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**Mixed Waste Focus Area Working Group:**  
**An Integrated Approach to**  
**Mercury Waste Treatment and Disposal**

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## ABSTRACT

In May 1996, the U.S. Department of Energy (DOE) Mixed Waste Focus Area (MWFA) initiated the Mercury Work Group (HgWG). The HgWG was established to address and resolve the issues associated with mercury-contaminated mixed wastes (MWs). During the initial technical baseline development process of the MWFA, three of the top four technology deficiencies identified were related to (1) amalgamation, (2) stabilization, and (3) separation and removal for the treatment of mercury and mercury-contaminated mixed waste (MW). The HgWG is assisting the MWFA in soliciting, identifying, initiating, and managing efforts to address these needs.

The focus of the HgWG is to better establish the mercury-related treatment needs at the DOE sites, refine the MWFA technical baseline as it relates to mercury treatment, and make recommendations to the MWFA on how to most effectively address these needs. To date, the HgWG has defined the scope and magnitude of the mercury MW problem. Based on this effort, solicitations and contract awards have been made to the private sector to demonstrate both the amalgamation and stabilization processes using actual MWs. A solicitation is also currently in progress to demonstrate the separation-and-removal process. This paper discusses the technology selection process, development activities, and the accomplishments of the HgWG, to date, through these various activities.

# Mixed Waste Focus Area Working Group: An Integrated Approach to Mercury Waste Treatment and Disposal

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## Background and Overview

Mercury (Hg) in various elemental and speciated forms is present in numerous U.S. Department of Energy (DOE) mixed-waste (MW)\* streams. In 1996, over 38,000 m<sup>3</sup> of mixed low-level and transuranic waste containing Hg had been inventoried in the DOE complex, as a whole. The locations of sites that make up the DOE complex are shown in Fig. 1. DOE's MW, like its low-level radioactive waste (LLW) are created by diverse institutions and facilities that use radioactive materials, including (1) nuclear power plants, (2) defense, energy, medical, and other research laboratories and reactors; (3) laboratories and industrial plants; and (4) decommissioning and remedial actions. The waste takes a variety of forms, such as medical treatment and research materials, contaminated wiping rags and paper towels, used filters and filter sludge, protective clothing, hand tools, equipment, parts of decommissioned nuclear power plants, and so forth. This paper is concerned with LLW that is or contains mercury. Because mercury is an U.S. Environmental Protection Agency (EPA) listed hazardous constituent, such LLW is actually MW. This paper discusses the technology selection process, HgWG technology development activities, and the accomplishments of the HgWG, to date, in addressing treatment technology development needs for mercury-contaminated MW.

## The Mixed Waste Focus Area (MWFA)

The MWFA, a program management function of DOE, has documented the needs delineated by each of the DOE sites in the MWFA technical baseline report. The MWFA has the charge of providing acceptable technologies to implement MW treatment systems. The EPA, U. S. Nuclear Regulatory Commission (NRC), and DOE share responsibility for MW and so must work together to streamline its regulation and resolve conflicts among federal regulations. The Federal Facilities Compliance Act, passed by Congress in 1992, requires EPA to develop treatment requirements for MW. Under the Federal Facilities Agreement, DOE is committed to develop plans and deploy facilities to treat its MWs.

Since its inception, the MWFA has brought a national focus to DOE's MW problem. Previously, each of the 48 sites at which DOE stores MW worked to develop its own cleanup technologies independent of the other sites. Now, the MWFA consolidates technology development at a national level within one organization, with individual sites as customers. The focus area has been described as a team composed of the problem-holders in the DOE Office of Waste Management (EM-30) and the technology developers in the DOE Office of Science and Technology (EM-50).

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\* Mixed waste is waste that contains both hazardous chemical components, subject to the requirements of the Resource Conservation and Recovery Act (RCRA), and radioactive components, subject to the requirements of the Atomic Energy Act.



