem was minimized in the pilot-scale project by using a washer/dryer system, which obviates the need for centrifugation of the solids.

With regard to the CF Systems Solvent Extraction Process, the sludge was mixed with large amounts of water to decrease viscosity. The process occurs at the solvent's critical point because of the different characteristics exhibited by the solvent at this temperature and pressure. For example, water at its critical point dissolves organic compounds. Propane and butane are more effective solvents at their critical points than water. As measured by organic vapor analysis, loss of propane and butane was minimal during treatment. Because propane and butane are gaseous at room temperature, they displace oxygen and may pose an asphyxiation hazard. They are, therefore, a safety hazard on site. Cost estimates of $150 to $450 per cubic yard do not include disposal of treated material.

Inadequate analytical methods may be a growing problem for evaluating new technologies. The commonly used methods for determining the concentrations of contaminants in soil involve solvent extraction followed by analysis of the extractant. Unfortunately, these solvents cannot achieve 100 percent extraction. In fact, numerous tests have shown that their "recovery efficiency" is often in the range of 60 to 80 percent, depending on the compound to be extracted. Therefore, two issues must be raised in attempts to evaluate Soil/Sediment treatment technologies: 1) Does it make sense to base evaluations of extractive technologies on extractive analytical procedures that face some of the same limitations as the extractive technologies themselves? 2) Can the results of an evaluation of an extractive technology be compared with the results of other nonextractive technologies (e.g., incineration)? We may conclude that existing analytical methods are sufficient for regulatory purposes, but not for research and development.

2.4 Biological/Chemical Treatment Technologies

2.4.1 Biodegradation of Chlorinated Aromatic Hydrocarbons

John E. Rogers, U.S. EPA, ERL Athens, Georgia

The state of the art is not sufficiently developed to present specific biodegradative technologies for treating contaminated sediments. This presentation provides information on progress made to date in understanding biochemical mechanisms of contaminant degradation.

Sediment obtained from a local pond contains microorganisms that degrade two dichlorophenols, 2,4-dichlorophenol and 3,4-dichlorophenol, into monochlorinated phenols in the para and meta positions, respectively. Studies indicate that adapting the indigenous microflora to either of the compounds is possible. The first period of contaminant removal might take as long as 12 weeks, whereas comparable removal of subsequent contaminant spikes may require only 1 week.

The following data were gathered from experiments in which sediment was adapted to 2,4-dichlorophenol:

- Degradation of 2,3-dichlorophenol yields primarily 3-chlorophenol and some 2-chlorophenol.
- Degradation of the 2,4- compound yields 4-chlorophenol.
- Degradation of the 2,5- compound yields 3-chlorophenol.
- Degradation of the 2,6- compound yields 2-chlorophenol.
- Degradation of the 3,4- compound usually yields 3-chlorophenol and (rarely) 4-chlorophenol.
- Degradation of the 3,5- compound yields 3-chlorophenol.

The following data were gathered from experiments in which sediment was adapted to 3,4-dichlorophenol:

- Degradation of 2,3-dichlorophenol yields 2-chlorophenol.
- Degradation of the 2,4- compound yields both 2- and 4-chlorophenol.
- Degradation of the 2,5- compound yields 3-chlorophenol.
- Degradation of the 2,6- compound yields 2-chlorophenol.
- Degradation of the 3,4- compound yields 3-chlorophenol.
- Degradation of the 3,5- compound yields 3-chlorophenol.

These results point to the presence of two distinctly different pathways for degradation of the dichlorophenol compounds.

The results of pentachlorophenol (PCP) addition to adapted sediments indicate that dechlorination progressions differ depending on whether the sediment is adapted to 2,4- or 3,4-dichlorophenol. Sediments adapted to 3,4-dichlorophenol first remove the chlorine in the para position, whereas those adapted to 2,4-dichlorophenol first remove the ortho chlorine. These results are consistent with those just described.

The results are especially significant in light of the fact that 3,4,5-trichlorophenol is quite toxic and should be avoided in PCP degradation if possible. Results have shown that formation of this compound can be bypassed by first removing the para chlorine, as shown in sediments adapted to 3,4-dichlorophenol.

Additional testing has also been performed on sediment from the East River (New York) and Borok Lake (Russia). Similar patterns of acclimation have been duplicated. Stepwise dechlorination of hexachlorobenzene and 2,4-dichlorophenol compounds is also being investigated.

