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Mixed Waste Integrated Program — Problem-Oriented Technology Development

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Mixed Waste Integrated Program —
Problem-Oriented Technology Development

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ABSTRACT

Mixed waste is defined as waste contaminated with chemically hazardous (governed by the Resource Conservation and Recovery Act) and radioactive species [governed by U.S. Department of Energy (DOE) orders]. The Mixed Waste Integrated Program (MWIP) is responding to the need for DOE mixed waste treatment technologies that meet these dual regulatory requirements. MWIP is developing emerging and innovative treatment technologies to determine process feasibility. Technology demonstrations will be used to determine whether processes are superior to existing technologies in reducing risk, minimizing life-cycle cost, and improving process performance. The Program also provides a forum for stakeholder and customer involvement in the technology development process.

The structure of MWIP reflects the two-pronged approach that is required for mixed waste technology development: (1) infrastructure - user, stakeholder, and regulator interfaces facilitate technology demonstration and support implementation in a systems context; and (2) technology development - testing of unit operations to collect data for technical evaluations. Mixed waste treatment process development is unique because regulatory, stakeholder, and user requirements and needs provide the driving forces for technology selection. Moving technologies from development to demonstration requires approvals and acceptance from these diverse oversight groups; therefore, an infrasture is needed to support demonstrations. Technology development is

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ongoing in technical areas required to process mixed waste: materials handling, chemical/physical treatment, waste destruction, off-gas treatment, final forms, and process monitoring/control.

MWIP is currently developing a suite of technologies to process heterogeneous waste. One robust process is the fixed-hearth plasma-arc process that is being developed to treat a wide variety of contaminated materials with minimal characterization. Additional processes encompass steam reforming, including treatment of waste under the debris rule. Advanced off-gas systems are also being developed.

Vitrification technologies are being demonstrated for the treatment of homogeneous wastes such as incinerator ash and sludge. An alternative to conventional evaporation for liquid removal—freeze crystallization—is being investigated. Since mercury is present in numerous waste streams, mercury removal technologies are being developed.

INTRODUCTION

The Mixed Waste Integrated Program (MWIP) is responding to the immediate need for mixed waste treatment throughout the U.S. Department of Energy (DOE) complex by modifying existing technologies for near-term implementation and by developing technologies where no treatment capability exists. A major regulatory driver is requirements imposed by the Federal Facility Compliance Act (FFCA) of 1992. This Program is the DOE Office of Technology Development's answer to a lack of mixed waste treatment technologies that have been demonstrated to work for both hazardous and radioactive constituents, a lack of mixed waste treatment capacity including commercial-scale equipment, and a lack of mixed waste disposal criteria throughout the DOE complex.

The Program provides a forum for stakeholder (i.e., public and regulators) and technology users (i.e., DOE Office of Waste Management and DOE Office of Environmental Restoration) involvement in the technology development process. Collaboration with those responsible for implementing and approving technologies during technology development should enable DOE to meet specific waste management and environmental restoration needs and time tables for waste treatment. Close collaboration with potential technology users to identify development needs ensures that technology development is oriented toward solving problems. Incorporating the interests and needs of regulators and the public is accomplished by initiating the permitting process during early stages of technology development and by working with the Western Governors' Association (WGA). This stakeholder involvement is expected to ease implementation of innovative and emerging technologies.

Technology development and demonstrations are being conducted throughout DOE and in private industry as needed to generate design data to improve waste treatment processes. Experiements conducted during technology development are typically conducted using standardized surrogate wastes while demonstrations are geared toward use of actual waste streams. Coordination provided by the Program allows scientists and engineers to research, develop, demonstrate, test, and evaluate suitable treatment processes because needs are clearly identified. MWIP's coordination role helps to maximize benefits from DOE's investment in technology development. The time and effort that might otherwise be spent by each site developing similar technologies is being spent more effectively because scientists and engineers from each site are working in cooperation with one another, and because information is being disseminated throughout the DOE complex and to U.S. industry.