Fig. 1. Locations of facilities and sites throughout the DOE complex.

### The Mercury Working Group

The MWFA established the Mercury Work Group (HgWG) in May 1996 to address and resolve issues associated with mercury and mercury-contaminated MWs. The primary goals of the HgWG are to help establish strategy and coordinate technology development. The HgWG seeks to better establish mercury related treatment needs at DOE sites, refine the technical baseline as it relates to mercury waste treatment, and make recommendations to the MWFA on effective means to address these needs. To that end, HgWG membership has been established with representatives from sites with the largest mercury-contaminated MW inventories. These sites include the Oak Ridge Reservation, Savannah River Site (SRS), Rocky Flats Environmental Technology Site (RFETS), and Idaho National Engineering and Environmental Laboratory (INEEL).

During the initial technical baseline development process, three of the top four MWFA technology deficiencies identified across the DOE complex were related to the need for amalgamation, stabilization, and separation-and-removal technologies for mercury and mercury-contaminated MW. Working through a "Unique Wastes Waste-Type Manager," the HgWG assists the MWFA in soliciting, identifying, initiating, and managing efforts to address technology development needs. From its inception, the mission of the HgWG has been to develop a thorough understanding of the physical and chemical characteristics of mercury-contaminated MW throughout the DOE complex. Often, the greatest barrier to establishing a path forward to disposition for waste is the lack of information about the waste. Hence, the initial strategy of the HgWG has been to work toward understanding mercury-contaminated waste and verifying inventories throughout the DOE complex.

Armed with a greatly improved understanding of the waste streams across the DOE complex, the HgWG has worked to sponsor private-sector technology demonstrations. These demonstrations are intended to apply to as broad a range of actual wastes as is practicable. It is anticipated that the results of HgWG-sponsored technology demonstrations will include two important accomplishments. First, the technology capabilities of the private sector will be defined. Second, the demonstrations will provide defensible cost and performance data that will be essential to address treatment needs.

### **Technical Baseline and Deficiencies**

In 1996, the MWFA established a technical baseline that forms the basis for determining technology development activities to be supported by the MWFA. This technical baseline is revised each year to reflect changes in DOE's strategies for MW management, changes in the technical baseline development process, and MWFA accomplishments. The published technical baseline report<sup>1</sup> presents a process for technology development management and a prioritized list of deficiencies—those MW treatment technology needs that the MWFA will address. One HgWG function is to assist the MWFA by providing input to the technical baseline development process for mercury waste.

The technical baseline development process identified two-dozen deficiencies for MW management, including three which serve as the focus for the HgWG. These three deficiencies which set the priorities for mercury related technology development in the working group, are shown in Table 1. These deficiencies are described in more detail elsewhere<sup>1</sup>. The focus of this paper is on these three priority deficiencies, ranking among the top four deficiencies identified in the technical baseline development process, which emphasize the need for technologies to treat mercury waste and waste contaminated with mercury.

### **Defining the Scope of the Problem**

Mercury, in various elemental and speciated forms, is present in numerous DOE MW streams. In 1996, over 38,000 m<sup>3</sup> of mixed low-level and transuranic waste containing mercury were identified in the DOE complex. Traditionally, mercury has been one of the most difficult contaminants to stabilize in hazardous or MW. Portland cement does not directly stabilize either elemental mercury or mercury salts, and high-temperature techniques such as incineration and vitrification will volatilize mercury, producing off-gases that are dangerous to workers. Even lower temperatures such as those used in sulfur polymer cement (SPC) encapsulation can volatilize mercury

contaminants. Thus, the volatility of mercury poses a challenge for mercury waste treatment technologies.