2.4.2 Chemical Treatment Research at RREL: Base Catalyzed Decomposition

Carl Brunner, U.S. EPA RREL

A major focus of the chemical treatment research being conducted at EPA's Risk Reduction Engineering Laboratory (RREL) is on the Base Catalyzed Decomposition (BCD) Process. The BCD Process uses a reagent formed by the combination of a base and a hydrocarbon solvent to dechlorinate chlorinated organics.

The BCD Process is the latest development in a series of dechlorination method studies that originated with the Alkali-Polyethylene Glycol (APEG) treatment technology. The chemistry of the BCD Process is quite different from APEG chemistry, however, in that it no longer requires the use of polyethylene glycol. The APEG process requires the use of large amounts of reagent and reaction temperatures of between 150 and 180°C. For the process to be cost-effective, the APEG reagent must be recovered.

Despite shortcomings of the APEG technology, full-scale soil treatment demonstrations have been conducted at several sites, including a U.S. Navy site in Guam. The PCB removal testing at Guam used a 400-gallon batch reactor heated to 150°C. Initial PCB concentrations in the soil ranged from 1010 to 1990 ppm. After 4 hours of treatment, more than 99.99 percent of the PCB was removed.

Attempts to reduce requirements for large amounts of chemicals in the APEG Process have led to several improvements, including development of the new BCD Process. Significant reductions in the cost of chemicals required for treatment have been achieved in this process.

A BCD Process Demonstration Unit is being constructed to continue the PCB treatment work at the U.S. Navy's Guam site. The design criteria for this unit are:

- Continuous operation
- One-ton-per-hour throughput
- Treatment of soil composed of clay, silt, sand, coral, and limestone and containing 20 percent moisture
- Reduction in PCB concentrations from 5000-6500 ppm to <2 ppm

Bench-scale tests of the BCD Process have demonstrated that effective PCB removal from soil can be achieved at reaction temperatures above 250°C for residence times greater than 30 minutes by using reagent concentrations of approximately 3 lb base and 1.0 lb solvent per 100 lb soil. Because the reactor is open to the atmosphere, some of the PCB is volatilized during treatment and must be collected and processed separately.

Use of the BCD Process for treatment of contaminated sediments in the same manner as is currently contemplated for soil treatment may require the evaporation of large amounts of water. To avoid this, operations could be conducted in a pressurized system. Reaction temperatures of 300°C would require an approximate reactor pressure of 1300 psi. Studies are underway to determine the practicality of such an arrangement. Successful operation in a pressurized reactor would eliminate the need for separate treatment of contaminants that would volatilize in a reactor operating at atmospheric pressure.

Another approach to using the BCD Process for sediment treatment would involve extraction of contaminants from sediment followed by chemical treatment of the concentrated extract. Several extraction processes are being developed that could apply to sediment.

Precise cost estimates are not available, but based on chemical costs for the BCD Process, total costs as low as $200 per dry ton may be obtainable. This makes the BCD Process a strong potential competitor to incineration. A company is currently being selected to market the BCD process.

2.4.3 Biological Technologies in the SITE Program

Ronald F. Lewis, U.S. EPA, RREL

Zimpro/Passavant, Inc., of Rothschild, Wisconsin, is demonstrating its process for biodegradation of organic contaminants at the Syncon Resins Superfund Site in Kearny, New Jersey. The combination of a traditional activated sludge process with a powdered activated carbon treatment adsorption unit and a wet air oxidation unit for further treatment of waste sludge permits treatment of aqueous waste streams with contaminant concentrations in excess of 1 percent.

Motec, Inc., of Juliet, Tennessee, has developed the Liquid-Solid Contact Digestion Process in which organic contaminants, including halogenated organics and some pesticides, are biodegraded. Waste is introduced via aqueous slurry to a bio-reactor, where it is mechanically agitated to suspend solids and to maintain optimum environmental conditions.

An above-ground, fixed-film bioreactor is used by Detox, Inc., of Dayton, Ohio. This reactor is designed to treat low concentrations (<20 ppm) of biodegradable contaminants such as ketones, benzene, toluene, and xylene. It is not applicable for some halogenated compounds. After aerobic metabolism, wastewater may be further treated by cartridge and activated carbon filters.

