Tooele Chemical Agent Disposal Facility: Update on National Research Council Recommendations

Committee on Review and Evaluation of the Army Chemical Stockpile Disposal Program, National Research Council

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Committee on Review and Evaluation of the
Army Chemical Stockpile Disposal Program
Board on Army Science and Technology
Commission on Engineering and Technical Systems
National Research Council

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Preface

The United States has maintained a stockpile of highly toxic chemical agents and munitions for more than half a century. In 1985, Public Law 99–145 mandated an "expedited" effort to dispose of M55 rockets containing unitary chemical warfare agents because of their potential for self-ignition. This program soon expanded into the Army Chemical Stockpile Disposal Program (CSDP), whose mission was to eliminate the entire stockpile of unitary chemical weapons. The CSDP developed the baseline incineration system for that purpose. Since 1987, the National Research Council (NRC), through its Committee on Review and Evaluation of the Army Chemical Stockpile Disposal Program (Stockpile Committee), has overseen the Army's disposal program and has endorsed the baseline incineration system as an adequate technology for destroying the stockpile. In 1992, after setting several intermediate goals and dates, Congress enacted Public Law 102–484, which directed the Army to dispose of the entire stockpile of unitary chemical warfare agents and munitions by December 31, 2004.

In the 1970s, the Army had commissioned studies of different disposal technologies and tested several of them. In 1982, the Army selected incineration as the method it would use for the disposal of agents and associated propellants and explosives and the thermal decontamination of metal parts. In 1984, the NRC Committee on Demilitarizing Chemical Munitions and Agents reviewed a range of disposal technologies and endorsed the Army's selection of incineration. In response to public concerns about incineration and the evolution of other potential disposal technologies, the NRC has also carried out several evaluations of alternative technologies and recommended the development of chemical detoxification technologies for application at the two stockpile storage sites where chemical agent is stored only in bulk (with no energetically configured munitions).

Incineration technology is embodied in today's baseline incineration system, which was developed largely at the Chemical Agent Munitions Disposal System (CAMDS) experimental facility at Tooele Army Depot, Utah. The first full-scale operational plant, the Johnston Atoll Chemical Agent Disposal System (JACADS), in the Pacific Ocean southwest of Hawaii, was completed in 1990 and is nearing the conclusion of chemical weapons disposal operations on Johnston Island. Construction of the first disposal facility in the continental United States was started in 1989 at the Tooele Army Depot (now Deseret Chemical Depot) in Utah. The design of the Tooele Chemical Agent Disposal Facility (TOCDF) represents a second generation baseline system, which incorporates improvements based on experience with the JACADS facility, advances in technology, and recommendations made by the Stockpile Committee. Systemization testing began in August 1993, and agent operations began on August 22, 1996.

The Stockpile Committee has monitored operations at the TOCDF since the start-up of systemization. The following NRC reports were issued by the Stockpile Committee in its TOCDF oversight role:

- *Review of Systemization of the Tooele Chemical Agent Disposal Facility*
- *Risk Assessment and Management at the Deseret Chemical Depot and the Tooele Chemical Agent Disposal Facility*

Published in 1996, the *Systemization* report reviewed the status of the TOCDF as systemization (pre-operational) testing was nearing completion and the facility was about to start agent operations. The report contained several sets of recommendations: some that were general and continuing; some that were to be coordinated with the start of agent operations; some that were to be completed prior to agent operations; and some that were to be completed during the first year of agent operations. The more recent *Risk Assessment and Management* (1997) report addressed issues related to the quantitative and health risk assessments performed for the TOCDF and the adjacent storage site and the Army's implementation of a risk management plan.

Following up on the recommendations in the *Systemization* report and the *Risk Assessment and Management* report, this report reviews the status of the TOCDF after more than two years of agent operations. This report also follows up on relevant recommendations from earlier Stockpile Committee reports and a recent letter report, *Public Involvement and the Army Chemical Stockpile Disposal Program*. The committee's intent is to document the Army's responses to these recommendations, noting which ones have been satisfactorily addressed and which ones have not been completely or adequately addressed. The latter group will provide a basis for the Stockpile Committee's oversight in the future. Although the focus of this report is on the TOCDF, some of the findings and recommendations also apply to other sites and to the CSDP as a whole.