**Table 1. Prioritized list of technology deficiencies for mercury and mercury-contaminated wastes**

Activity	Description
1. Mercury Stabilization (MWFA priority 2)	Toxic metal contaminants regulated under the Resource Conservation and Recovery Act (RCRA) contained in MWs require removal or stabilization to control solubility under the conditions of the Toxic Characteristic Leach Procedure (TCLP) before the wastes can be disposed. Under RCRA, mercury at contamination levels less than 260 ppm (<260 ppm requires retorting) require stabilization to control mercury solubility to the Universal Treatment Standards (UTS) (<0.2 ppm). Verification of treatment (i.e. penetrating the entire matrix and stabilizing essentially all of the mercury in the system) is required.
2. Mercury Separation/ Removal (MWFA priority 7)	The presence of mercury complicates the design of off-gas systems, stabilization of residuals, and monitoring of all effluents. It may be advantageous to remove the mercury as a pretreatment to simplify downstream operations. New techniques must be developed to remove (physically or chemically) the mercury for separate stabilization. Waste matrices from which mercury separation may be required include soil, all types of process residues or sludges and particulate materials, and debris. Processing methods must ensure adequate removal, and include measuring and monitoring methods to control and verify the process.
3. Mercury Amalgamation (MWFA priority 8)	Elemental mercury may be derived as a product of retorting high mercury (>260 ppm) wastes, or recovered from the off-gas of a thermal treatment unit, in addition to the elemental mercury streams in the DOE MW inventory. Radioactive mercury can probably not be completely purified and verified for recycle. Disposal of the mercury will require amalgamation to form a stable, insoluble product for disposal. Methods and equipment designs are required for amalgamating bulk non-recyclable mercury.

The RCRA defines several categories of mercury wastes (40 CFR Part 268.40), each with a defined technology based treatment standard, or a UTS. For non-wastewaters with mercury concentrations at or above 260 mg/kg (ppm) and RCRA-regulated organic contaminants (other than incinerator residues), incineration (IMERC) or retorting (RMERC) is the identified treatment standard. For non-wastewaters with mercury concentrations at or above 260 ppm that are inorganic, including incinerator and retort residues, RMERC is the identified treatment standard. Amalgamation (AMLGM) is identified as the treatment standard for elemental mercury. However, mercury condensates from RMERC processes also require amalgamation. Residues from IMERC processes with contamination levels at or above 260 ppm of mercury will require RMERC, followed by AMLGM of the condensate. IMERC residues with less than 260 ppm will also require some form of stabilization (e.g., SPC) to meet the RCRA Toxicity Characteristic Leaching Procedure (TCLP)\* limit for mercury of 0.20 mg/l.

\* This procedure (TCLP) is described in Method 1311 of EPA Publication SW-846.

## Developing Technology Solutions

The technology development path from requirements to commercially-viable technology for each identified deficiency may be complex and multifaceted based on the number of requirements, the variety of waste media to be treated, and the number and amount of different radiological contaminants and hazardous co-contaminants in the waste. The existence of different customer criteria at different sites combined with different stakeholder issues, varying regulatory concerns, and inconsistent final waste form disposal requirements further complicates the technology development path for deficiency resolution. Hence, parallel technology development paths are sometimes needed to ensure that all requirements are satisfied and the most optimal (end-user serving and cost effective) solutions are advanced through the various stages of development, deployment, and commercialization. The overall MWFA technology development path is discussed more in the technical baseline report<sup>1</sup>.

The development path for a particular deficiency or group of related deficiencies is managed by the MWFA through a document known as the *Development Plan*. The *Development Plan* for mercury<sup>2</sup> defines the plan to address deficiencies associated with the treatment and stabilization of MWs consisting of or containing mercury.

## HgWG Technology Development Activities

Several development activities have been initiated or are planned by the HgWG to resolve the deficiencies for mercury and mercury-containing waste (see priorities described earlier). These activities were selected based on the deficiency requirements and the need to provide the best opportunity for equipping the end user with an optimized, cost-effective technology alternative within the user's respective schedule constraints. Activities now underway focus on the execution of a series of demonstrations for amalgamation and stabilization in addition to efforts to improve the understanding of the depth and extent of mercury contamination within the DOE complex. Work sponsored in the area of separations is currently limited to tracking the progress of demonstrations and studies funded elsewhere.