ECOVA Corporation of Redmond, Washington, is testing its in situ biotechnology at the Goose Farm Superfund Site in Plumstead Township, New Jersey. The process, in which aerobic bacteria use chlorinated or nonchlorinated toxic organics as their carbon source, can be duplicated in a bioreactor when soil impermeability precludes in situ treatment. At Goose Farm, oxygen and nutrients will be introduced to the soil to foster bacterial growth, and ground water will be captured at a down-gradient extraction well and recharged repeatedly through the contaminated zone.

The Biotrol Aqueous Treatment System developed by Biotrol, Inc., of Chasta, Minnesota., has been demonstrated at the MacGillis and Gibbs Superfund Site in New Brighton, Minnesota. The system uses a fixed-film bioreactor to which specific micro-organisms may be added to degrade target contaminants. Preliminary cost estimates for this technology are available. The device treats ground water or process water contaminated with soluble organic compounds such as hydrocarbons and penta-chlorophenol, and it may prove applicable to fuels and solvents leaking from under-ground storage tanks.

The AlgaSORB sorption technology of Bio-Recovery Systems, Inc., Las Cruces, New Mexico, is in the Emerging Technology Program. The process, tested at a mercury-contaminated site in Oakland, California, removes heavy metal ions from aqueous solutions. Algal cells in a silica gel medium are packed in columns through which water passes. Heavy metal ions adhere to the algae. When they are sub-sequently stripped away by reagents, a small volume of highly toxic solution and reusable algae/gel remain.

Preproposals being evaluated for the Emerging Technology Program include processes for the treatment of highly chlorinated solvents such as chloroform and trichloroethylene.

2.4.4 Panel Discussion: Biological/Chemical Treatment Technologies
Moderator: Dennis Timberlake, U.S. EPA, RREL

Members of this panel included John Rogers of the U.S. EPA Environmental Research Laboratory in Athens, Georgia, and Carl Brunner and Ron Lewis of the U.S. EPA Risk Reduction Engineering Laboratory (RREL). Discussions dealt with aspects of recently developed biological and chemical technologies for remediation of contaminated sediments.

Developing biological technologies from bench-scale to field-scale is difficult because acclimation of microbes does not occur as easily in the field as it does in the laboratory. Whereas contaminant concentrations tend to be higher under controlled conditions and restricted to a single compound, several contaminants in somewhat lower concentrations are usually found under field conditions. In the field, larger numbers of microbes are usually found around the periphery of contaminated areas. Within the contaminated area, high pollutant concentrations normally have a toxic effect on microbial populations. Proliferation of microorganisms is usually limited by the lack of availability of an electron acceptor (e.g., oxygen, nitrate) and a primary carbon source. When the contaminant concentration is not high enough to allow microbial growth, supplying these factors often facilitates growth and the associated degradation of contaminants.

Microbes that degrade contaminants include bacteria and fungi. These may be found as natural organisms either preexisting or indigenous to the site, or they may be conventional mutants acclimated under controlled conditions. Microbes from another source may be added to an experiment to enhance initial rates of degradation and to facilitate a process whereby indigenous microbes eventually become the primary degraders. Under natural conditions, the addition of an electron acceptor and major nutrients (e.g., nitrogen and phosphorus) is necessary to enhance microbial degradation sufficiently for significant contaminant removal and site remediation.

Mixing the sediment increases degradation rates by improving access of the microbes, which normally exist in the aqueous fraction, to the contaminants, which are normally found in the organic soil fraction. Because it enhances contact between the aqueous and organic fractions, the use of a surfactant improves the rate of contaminant degradation. The surfactants themselves must be either biodegradable or non-toxic so their use does not increase the hazards associated with a site. Such a surfactant may then be left on-site subsequent to treatment.

The bioslurry reactor was discussed as the best option currently available for treating sediments that contain high concentrations of oil. It has been used successfully in 15 to 20 percent soil slurries. Soil tillage methods are more useful for materials containing higher concentrations of solids in which biodegradation will occur more slowly.

Pesticides are difficult to extract and treat, especially at low concentrations. The Base Catalyzed Decomposition (BCD) process may be useful for dechlorinating chlorinated pesticides.

2.5 Other Technologies of Interest

2.5.1 Low-Temperature Thermal Treatment

Paul DePercin, U.S. EPA, RREL

In low-temperature thermal technologies, temperatures can range from 200 to 1000°F. Most are indirectly fired. Indirect heating reduces the amount of gases involved, increases efficiency, and permits the unit to be transported. The three types of processes are rotary dryer, heated screw auger, and fluidized-bed.