MISSION STATEMENT

The mission of MWIP is to develop, demonstrate, and deliver technologies that are responsive to customer needs and to achieve compliance with regulatory requirements for the treatment and disposal of DOE mixed low-level waste and mixed transuranic waste. Treatment technologies must have improved performance, reduced risk, and minimized life-cycle costs over existing technology or provide treatment for waste streams for which no current treatment technology exists. Technology implementation must be within a time frame that is acceptable to the Program's stakeholders. The products of MWIP (e.g., demonstrated technologies, ready for implementation, with public acceptance) must be delivered to Congress to establish Program success. MWIP will accomplish this by achieving the following:

- Implementing an infrastructure that involves stakeholders (e.g., customer, regulators, public) in the identification of needs and development of technologies, thereby ensuring that treatment systems are acceptable for implementation. Integrating mixed waste technology development activities across EM and across DOE by using a systems engineering approach to identify and validate customer needs. Providing technical assistance and/or recommendations regarding treatment options to support the development of site treatment plans required by the FFCA.

- Accelerating the evolution of needed technology by process development and field demonstrations (using actual mixed waste) of unit operations and systems that fill technology gaps (e.g., versatile thermal and nonthermal treatment systems, advanced off-gas systems, and mobile treatment units). Using multidisciplinary teams consisting of industry, university, and DOE experts to develop these technologies.

PRESENT SITUATION

Types and Sources of Mixed Waste

During the next 5 years, DOE will manage over 1,200,000 m^3 of mixed low-level and mixed transuranic waste at 50 sites in 22 states (see Table 1). (The difference between mixed low-level and mixed transuranic waste is in the concentration of elements that have a higher atomic weight than uranium.) Nearly all of this waste will be located at 13 sites. More than 1200 individual mixed waste streams exist with different chemical and physical matrices containing a wide range of both hazardous and radioactive contaminants. Their containment and packaging vary widely (e.g., drums, bins, boxes, and buried waste). This heterogeneity in both packaging and waste stream constituents makes characterization difficult. This results in costly sampling procedures and increased risk to workers.

Table 1. DOE-Managed Mixed Low-Level Waste and Mixed Transuranic Waste Volumes

Source of Mixed Waste	Volume (m^3)
Current Site Inventories	
Mixed Low-Level Waste	247,000
Mixed Transuranic Waste	58,000
Operations Generated (Five-Year Projection)	
Mixed Low-Level Waste	280,000
Mixed Transuranic Waste	2,800
Environmental Restoration (Five-Year Projection)	
Mixed Low-Level Waste	620,000
Mixed Transuranic Waste	300
Total	1,208,100

NOTE: Information from the Interim Mixed Waste Inventory Report

Regulatory Situation

The FFCA of 1992 waives sovereign immunity for federal facilities, thereby allowing DOE to be subject to fines and penalties for failure to manage mixed waste according to the Resource Conservation and Recovery Act (RCRA). This congressional mandate for DOE to treat its mixed waste establishes a 3-year timetable for development of site treatment plans during which time there is a delay of the waiver of sovereign immunity for mixed waste land disposal restriction violations (see Table 2).

Table 2. Federal Facility Compliance Act Milestones

Deliverable	Date
Conceptual Site Treatment Plans	October 1993
Draft Site Treatment Plans	August 1994
Final Proposed Plan	February 1995
Plans in place, orders issued (U.S. Environmental Protection Agency/state)	October 1995

The FFCA gives states approval authority over the site treatment plans. After plans have been reviewed, it is anticipated that equity brokering between states will occur regarding treatment and storage and disposal facility location.

Stored and future-generated mixed low-level waste must be treated according to RCRA guidelines covered in the FFCA or in other existing compliance agreements. Stored and future-generated mixed transuranic waste must be prepared to meet transportation and waste acceptance criteria (not RCRA disposal requirements). EM-30 has the responsibility for preparing the DOE response to the FFCA, which requires that DOE develop plans and schedules for treating its mixed waste by October 1995. Additional schedule requirements have been established by other existing compliance agreements (e.g., Federal Facility Compliance Agreements) and, in some cases, have shorter deadlines than the FFCA.

Differing requirements will require negotiations and agreements between the states and DOE. The National Governors' Association (NGA) is providing a forum for states, the U.S. Environmental Protection Agency (EPA), and DOE to discuss FFCA implementation. The NGA has endorsed the Western Governors' Association (WGA) initiative to foster use of innovative technologies and early involvement of regulators and stakeholders in technology demonstrations. The MWIP has been involved and will continue to build on this initiative.

Key Stakeholder Considerations

Public

The public interest in safety and environmental issues related to nuclear waste demands that DOE use adequate methods of dealing with nuclear defense wastes. The most effective treatment methods must be used to treat mixed wastes in a safe and cost-effective manner, and implementation must have public acceptance. Existing EM activities are designed to facilitate public outreach and interaction with a diverse set of environmental activist organizations, citizen and business groups, Indian tribes, state/local governments, and elected officials. Examples of these initiatives include WGA-Develop On-site Innovative Technologies (DOIT) Committee's Mixed Waste Working Group, and Site-Specific Advisory Boards.