The committee greatly appreciates the support and assistance of National Research Council staff members Donald L. Siebenaler, Harrison T. Pannella, William E. Campbell, Delphine D. Glaze, Margo L. Francesco, and Carol R. Arenberg, in the production of this report.

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Committee On Review And Evaluation Of The Army Chemical Stockpile Disposal Program

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This report has been reviewed by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the authors and the NRC in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The contents of the review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in the review of this report:

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While the individuals listed above have provided many constructive comments and suggestions, responsibility for the final content of this report rests solely with the authoring committee and the NRC.

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Acronyms

ACAMS	automatic continuous air monitoring system
ATB	agent trial burn
BRA	brine reduction area
CAC	Citizens Advisory Commission
CAMDS	Chemical Agent Munitions Disposal System
CEMS	continuous emission monitoring system(s)
CMP	change management process
CSDP	Chemical Stockpile Disposal Program
CSEPP	Chemical Stockpile Emergency Preparedness Program
CWC	Chemical Weapons Convention
DAAMS	depot area air monitoring system
DCD	Deseret Chemical Depot
DFS	deactivation furnace system
DRE	destruction removal efficiency
DSHW	Utah Division of Solid and Hazardous Waste
DUN	dunnage furnace
EG&G	Edgerton, Germerhausen and Grier
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FTIR	Fourier transform infrared (spectrometer)
GA	tabun (a nerve agent)
GB	sarin (a nerve agent)
GC-MSD	gas chromatograph-mass spectrometric detector
H	nondistilled mustard
HD	distilled mustard
HRA	health risk assessment
HT	thickened mustard
ITEQ	International Toxic Equivalence
JACADS	Johnston Atoll Chemical Agent Disposal system
LIC	liquid incinerator

MPF	metal parts furnace
NRC	National Research Council
OSHA	Occupational Safety and Health Administration
OVT	operational verification testing
PAS	pollution abatement system
PCB	polychlorinated biphenyl
PCDD/F	polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans
PFPD	pulsed-flame photometric detector
PFS	PAS carbon bed filter system
PLL	Programmatic Lessons Learned
PMCD	Program Manager for Chemical Demilitarization
POIO	Public Outreach and Information Office
PQL	practical quantification limits
QRA	quantitative risk assessment
RCRA	Resource Conservation and Recovery Act
RIR	recordable injury rate
RMP	Risk Management Plan
SVOC	semivolatile organic compound
TOCDF	Tooele Chemical Agent Disposal Facility
TSCA	Toxic Substances Control Act
VOC	volatile organic compound
VX	a nerve agent

Executive Summary

This report reviews the status of the U.S. Army Chemical Stockpile Disposal Program (CSDP) operations at Tooele, Utah, with respect to previous recommendations and observations made by the National Research Council (NRC) Committee on Review and Evaluation of the Army Chemical Stockpile Disposal Program (Stockpile Committee). The committee recognizes actions that have satisfied recommendations, identifies recommendations that require further action, and provides additional recommendations for improving the overall CSDP performance at the Tooele Chemical Agent Disposal Facility (TOCDF), Tooele, Utah, and other sites. In a 1994 NRC report, *Recommendations for the Disposal of Chemical Agents and Munitions,* the Stockpile Committee established the following general criterion for evaluating CSDP activities: "The Chemical Stockpile Disposal Program should proceed expeditiously and with technology that will minimize total risk to the public at each site."