This technology requires a feed consisting of solids with less than 20 percent organics and a 10 to 40 percent moisture content. A feed with a moisture content of less than 10 percent is not as effective because water evaporation helps to remove heavy organics. Thermal treatment does not work well on organic polymers, tars, and pitches.

The two choices for handling of residuals are condensation and adsorption or combustion. The drawback to combustion is that it might be subject to hazardous waste incineration regulations that require destruction efficiencies of 99.99 percent or 99.9999 percent. Protocols for two levels of treatability studies--muffle furnace and pilot-scale studies--are being developed.

Treatment facilities in both the United States and Europe have produced favorable results, as demonstrated by the following examples:

1) In the Netherlands, an initial concentration of 30,000 ppm aliphatics in sand was reduced to less than 20 ppm at 800°C at Marneveld. At Schiedam, a concentration of 60,000 ppm cyanide complexes in loamy sand was reduced to less than 5 ppm at 800°C.

2) Superfund Best Demonstrated Available Technology (BDAT) studies using synthetic soils (SARM I and SARM II) demonstrated significant reductions in organic concentrations. In the SARM I tests, acetone concentrations were reduced from 4330 to 71 ppm at 550°F.

3) Chemical Waste Management's pilot-scale facility reduced the polychlorinated biphenyl (PCB) concentration in a sandy soil from 1480 to 8.7 ppm.

4) The Hazardous Waste Research and Information Center Gas Plant Study

demonstrated significant reductions of polyaromatic hydrocarbons (PAHs) in different soils at 300°F and 400°F. Greater reductions in PAH concentrations occurred at the higher temperature.

Low-temperature thermal technologies have been shown to be effective for treating certain wastes containing volatile and semivolatile organics, volatile metals, nonvolatile organics (PCBs, PCPs), and cyanides.

2.5.2 *UV/Ozonation SITE Project*

Norma Lewis, U.S. EPA, RREL

Ultrox International in Santa Ana, California, developed an ultraviolet (UV) radiation/oxidation technology to treat ground water contaminated with volatile organic compounds (VOCs). This treatment technology was evaluated in the field at the Lorentz Barrel and Drum site in San Jose, California, as part of the Superfund Innovative Technology Evaluation (SITE) program.

The UV/Oxidation technology uses ultraviolet light, hydrogen peroxide, and ozone to photooxidize water-soluble organic compounds. Advantages of this process include its ability to accommodate ground water, industrial waste waters, and leachates in the reactor; economical treatment of volatile, semivolatile, and nonvolatile compounds; and the convenience of a skid-mounted, portable system. Some limitations also exist. For example, this technology targets liquids and cannot treat sludges or solids. Bicarbonate levels may slow the reaction time, and metal compounds in concentrations above 20 ppm may interfere with the process and require pretreatment. Appropriate waste streams are liquids contaminated with the EPA's Priority Pollutant organic contaminants. This system destroys toxic or refractory compounds and chlorinated hydrocarbons.

Basic components of the system are the Ultrox UV/Oxidation Reactor module with UV lamps in quartz sheaths and vertical baffles, the air compressor/ozone generator module, and the hydrogen peroxide feed unit.

The Ultrox system achieved greater than 90 percent removal of VOCs. Most of the VOCs were removed through chemical oxidation; however 1,1,1-trichloroethane and 1,1-dichloroethane were also removed by stripping. The treated ground water at the site met the National Pollutant Discharge Elimination System (NPDES) effluent standards for discharge into the local waterway at a 95 percent confidence level. No VOC emissions from the Ultrox system were detected and no new VOCs, semivolatiles, PCBs, or pesticides were detected in the effluent.

2.5.3 *Solidification/Stabilization of Dredged Materials and Sediment*

Tommy Myers, U.S. Army Corps of Engineers

Solidification is the process of eliminating free water in a semisolid by hydration. Physical stabilization is defined as the immobilization of a contaminated solid through alteration of its physical properties to produce a dimensionally stable product. Chemical stabilization is the alteration of the chemical form of the contaminants in a semisolid to make them less soluble or reactive.

Several different setting agents are available for solidification/stabilization (S/S) treatment. The most commonly used agents (individually or in combination) are as follows:

- Portland cement
- Kiln dust
- Slag
- Lime
- Soluble silicates
- Organic clays

Two properties affect the primary containment of hazardous constituents within the S/S-treated product:

- Permeability--effective porosity of the solidified product
- Durability--strength of the product

Secondary containment is accomplished by chemical stabilization of the contaminants. This can occur through the following mechanisms:

- Conversion to a less soluble form
- Adsorption
- Chemisorption
- Passivation
- Entrapment
- Microencapsulation

Solidification/stabilization of contaminated sediments may be implemented either in situ or after dredging. To date, however, the Corps has no field experience in applying either strategy to contaminated sediments.