Regulatory Agencies

EPA and state agencies are required to enforce the FFCA. In fact, the FFCA gives states (and in some cases EPA) approval authority over the site treatment plans. The above-mentioned public participation groups also include regulators and can provide a forum for building consensus regarding treatment options. Regulatory involvement at the project level can identify areas of concern early in the development of a technology so that technical issues that are important to the public and the regulators are addressed during process development. This involvement can potentially expedite implementation of innovative technology. An example of this concept is the WGA-DOIT Committee's Mixed Waste Working Group, which is bringing together stakeholders from around the nation to chart a course and develop consensus for accelerated testing of innovative mixed waste technologies and encouraging new private-sector partnerships through formal solicitation of proposals for creative new technological, regulatory, or institutional approaches to mixed waste. The Mixed Waste Working Group has identified nine DOE projects for candidate 1994 demonstrations that offer potential for breakthrough innovation, regulatory and host community acceptance, broad deployment, and ultimate commercialization.

U.S. Industry

There are limited incentives for industry involvement in technology development. Because mixed waste is not well characterized and treatment objectives have not been established, requests for proposals and even discussions regarding innovative treatment schemes are general rather than definitive. There is much industrial interest in mixed waste treatment issues, but since the problems are not well defined, participation has been limited to those who are willing and able to accept some risks. Further, definitive plans for privatization of treatment have not been established at several sites; therefore, industrial firms are reluctant to enter into demonstration projects if this will preclude them from bidding on actual remediation projects (due to procurement requirements for competitive bidding). Finally, most private-sector firms consider the use of innovative technologies during an actual waste treatment project too risky to undertake.

In spite of these barriers, industrial participation in technology development has been increasing. Individual research projects sponsored by MWIP include joint industrial and university participants. The Program makes extensive use of industrially available equipment and private-sector consultants. DOE Headquarters has directed several procurement initiatives directly related to MWIP including process monitoring/controls and a metal-melting process through Programmatic Research and Development Announcements. Small business contracts are let through Research Opportunity Announcements.

State of Technology Development

Hazardous waste treatment is a relatively mature technological area although processes for treatment of hazardous waste have not been fully demonstrated for use with mixed waste. Major technology gaps include adaptation of existing processes to handle radionuclides present in mixed transuranic waste and mixed low-level waste, as well as the RCRA hazardous constituents. The process equipment design must be adapted to safely manage the radioactive constituents. The fate of radionuclides during processing and the retention of radionuclides in the final waste form must be determined. In addition, the range in the amount and type of contaminants is wider than are typically seen in hazardous waste streams. Therefore, mixed waste treatment technology development is more likely to be evolutionary than revolutionary in that existing technologies will be demonstrated using DOE complex mixed waste.

MWIP INFRASTRUCTURE INITIATIVES

The Program has fostered and participated in cooperative efforts that are now being implemented throughout EM. For example, MWIP is working with EM-30 on strategic planning for mixed waste. Baseline flowsheets, developed by the Mixed Waste Treatment Project, have served as the basis for MWIP technology development needs identification and selection of projects for development. This has resulted in focusing technology development activities on overcoming major obstacles to progress in mixed waste treatment to ensure that treatment leads to disposal. Major needs include (1) robust treatment processes, (2) enhanced waste forms to facilitate disposal, and (3) a systems approach to the mixed waste problem to ensure development of technology with improved cost/benefit over existing technologies.

MWIP has addressed the need for public acceptance of emerging technologies through participation with the WGA-DOIT Committee's Mixed Waste Working Group and through project-specific interaction with local regulators. Incorporating the interests and needs of regulators and the public is accomplished by initiating the permitting process during early stages of technology development and by working with the Western Governors' Association (WGA). This stakeholder involvement is expected to ease implementation of innovative and emerging technologies.

MWIP is joining with EM-30 in reviewing site-specific treatment plans in order to make recommendations regarding consistency in technical approach across the DOE complex (including use of emerging technologies) and to support sites with limited technical resources. This joint participation has allowed MWIP to take a national view of mixed waste issues while maintaining access to site-specific needs and issues.