The TOCDF is the first operational baseline incineration system for the disposal of chemical agents and munitions in the continental United States. The facility is adjacent to the Deseret Chemical Depot (DCD), where 43 percent of the total chemical agent stockpile was stored before the start of TOCDF operations in August 1996. Since then, more than 20 percent of the chemical agent stored at the DCD has been destroyed. The Johnston Atoll Chemical Agent Disposal System (JACADS), located about 700 miles southwest of Hawaii, was the prototype baseline incineration system and the first to become operational (July 1990). To date, it has destroyed more than 80 percent of the chemical agent and munitions stored on Johnston Atoll (originally about 6 percent of the total stockpile). Baseline facilities are under construction at three additional storage sites in the continental United States (Anniston, Alabama; Umatilla, Oregon; and Pine Bluff, Arkansas).

Chemical agents are stored at four additional sites. Two of these, Aberdeen, Maryland, and Newport, Indiana, contain only bulk quantities of agent (no munitions).

Chemical-based "neutralization" disposal technologies are being implemented at these sites. The remaining two sites, Pueblo, Colorado, and Blue Grass, Kentucky, contain chemical agent in munitions. Alternative disposal technologies, which are presently undergoing evaluation, may be implemented at these sites. The focus of this report is primarily on operational and planned baseline incineration facilities, especially the TOCDF, but broader programmatic matters, such as risk management and public involvement, are also addressed and are applicable to all CSDP sites.

The major aspects of TOCDF operations reviewed in this report are:

- systems performance and plant operations (Chapter 2)
- trial burn tests to establish compliance with Resource Conservation and Recovery Act (RCRA) and Toxic Substances Control Act (TSCA) emission levels (Chapter 2)
- improvements to the monitoring systems for airborne agent (Chapter 2)
- risk management (Chapter 3)
- safety programs and performance (Chapter 4)
- public and community interactions (Chapter 5)

Findings and recommendations are presented in Chapter 6.

SYSTEMS PERFORMANCE AND PLANT OPERATIONS

The Army and its TOCDF contractor, EG&G Defense Materials, Inc., have satisfied many, but not all, of the Stockpile Committee's recommendations related to system performance and plant operations. The start-up period has been completed, and operations so far indicate that program destruction goals can be met. Because of TSCA permit delays on the deactivation furnace system (DFS), the Environmental Protection Agency

(EPA) mandated a delay in processing M55 rockets, which has significantly slowed the planned reduction of stockpile storage risk. In the interim, operations were continued on bulk items. Following the successful DFS trial burn in November 1998, the Army was processing M55 rockets at half rate under a RCRA permit limitation.[1] When the TSCA permit was issued in mid-1999, the RCRA limitation was lifted. The TOCDF is now authorized to process M55 rockets at the full rate and is proceeding toward meeting its original risk reduction goals as soon as possible.

Some early operational problems were linked to important safety management issues. These problems, and the investigations necessitated by them, have taken time and management resources that might otherwise have been applied to improving operating performance.

Unresolved issues involving the disposal of dunnage and problems with the slag removal system heater are not critical to continuing safe performance, but their prompt resolution (in the interest of minimizing waste and reducing the number of plant shutdowns for heater replacement) remains a high priority. For example, because it is more economical to ship waste brine off site, the Army has not retested the compliance of the brine reduction area (BRA) with particulate emissions standards. If off-site brine disposal becomes infeasible, this could affect TOCDF operations.

TRIAL BURN TESTS TO ESTABLISH COMPLIANCE WITH RCRA AND TSCA

The committee has reviewed and evaluated the results of trial burns conducted on the various incinerators comprising the baseline system. Trial burns were conducted in accordance with RCRA and TSCA protocols. The acceptance criteria for the RCRA trial burn of the liquid incinerators, the DFS, and the metal parts furnace have been met. A second test of the DFS polychlorinated biphenyl (PCB) destruction efficiency showed that emissions levels meet TSCA criteria. The TOCDF has been issued a TSCA permit for the DFS, and activities to obtain a national TSCA permit are still ongoing. Certification of the BRA is not required as long as waste brine is being processed off site. An application was submitted in late 1998 for the RCRA permit renewal, allowing six months for regulators to review the application before the present permit expired in June 1999. At the time of publication, the regulators had completed work with the Army on the permit renewal, but its issuance was pending until the conclusion of a public comment period.