2.5.4 *Panel Discussion: Other Technologies of Interest*

Moderator: Steve James, U.S. EPA, RREL

Members of this panel included Paul dePercin and Norma Lewis of the U.S. EPA, Risk Reduction Engineering Laboratory (RREL), and Tommy Myers of the U.S. Army Corps of Engineers (COE). Panel members responded primarily to questions directly related to the technologies covered in their presentations.

No costs are yet available for the low-temperature thermal treatment technologies; however, these costs are expected to be much lower than those for incineration. Retention time in the reactor will vary from 5 to 30 minutes, depending on throughput. As opposed to incineration, no dioxin or furan formation is associated with this technology because no oxidation of contaminants occurs.

Although solidification/stabilization is not yet a proven technology for contaminated sediments and dredged materials, significant interest has been shown in its use for sediments. It has been used in Japan for treatment of sediments, and it has been used extensively in the United States for treatment of hazardous wastes. The most significant problem is the uncertainty regarding the chemical stabilization of organic compounds. Laboratory studies suggest that these technologies do satisfy certain treatment objectives, but there is a complete absence of long-term monitoring data indicating no movement of contaminants.

With regard to ultraviolet (UV) radiation/ozonation technologies, ozone and hydrogen peroxide are used to accelerate oxidation by introducing free radicals. This technology has been used elsewhere to treat drinking water. Excalibur Enterprises, Inc., will be demonstrating a UV/ozonation technology in the Fall of 1990 at the Coleman Evans Site in Jacksonville, Florida. It may be of particular interest for treatment of contaminated sediments.

The Zimpro-Passavant wet air oxidation process requires high temperature and pressure to oxidize organic compounds in the presence of air. Wet air oxidation may cause a corrosion problem in the reactor vessel because of the corrosive nature of the oxidant. Consideration has been given to the use of deep vertical reactors (1 mile into the ground) which provide a high hydrostatic pressure for a kind of supercritical wet air oxidation process.

An alternative for remediation of mercury in contaminated sediments may be solidification. Research into mercury removal is currently being conducted at Utah State University and is now in the proof-of-concept stage.

SECTION 3

OPEN DISCUSSION: FUTURE DIRECTION FOR CONTAMINATED SEDIMENTS TREATMENT

Moderator: Alden Christianson, U.S. EPA, RREL
Contributors: M. Conlon (OWRS), M. Kravitz (OWRS), T. Wall (OWRS)

3.1 Introduction to Open Discussion

For the final session of the workshop, participants were invited to submit questions for discussion. Most of the questions reflected the need for additional research and improved data, and the development of Agency policy to address these needs. They discussed overall approaches to pollution prevention and forthcoming strategies, the development of criteria for action and target levels, monitoring requirements, cost/benefit concerns, short-term vs. long-term considerations, and the need for characterization of ecosystems.

A synthesis of representative questions yields the following:

- What biological/chemical criteria and protocols should be used to determine action levels and treatment effectiveness? Is EPA reviewing and revising its risk assessment methodology?

- Are plans currently in place to conduct treatability studies on contaminated sediments? How can performance data collection efforts be enhanced and the data be made available?

- Are treatment technologies being developed for contaminated sediments that contain mixed wastes (i.e., organic compounds, metals, and radioactives)? Is information forthcoming on process trains to treat sediments contaminated with both metals and organic compounds?

- Would an improved understanding of the natural environment and chemical behavior in that environment facilitate the development of more efficient treatment methods?

- Given the likely increased consideration of food-chain effects from contaminated sediments that will result from the new EPA Sediment Strategy, what is being done to increase the focus on technologies predominantly applicable to wet materials?

- Inasmuch as the waterways have been repositories for all kinds of wastes, do guidelines exist for protection of people during laboratory investigation, treatment, and posttreatment phases of projects involving waterway sediments?

- Can new technologies being evaluated under the SITE Program be applied to corrective action at RCRA facilities and other non-Superfund sites (e.g., contaminated sediment sites)?

- Will disposal of treatment residuals be covered under existing NPDES permits?