Continued interaction with and feedback from MWIP's customers have lead to recent initiatives:
(1) mobile treatment systems for transport to various sites for waste destruction; (2) removal of debris from land disposal restriction waste using thermal desorption or other approved debris rule treatments; (3) process diagnostics for on-line and real-time process controls and monitors; and (4) interfacing with regulators to link preprocessing characterization of waste streams to the treatment process (e.g., robust treatment systems may require less pre-processing characterization). Future plans include characterizing waste for transportation and developing and demonstrating materials-handling systems for waste containers other than drums.

Development of waste form performance criteria and standardized test methodologies is critical to the resolution of mixed waste problems. Neither disposal criteria nor uniform test methods have been established. Consensus of the technical community, regulators, and stakeholders is necessary to establish these criteria. As the technical arm of EM addressing mixed waste, MWIP has documented test methods and is proposing revisions to the DOE performance assessment methodology.[1] An objective of MWIP is that these data will be used in establishing waste acceptance criteria for disposal.

Systems Analysis

The cost of treating and disposing of mixed low-level waste and mixed transuranic waste is estimated in the multibillion dollar range. This cost provides incentives to develop versatile treatment capabilities that do not require excessive characterization costs for safe and effective operations and that can be standardized to assist with regulatory and public acceptance. MWIP's customers, EM-30 and EM-40, are responsible for treating mixed waste and for selecting treatment technologies. There is disagreement over the acceptability of existing, proven technologies and their effective implementation in systems to treat a wide diversity of DOE waste streams. Incentives for use of evolving and/or innovative technology are dependent upon the potential for reduction in life-cycle cost, reduction in risk, and improved performance. Results of systems analyses conducted under MWIP have been documented.[2,3,4,5]

The challenge for MWIP is to clearly establish the cost/benefit of using emerging technologies and technology systems to support selection for implementation. Technology selection will, therefore, be based on the following:

- A systems analysis, founded on technical rationale, that identifies deficiencies and gaps in present technologies that prevent fast and effective implementation of waste treatment systems.

- A systems analysis that clearly demonstrates the cost/benefit of implementing emerging and/or modified technologies.

- Public and regulator participation in and acceptance of emerging and/or innovative technologies. These factors play a major role in specific technologies being selected for implementation. Consensus building between numerous stakeholders is the preferred method of determining those technologies that will be developed and deployed.

One component of the systems analysis is to ensure that data are comparable when they are collected from experiments conducted at various locations by researchers with diverse backgrounds. To this end, surrogate formulations have been devised that represent major categories of waste throughout the DOE complex.[6,7,8] For more waste stream-specific applications, simulants have been developed.[9] An additional factor that contributes to data comparability is the specification of the parameters of importance for which data must be collected.[10,11]

MWIP TECHNOLOGY DEVELOPMENT INITIATIVES

MWIP is conducting laboratory tests and field demonstrations using site-specific wastes to provide data for decision making regarding full-scale implementation. MWIP uses diverse contractor support from the national laboratories, academia, and private industry, allowing for a wide range of experience and expertise pertinent to mixed waste treatment to be applied. Based on analysis of technology development needs, the Program has identified the following areas for development and demonstration: materials handling, chemical/physical treatment, waste destruction, off-gas treatment, final forms, and process monitoring/control. Table 3 summarizes MWIP technology development initiatives by the "core" unit operation and board class of waste streams. Descriptions of each project have been compiled elsewhere.[12,13,14]

Chemical/Physical Treatment

Pretreatment may be required before mixed waste can be processed. Technologies are generally available for pretreatment and effluent polishing (e.g., ion exchange, filtration, evaporation).[15] Additional treatment is required to destroy organics and to stabilize or, where appropriate, to recycle radioactive or metallic or other constituents of the waste subject to RCRA land disposal restrictions. Decontamination technologies are being considered to prepare waste for reuse within the DOE complex.[16]

Table 3. Technology Development Needs by Functional Area and Waste Class[a]

Waste Class/ Functional Area	Homogenous Waste: Sludges, Aqueous, and Organic Liquids	Heterogeneous Waste: Debris and Others
Waste Destruction	• Concentration • Separations and removal of specific species for subsequent processing • NO_x-Ammonia destruction • Innovative thermal processes with closed-loop off-gas systems • Nonthermal processes with closed-loop off-gas systems – Freeze crystallization • Particulate removal • On-line monitoring/control • Mobile systems	• Decontamination • Mercury removal • Mercury vapor control • Innovative thermal processes with closed-loop off-gas systems • Nonthermal processes with closed-loop off-gas systems • Particulate removal • On-line monitoring/control • Mobile systems • Metal reuse
Waste Stabilization	• Concentration • Pretreatment processes such as — Nitrate/organic destruction — Mercury removal • Separations and removal of specific species for waste stabilization • Enhanced, stable waste forms • Waste form testing and performance assessment • Transportation	• Separations and removal of specific species for waste stabilization • Enhanced, stable waste forms • Transportation

[a]Note: Waste minimization initiatives are applicable for all technical areas and waste classes in Table 3.