IMPROVEMENTS IN MONITORING SYSTEMS

False-positive alarms from the current automatic continuous air monitoring system continue to occur and interrupt agent destruction operations. Although the Army appears to be making reasonable progress in addressing the committee's previous recommendations-including upgrading both the automatic continuous air monitoring system and the depot area air monitoring system—the development, testing, and deployment of more reliable agent monitors should be expedited as much as possible. The development and testing of Fourier transform infrared technology for the real-time detection of an agent release is also proceeding, but real-time alarms are still in development.

RISK MANAGEMENT

The risk management program[2] uses the health risk assessment (HRA) and quantitative risk assessment (QRA) as quantitative tools to evaluate and manage the

[1] Because of artifact contamination, some of the initial DFS test runs after the destruction and removal of polychlorinated biphenyl (PCB) were inconclusive. The retest unambiguously demonstrated compliance with TSCA requirements.

[2] Risk management is a decision-making process for balancing alternative strategies and consequences and a process for implementing those decisions. Risk management is based on: (1) a thorough assessment of performance and the full spectrum of risks to the public, workers, the environment, and property; (2) the prioritization of risks so they can be addressed in order of seriousness; (3) methods of assessing the impact of proposed changes in procedures, management, or equipment; (4) evaluations of abnormal incidents for effects on facility risk; and (5) a commitment to continual evaluation and improvement. Risk management usually involves the following steps:

- understanding the risk (including identifying major contributors to risk)
- suggesting alternative ways to reduce risk
- evaluating alternatives for risk reduction
- selecting preferred alternatives (including implementing decisions)

facility risks.[3] The HRA for the TOCDF, completed by the Utah Department of Environmental Quality before the start of agent operations, showed that risks were well below regulatory thresholds. However, the data from the TOCDF trial burn indicate that a few compounds were measured at higher concentrations than were assumed in the HRA; the detection limits for others were too high to confirm the validity of the assumed HRA emission rates. Furthermore, a review of some of the models used in the HRA revealed that the HRA did not use the air-dispersion and deposition models and risk assessment methods then recommended by the EPA (i.e., all guidance and updates issued by the EPA through December 1994).

Now that the TOCDF trial burns have been completed, the State of Utah or the Army may wish to issue a brief update of the results of the HRA based on actual TOCDF emissions data and the original EPA guidance. Although the risks posed by individual compounds may change in the updated results, the overall estimate of risk is not likely to change significantly. The committee urges that the results of the revised HRA be made widely available.

Although higher emission rates were found during the trial burn, they would not necessarily significantly change the results of the HRA because the HRAs performed to meet regulatory compliance requirements and HRAs directed toward risk management have different focuses. The former use high-biased assumptions designed to provide realistic bounds but may significantly overstate anticipated effects. The latter use more realistic estimates as a basis for risk mitigation. Hence, significant changes in the emission rates of individual compounds, particularly those that do not contribute significantly to overall risk, may not significantly change HRA results.

The implementation of an effective risk management program at the TOCDF will have important implications for the CSDP as a whole. The Stockpile Committee has made several recommendations in previous NRC reports for improving risk management. In both the 1996 report, *Review of Systemization at the Tooele Chemical Agent Disposal Facility,* and the 1997 report, *Risk Assessment and Management at Deseret Chemical Depot and the Tooele Chemical Agent Disposal Facility,* the committee observed that certain aspects of risk assessment and risk management at DCD/TOCDF and throughout the CSDP program required further work and refinement. For example, based on experience from the TOCDF, the committee now recommends that Phase 2 QRAs[4] for chemical disposal facilities under development be performed as soon as feasible. This will allow risk mitigation measures to be implemented through design changes as necessary.