Workshop participants were also concerned with costs:

- Will greater costs be generated by treating rather than confining sediments, or will long-term maintenance and monitoring costs outweigh those generated by permanent contaminant destruction (e.g., by thermal or biological treatment)?

- How are the treatment and management of residuals (e.g., contaminated wash water, clothing, incinerator ash) figured into measurements of cost and overall effectiveness of decontamination efforts?

- With treatment costs rising above $100/yd^3, should regional treatment complexes be considered to achieve economy of scale?

The following question highlights the importance of communication among involved parties:

- Are all participants in contaminated sediments cleanup efforts (e.g., EPA Headquarters, RREL, SITE Program, RCRA, Corps of Engineers, Bureau of Mines, NPDES Enforcement, NOAA) working to prevent duplication of efforts? Would it be appropriate to establish a newsletter for all involved parties, included Regions, States, and local governments?

The remainder of this section attempts to provide answers to many of these questions.

3.2 Assessment of Sediment Quality and Development of a Sediment Management Strategy

3.2.1 Assessment of Sediment Quality

The Sediment Classification Methods Compendium, prepared by EPA's Sediment Oversight Technical Committee, describes the various methods used to assess the quality of potentially contaminated sediments. The compendium provides a description of each method, associated advantages and limitations, and existing applications.

The sediment quality assessment methods described can be classified into two basic types: numeric or descriptive (Table 2). Numeric methods are chemical-specific and can be used to generate numerical sediment quality values. Descriptive methods are not chemical-specific and cannot be used alone to generate numerical sediment quality values for particular chemicals.

In a sediment bioassay, mortality (or other biological endpoint) of test organisms exposed to sediment from a site with suspected contamination is compared with mortality in an analogous reference sediment. Bioassays can be used to evaluate either acute or chronic toxicity. Ideally, assessment of a site should be performed by using several species (i.e., several different bioassays). The American Society of Testing Materials (ASTM) is currently working on standardized testing protocols for a number of species. Other methods discussed in the compendium include the Equilibrium Partitioning (EqP) and Apparent Effects Threshold (AET) approaches, the Tissue Residue approach, and the Sediment Quality Triad.

The EqP approach uses water quality criteria and partitioning coefficients (between sediment and pore water) of specific contaminants to derive a sediment quality value. The sediment quality value for a given contaminant is determined by calculating the sediment concentration of the contaminant that would correspond to a pore water concentration equivalent to the EPA water quality criterion for the contaminant. EqP-derived sediment quality values will soon be available for a number of nonionic organic chemicals, and research is continuing on development of values for metals.

The Sediment Quality Triad approach uses measures of sediment chemistry, sediment toxicity, and benthic infauna community structure to identify pollution-induced degradation. In the AET approach, biological data (e.g., benthic community structure or laboratory bioassays) and chemical analyses of contaminants in sediments are used to identify concentrations of specific chemicals above which specific biological effects would always be expected.

TABLE 2. SEDIMENT QUALITY ASSESSMENT METHODS[a]

Method	Type			Concept
	Numeric	Descriptive	Combination	
Bulk Sediment Toxicity		x		Test organisms are exposed to sediments that contain unknown quantities of potentially toxic chemicals. At the end of a specified time period, the response of the test organisms is examined in relation to a specified biological endpoint.
Spiked-Sediment Toxicity	x			Dose-response relationships are established by exposing test organisms to sediments that have been spiked with known amounts of chemicals or mixtures of chemicals.
Interstitial Water Toxicity	x			Toxicity of interstitial water is quantified and identification evaluation procedures are applied to identify and quantify chemical components responsible for sediment toxicity. The procedures are implemented in three phases: 1) characterization of interstitial water toxicity, 2) identification of the suspected toxicants, and 3) confirmation of toxicant identification.
Equilibrium Partitioning	x			A sediment quality value for a given contaminant is determined by calculating the sediment concentration of the contaminant that would correspond to an interstitial water concentration equivalent to the U.S. EPA water quality criterion for the contaminant.
Tissue Residue	x			Safe sediment concentrations of specific chemicals are established by determining the sediment chemical concentration that will result in acceptable tissue residues. Methods to derive unacceptable tissue residues are based on chronic water quality criteria and bioconcentration factors, chronic dose-response experiments or field correlations, and human health risk levels from the consumption of freshwater fish or seafood.
Freshwater Benthic Community Structure		x		Environmental degradation is measured by evaluating alterations in freshwater benthic community structure.
Marine Benthic Community Structure		x		Environmental degradation is measured by evaluating alterations in marine benthic community structure.
Sediment Quality Triad	x	x	x	Sediment chemical contamination, sediment toxicity, and benthic infauna community structure are measured on the same sediment. Correspondence between sediment chemistry, toxicity, and biological effects is used to determine sediment concentrations that discriminate conditions of minimal, uncertain, and major biological effects.