Pretreatment may also be required in conjunction with waste stabilization. An alternative to evaporation to concentrate waste by liquid removal is freeze crystallization. Destruction of nitrates and organics and removal of mercury may be achieved most effectively at the beginning of a waste treatment process.[17,18]

Fixed-Hearth Plasma

Incineration is applicable for treatment of many mixed waste streams, but it has limited public acceptance. Other waste destruction technologies have been evaluated.[19] The fixed-hearth plasma-arc furnace is being demonstrated using a variety of mixed wastes.[20,21] This process offers benefits of direct production of enhanced final waste forms, potentially reduced waste feed characterization, potentially reduced off-gas volumes, and the ability to treat a broader array of waste streams. Proof-of-principle tests are nearing completion. Currently a pilot-scale system is being designed and will be constructed and tested to gain the process engineering information needed to design a field-scale unit. The field-scale system will be demonstrated and a final assessment of the technology will be made by FY 1996.

Off-gas systems are commercially available for particulate capture, destruction of products of incomplete combustion, and abatement of nitrogen oxides. However, improvements in off-gas treatment are needed and are being developed under MWIP. Off-gas technology development initiatives include cleanable high-efficiency particulate air (HEPA) filters and systems designed to capture mercury.[22] Current capabilities for process control and monitoring, especially for off-gas subsystems, are not adequate for DOE needs.

Alternatives to Thermal Treatment

Alternatives to thermal treatment processes require development. Examples of alternatives to thermal treatment that are being developed under MWIP include thermal desorption, steam reforming, and biocatalytic destruction of nitrate/nitrite. A literature survey found that acid digestion and catalyzed wet air oxidation appear to be attractive alternatives to thermal treatment.[23] Investigation of these technologies is planned.

Vitrification

Grouting is a commonly used process for stabilization of waste. However, the ultimate disposition of grouted waste is highly uncertain due to the lack of disposal requirements or disposal sites. The volume increase associated with grouting conflicts with waste minimization policies and makes the final product costly to store or dispose of.

A viable alternative to waste grouting is vitrification of low-level mixed waste with emphasis on sludges. Building on in-depth data generated for high-level waste vitrification has contributed to the success of mixed low-level waste glass formulations and bench-scale and pilot-scale experiments. Glass formulations for surrogate wastewaters and incinerator ashes are being tested in bench-scale tests and using pilot-scale vitrifiers to obtain operational data. For example, a vitrification demonstration of surrogate incinerator ash using the "Vortec" system was completed in December 1993.[24] Tests of actual waste streams using a "Stir Melter" pilot-scale vitrification system are scheduled for FY 1994. Demonstrations of a field-scale unit using actual wastewater, sludge, and/or incinerator ash are scheduled for completion during FY 1995. Operational data will be available to design and install full-scale, perhaps mobile, units. These data will include the limits of vitrification equipment for destruction of some RCRA organic constituents.[25,26,27,28,29]

CONCLUSION

DOE faces major technical challenges in the management of low-level radioactively contaminated mixed waste. Several conflicting regulations and lack of definitive mixed waste treatment standards hamper implementation of mixed waste treatment technologies. Disposal capacity for mixed waste is also expensive and severely limited. DOE now spends millions of dollars annually to store mixed waste because of the lack of accepted treatment technology and disposal capacity. Currently available waste management practices require extensive, and hence expensive, waste characterization before treatment. Therefore, DOE must pursue technology that leads to better and less expensive characterization, retrieval, handling, treatment, and disposal of mixed waste.

Selection of technologies that are acceptable and have improved cost/benefit over existing technologies will be facilitated by pursuing a two-pronged approach to ensure technologies will be used after they are developed.

- teaming with potential technology users to identify, develop, and implement needed technology;

- enhancing mechanisms for regulator and stakeholder involvement;

- enhancing mechanisms for implementing technology development results;

- focusing technology development activities on major problems such as the need for robust treatment processes and enhanced waste forms; and

- involving industry in developing and implementing solutions including both technology transfer to and technology transfer from DOE to the private sector.

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