### Mercury Amalgamation

Table 2 lists development activities, schedule, and current status for amalgamation technologies sponsored by the HgWG. As indicated in Table 2, contracts have been let for mercury-amalgamation demonstrations to two private firms: Nuclear Fuels Services (NFS) in Erwin, Tennessee and ADA Technologies in Englewood, Colorado. Quantities of elemental mercury from six different sites will be used for these demonstrations. NFS will process waste from INEEL, the East Tennessee Technology Park, on the Oak Ridge Reservation, and SRS. ADA will process wastes from Fernald, Lawrence Berkeley National Laboratories (LBNL), and Lawrence Livermore National Laboratories (LLNL). These demonstrations are expected to eliminate at least four *Mixed Waste Inventory Report* (MWIR) streams<sup>3</sup> while presenting the subcontractors with the broad range of expected co-contaminants to challenge their processes.

### Mercury Stabilization

Table 3 lists HgWG development activities, schedule, and current status for stabilization technology development activities, similar to Table 2. Wastes for demonstrations of stabilization technologies were selected in June 1997. "Best and Final" proposals are expected in the summer of 1997. It is planned to have contracts in place for three vendors, as yet undetermined, soon

thereafter. The original plan called for two demonstrations, but an additional demonstration will be used to address unique problems found after the initial contracts are awarded. Test plans are expected in September 1997.

**Table 2. HgWG activities to address priority technology deficiencies for mercury and mercury-contaminated wastes requiring amalgamation**

Date	Activity	Status
July 1996	<i>Commerce Business Daily</i> (CBD) announcement for scoping demonstrations for the three priority deficiencies.	40 responses received
November 1996	Issued requests for proposals (RFPs) and statements of work (SOWs) for Hg amalgamation treatment	2 vendor responses (NFS and ADA Technologies)
February 1997	Waste streams selection	Streams selected
April 1997	Award of contracts to treat six different elemental Hg waste streams from five DOE sites	Contracts awarded to both vendors
June-July 1997	Hg amalgamation vendor test plan evaluation	Test plans received from vendor
August 1997	Delivery of wastes to vendors	Wastes delivered
September-October 1997	Amalgamation testing	On schedule for completion
December 1997	Technical Progress Report (TPR)	Scheduled for completion

**Table 3. HgWG activities to address priority technology deficiencies for mercury and mercury-contaminated wastes < 260 ppm requiring stabilization**

Date	Activity	Status
November 1996	Issuance of stabilization demonstrations RFP and SOW	5 vendor responses received
March 1997	Waste stream selection	Initial selections attempted
June 1997	Waste stream selection	Selection completed
On-going	Award of contracts to treat two waste streams	Expect to award a total of three contracts

## Inventory Evaluation and Update

The contract award process has been significantly impeded by incorrect and missing information for waste streams nationwide. Information listed in the MWIR for mercury-contaminated wastes was greatly improved as part of the HgWG activities. Table 4 summarizes inventory information on mercury and mercury-contaminated MW for the DOE complex before and after HgWG activities. As a result of working group efforts, the amount of waste that must actually be dealt with was reduced by a factor of about 3. Likewise, the amount of waste that could not be categorized was reduced by a factor of about 5.