(continued)

TABLE 2 (continued)

Method	Type			Concept
	Numeric	Descriptive	Combination	
Apparent Effects Threshold	x		x	An AET is the sediment concentration of a contaminant above which statistically significant biological effects (e.g., amphipod mortality in bioassays, depressions in the abundance of benthic infauna) would always be expected. AET values are empirically derived from paired field data for sediment chemistry and a range of biological effects indicators.

[a] Adapted from the U.S. Environmental Protection Agency. 1989. Sediment Classification Methods Compendium. Draft Final report.

In the Tissue Residue approach, acceptable levels of contaminants in biota are determined (i.e., acceptable in terms of consumption by humans, or the health of the particular species). The relationship between sediment and tissue contaminant concentrations (e.g., accumulation factors) is then used to determine acceptable sediment concentrations.

It is important to remember that the approaches to sediment quality assessment discussed in the compendium are not at an equal stage of development, and each has associated advantages and limitations. Hence, certain approaches (or combinations) are more appropriate for specific management actions than are others.

3.2.2 Development of a Sediment Management Strategy

The EPA is now developing a number of issue papers that will provide the basis for an Agency-wide sediment management strategy. The 14 issue papers listed here are currently being prepared by four Agency work groups.

Work Group on Assessment and Identification of Risk

- Summary of Information on Risks
- Need for a National Inventory of Contaminated Sites and Facilities Contributing to Sediment Contamination
- Need for a System to Rank Sites and Facilities for Followup Action
- Development of a Consistent Approach to Assessing Sediment Quality

Work Group on Prevention of Sediment Contamination

- Controlling Point Sources
- Controlling Nonpoint Sources
- Evaluating the Role of Pesticides in Contaminated Sediments
- Evaluating the Role of Toxic Compounds in Contaminated Sediments

Work Group on Remediation

- Roles and Responsibilities for Remediation
- Consistent Identification of Sediments Requiring Remediation
- Development of Consistent Target Levels for Cleanup Actions
- Evaluation of Authorities for Enforcement-Based Remediation

Work Group on Managing Dredged Materials

- Balancing Environmental and Economic Factors
- Applicability of RCRA to Dredged Materials

With the exception of the summary of risk information, each of these papers discusses a range of options, from no action to comprehensive, full-scale sediment management. The current schedule calls for meetings among Federal Agencies and a single State representing each EPA region to discuss related issues and options during Fall 1990.

3.3 Identification of Applicable Technologies

The EPA has increased its focus on treatment technologies for contaminated sediments. Workshops such as this one are being scheduled to gather information and to provide a forum for experts to meet and discuss recent developments.

In response to the overwhelming need for guidance, data collection is planned to begin on innovative processes and control technologies. Data will be collected from bench-, pilot-, and full-scale studies and be entered into currently existing data bases that are in the process of being expanded to accept information on soil and sediments.

A screening assessment of various technologies is contained in a report currently undergoing review by the Assessment and Remediation of Contaminated Sediments (ARCS) Engineering Technology Work Group.

Bench-scale testing of selected treatment methods is scheduled to begin within the next 6 months. This work will be performed under the ARCS Quality Assurance/ Quality Control Program and is expected to provide valuable and much needed treatability information. Selected technologies will subsequently be scheduled for pilot-scale testing.

With regard to solidification/stabilization, data generated on these technologies in the past by the Atomic Energy Commission (AEC) may be useful for contaminated sediment applications.

A question was posed as to whether EPA plans to recycle or reclaim metals in contaminated sediments. The Bureau of Mines conducted studies for ARCS and the Superfund program on metals reclamation. With the exception of high concentrations of iron in Indiana Harbor, however, metals usually are not present in sufficiently high quantities to make reclamation an attractive option.

3.4 Miscellaneous Points

Concerning whether treatment residuals will fall under NPDES permits, it was the consensus of those present that, while it is quite possible that this will be the case, no final determination has yet been made.

To date, cost data are extremely limited. Additional work is necessary to establish information on comparative costs of the various technologies. With regard to economies of scale, it would not be feasible to transport sediment from a site with one-half million cubic yards of contaminated material. Regional treatment complexes may be useful for smaller sites, but transportable technologies will probably be necessary for remediation of larger sites.