The committee is pleased with the manner in which the Army has responded to safety issues identified in QRAs. However, risk management continues to be an informal, albeit thorough, process. The committee is concerned that an informal process driven by key individuals in the office of the Program Manager for Chemical Demilitarization (PMCD) could break down with a change in personnel or that the risk management process might not be fully transferred to specific sites. Therefore, the committee urges the PMCD to consider the establishment of a formal management program for QRA-identified safety issues, including a tracking mechanism for identifying new issues and monitoring their resolution.

The committee concluded that another critical aspect of risk management is the change management process (CMP). In this process, effects on risk as measured by the HRA and QRA, as well as public input, are used to evaluate proposed system or operational changes. The PMCD claims that public involvement will be part of changes with a significant impact on risk or changes that are of public concern. The committee believes that public involvement is an important element in the timely disposal of the stockpile—including, but not limited to, the CMP.

The committee strongly believes that the Army should rapidly document and formalize the effective risk

[3] The TOCDF QRA estimates the risk to the public and workers from accidental releases of chemical agent associated with all activities during storage at DCD and throughout the disposal process at the TOCDF. The HRA is a screening analysis to estimate possible off-site human health risks associated with exposure to airborne emissions from the TOCDF under normal and upset conditions. The HRA also estimates risks to wildlife and the environment. Whereas the HRA is a screening tool using conservative upper limit assumptions on releases of hazardous materials, the QRA is a more exhaustive and thorough analysis using actual data and addressing uncertainties.

[4] A Phase 1 QRA evaluates public risks from a proposed facility before it is constructed. A Phase 2 QRA is a detailed evaluation of the risks and consequences of accidental releases of agent to workers and the community based on the site-specific design and operations.

management programs being used on the site-specific and programmatic levels. Cross-communication, cooperation, and learning between sites has greatly enhanced the entire program. The Army must continue and strengthen this process to improve safety and environmental performance.

SAFETY PROGRAMS AND PERFORMANCE

The Stockpile Committee has been monitoring the CSDP safety performance since its evaluations of operational verification testing at JACADS in 1993 and 1994 and has recommended improvements in the overall management of safety, particularly the development of a well qualified, well trained workforce that operates within an established safety culture. Safety at the TOCDF has also become a public issue because of detailed allegations by two former employees that safety programs and performance at the facility were deficient. As a result of these allegations, seven independent assessments of the safety program at the TOCDF have been conducted. All these assessments reached the same conclusion—that agent operations are being conducted safely.

The Stockpile Committee agrees that TOCDF agent operations are being conducted in a manner that protects the public. Nevertheless, instances of failure to wear required protective equipment, poor housekeeping, and some unsafe working conditions observed by the committee during site visits indicate that a total safety culture has yet to take root at the TOCDF. The recent spill of 140 gallons of nerve agent GB within the containment area caused by the improper reassembly of a filter following maintenance suggests that more training and emphasis on following procedures are needed for maintenance and other operations-related activities.

In response to the committee's observations and recommendations, and out of a stated desire to improve safety performance, TOCDF management has implemented several programs and initiatives to develop and maintain a "safety culture" at the site. Despite these efforts, safety performance has not improved significantly since the agent destruction operations began.

The formal and informal communications about safety that are now issued by TOCDF management on a regular basis have reinforced the commitment to safety and created an environment in which safety is valued. These communications should be continued. The committee is satisfied that some progress has been made toward creating a better environment for the development of a safety culture at the TOCDF. Continued attention to balancing the safety of agent operations and traditional industrial safety issues, as well as continued management involvement and commitment, will be necessary.

PUBLIC AND COMMUNITY INTERACTIONS

The Stockpile Committee's recommendations regarding public involvement in the CSDP and emergency management/preparedness in the 1996 *Systemization* report dealt only with activities at the TOCDF. The recommendations in the 1997 *Risk Assessment and Management* report were related to risk management in the overall disposal program.