**Table 4. HgWG inventory evaluation for mercury and mercury-contaminated MW**

Type of Hg waste stream	Inventory (m <sup>3</sup> ) in April 1997	Inventory (m <sup>3</sup> ) in August 1997
Elemental	12	17
Less than 260 ppm	20,038	7,328
Not less than 260 ppm	118	347
Unknown	9,714	2,267
Total	29,882	9,959

## Stabilization Demonstrations with High-Mercury Waste

Heretofore, most sites have not pursued the stabilization of highly contaminated mercury debris because of the misconception that since there is a Best Demonstrated Available Technology (BDAT) standard for wastes with mercury at >260 ppm, the alternate debris treatment standards (under the Debris Rule) could not be used. Clarification of this issue has been received from EPA, indicating that the intent was to exclude only those waste codes (technologies) specifically listed in the preamble to the Debris Rule's promulgation—not all that had BDAT standards. The stabilization of debris at >260 ppm has not been accomplished at beyond bench-scale. This activity will demonstrate the stabilization of high-mercury waste and set the precedent for other DOE sites to follow.

## Future Activities of the HgWG

Development and demonstration activities are ongoing for mercury and mercury-contaminated waste. Future activities may be summarized as follows:

- Continue characterization and evaluation of Hg wastes
- Complete amalgamation demonstrations (elemental Hg), testing, evaluation, and reporting
- Complete stabilization demonstrations (<260 ppm Hg), testing, evaluation, and reporting
- Continue to work with EPA to develop stabilization standards for high-mercury (>260 ppm) waste
- Initiate demonstrations for stabilization of high-mercury wastes

## Summary and Conclusions

The first task of the HgWG was to develop a thorough understanding of the physical and chemical characteristics of the mercury-contaminated MWs throughout the DOE complex. This task has achieved significant results to date. Over the past year, estimates of the amount of waste to be treated have been refined based on improved information gathered by the HgWG to eliminate two-thirds of the previous mercury waste inventory. The planned treatment for these wastes are now better understood. The HgWG continues to work with site representatives to identify and understand perceived technology development needs for each site, focusing on those sites with the most mercury contaminated MWs, whose representatives comprise the HgWG. The HgWG will also work with sites having less inventory so as to maximize the effectiveness of efforts to address mercury related needs complex-wide.

The HgWG, with a more thorough understanding of the DOE-complex needs, has enabled the MWFA to begin addressing these needs. This is being accomplished through two primary mechanisms: (1) RFPs to industry for amalgamation, stabilization, and separation-and-removal technologies, and (2) Calls for Proposals (CFPs) to DOE for mercury separation-and-removal technologies. The CFPs were issued in July 1996, and responses are currently being reviewed and evaluated. The HgWG prepared an announcement published in the CBD in July 1996 soliciting interest from the private sector for participation in the upcoming RFP. Nearly 50 expressions of interest were received by the HgWG.

This course of action was determined based on the responses received to a request for information (RFI) related to the three primary mercury technology needs. RFI responses indicated that the technical bases exist in private industry to treat, at or near the production scale, those mercury contaminated wastes that would require stabilization or amalgamation. Demonstrations of specific related technologies planned or now underway serve as the venue through which the technical bases will be applied to the unique problems associated with the DOE complex mercury contaminated MW. Demonstrations have been identified and have either been initiated within the past year, or will be initiated in the coming year. Demonstrations are at a sufficiently large scale to assist smooth, timely transition of the successful processes to production readiness for implementation as available treatment systems for applicable DOE wastes.

RFI responses also indicated that mercury separation and removal is a technology area that still requires the efforts of the research and development community within both DOE and the private sector. Consequently, in addition to the RFP, a CFP for mercury separation-and-removal technologies was issued in July 1996, which has led to plans for future demonstrations.

The HgWG is handling the procurement actions associated with these demonstrations and the coordination with the affected sites is also the responsibility of the HgWG. Additionally, research and development activities initiated through other efforts that impact on meeting DOE complex needs related to mercury contaminated MW are also administered and coordinated for the MWFA by the HgWG. In short, the HgWG provides the central focal point for all of the MWFA mercury related technology development activities, ensuring that the deficiencies are adequately defined, needs are effectively addressed, duplicative efforts are eliminated, and that DOE sites can attain full regulatory compliance relative to mercury contaminated MW.

## References

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