APPENDIX A
AGENDA

WORKSHOP ON INNOVATIVE TECHNOLOGIES FOR TREATMENT OF CONTAMINATED SEDIMENTS

Cincinnati, Ohio
June 13-14, 1990

Wednesday - June 13, 1990

8:00 am	ONSITE REGISTRATION	

SETTING THE SCENE - Moderator: A. Christianson (RREL)

9:00 am	Welcome and Challenge to the Participants	J. Convery (RREL)
9:10 am	Overview of EPA Efforts on Contaminated Sediments	M. Conlon (OWRS)
9:35 am	The GLNPO Program and Contaminated Sediments Management	P. Horvatin (GLNPO)
10:00 am	The Canadian Experience With Contaminated Sediments	I. Orchard (Environment Canada)
10:25 am	BREAK	
10:50 am	ARCS Engineering/Technology Work Group Status	S. Yaksich (COE)
11:20 am	SITE Program Overview	R. Olexsey (RREL)
11:35 am	Panel Discussion and Question and Answer Session	All Participants
12:00 noon	LUNCH (on your own)	

DREDGED MATERIALS REMOVAL, PRETREATMENT, AND DISPOSAL - Moderator: J. Martin (RREL)

1:15 pm	Dredging and Pretreatment Operations for Contaminated Sediments	S. Garbaciak (COE)
1:35 pm	Material Handling Research at RREL	R. Griffiths (RREL)
1:55 pm	Disposal of Dredged Material: Current Practice	S. Garbaciak (COE) for J. Miller
2:15 pm	Research on In Situ Techniques and Their Application in Confined Treatment Facilities	M. Roulier (RREL)
2:35 pm	Panel Discussion and Question and Answer Session	All Participants
3:00 pm	BREAK	

EXTRACTION TECHNOLOGIES - Moderator: J. Herrmann (RREL)

3:20 pm	Review of Removal, Containment, and Treatment Technologies for Remediation of Contaminated Sediments in the Great Lakes	D. Averett (COE)
3:40 pm	Extraction Technology Research at RREL	R. Griffiths (RREL)
4:00 pm	Low Energy Solvent Extraction	J. Martin (RREL)
4:20 pm	ADJOURN	

Thursday - June 14, 1990

EXTRACTION TECHNOLOGIES (CONT.) - Moderator: J. Herrmann (RREL)

8:30 am	Solvent Extraction Using the BEST Process	M. Meckes (RREL)
8:50 am	Liquified Gas Extraction Using the CF Systems Process	L. Staley (RREL)
9:20 am	Panel Discussion and Question and Answer Session	All Participants
10:00 am	BREAK	

BIOLOGICAL/CHEMICAL TREATMENT TECHNOLOGIES - Moderator: D. Timberlake (RREL)

10:20 am	Biodegradation of Chlorinated Aromatic Hydrocarbons	J. Rogers (Athens)
10:40 am	Chemical Treatment Research at RREL: Base Catalyzed Decomposition	C. Brunner (RREL)
11:00 am	Biological Technologies in the SITE Program	R. Lewis (RREL)
11:20 am	Panel Discussion and Question and Answer Session	All Participants
12:00 noon	LUNCH (on your own)	

OTHER TECHNOLOGIES OF INTEREST - Moderator: S. James (RREL)

1:15 pm	Low-Temperature Thermal Treatment	P. dePercin (RREL
1:35 pm	UV/Ozonation SITE Project	N. Lewis (RREL)
1:55 pm	Solidification/Stabilization of Dredged Materials and Sediment	R. Myers (COE)

2:15 pm	Panel Discussion and Question and Answer Session	All Participants
2:35 pm	BREAK	

FUTURE DIRECTION FOR CONTAMINATED SEDIMENTS TREATMENT

2:55 pm	Issues Identification and Presentation	A. Christianson (RREL)
3:30 pm	Open Disucssion (including legislative issues)	All Participants
4:00 pm	ADJORN	

Glossary:

RREL - Office of Research and Development/Risk Reduction Engineering Laboratory

OWRS - Office of Water Regulations and Standards

GLNPO - Great Lakes National Program Office

Environment Canada - Canadian Environmental Protection Agency

COE - U.S. Army Corps of Engineers

Athens - Office of Research and Development/Environmental Research Laboratoy

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