Since 1996, important changes have been made in the PMCD management of the CSDP, especially in the Public Outreach and Information Office (POIO). After a comprehensive self-examination, the POIO redefined its mission and organization and is no longer the primary point of contact for local public involvement activities for specific sites. Much of the responsibility for site-specific public involvement activities has been delegated to on-site contractors. Although it is still too early to assess the impact of the reorganization and realignment of the POIO, the supporting documentation and goals are much improved.

Although reorganization of the POIO and its goals is important, as is the shift to developing strategies to increase public involvement, neither is a satisfactory substitute for an organizational culture that proactively seeks the involvement of stakeholders and the personnel of the local outreach office. Neither the personnel of the local outreach office nor the public had input into the draft CMP prior to the Army's first public presentation of the process. The committee was disappointed by the CSDP's failure to implement its CMP for any proposed change to the facility. The Army needs to engage the public, not only in changes to already established technology at baseline sites—a topic of limited interest as evidenced by poor public turnout—but also in pending decisions on topics of interest to neighboring communities, such as plans for decommissioning a facility.

Despite improvements in outreach at the local level and the reorganization of the POIO, the committee sees little evidence that stakeholder and public views have been incorporated into the decision-making process. The CSDP has clearly expanded its ability and capacity for public outreach, but it has not yet achieved the meaningful public involvement the committee recommended.

The Chemical Stockpile Emergency Preparedness Program (CSEPP) has also been reorganized. The Army still controls on-site emergency preparedness, but all off-site responsibilities, including budgeting, have been assigned to the Federal Emergency Management Agency. Consequently, off-site preparations are no longer within the scope of the Stockpile Committee's oversight. The committee remains concerned about CSEPP' s relation to the CSDP and the horizontal fragmentation of responsibility at the federal level. Since the TOCDF became operational, local emergency preparedness activities have intensified and have resulted in some excellent preparedness exercises. The emergency communications system in Tooele County is nearly complete, the decontamination equipment is substantially in place, and tone alert radios are being distributed. At least at Tooele, indications are that the activities of on-site and off-site emergency managers are well coordinated.

1

Introduction

DESCRIPTION OF THE CHEMICAL AGENT AND MUNITIONS STOCKPILE

For more than 50 years, the United States has maintained a stockpile of chemical agents and munitions distributed among eight sites in the continental United States and at Johnston Atoll in the Pacific Ocean. Two basic types of chemical agents comprise the stockpile: neurotoxic (nerve) agents and mustard (blister) agents. Both types are frequently, and erroneously, referred to as "gases" even though they are liquids at normal temperature and pressure.[1]

The nerve agents include organic phosphorus compounds designated as VX, GB (sarin), and GA (tabun). These chemicals present a significant toxic hazard because of their action on the nervous systems of humans and animals through inhibition of the acetylcholinesterase enzyme. VX is more acutely toxic than GB, but the latter represents a greater potential hazard because of its higher volatility (about the same as water) and, thus, the greater likelihood of being inhaled. Chronic health effects and cancer from low-level exposures have not been associated with nerve agents or with chemically (and toxicologically) similar commercially available organic phosphorus insecticides (Leffingwell, 1993). Only short-term symptoms have been documented in individuals who have survived exposure to nerve agents.

The mustards (designated H [nondistilled mustard], HD [distilled mustard], and HT [thickened mustard]) do not present significant acute lethal hazards. Their principal effect is severe blistering of the skin and mucous membranes. They have been implicated as possible carcinogens, however, and may present a cancer hazard to individuals suffering acute exposure (Leffingwell, 1993; IOM, 1993). Estimates of induced cancers from accidental agent exposures only apply to mustard agents.

Once chemical agents are fully dispersed, they do not tend to persist in the environment because of their high chemical reactivity, particularly with water. However, in extremely dry desert climates, they can persist for a considerable period of time (U.S. Army, 1988).

The chemical agents in the U.S. stockpile are stored in a variety of containers, including bulk (ton) containers, rockets, projectiles, mines, bombs, cartridges, and spray tanks. Figure 1-1 summarizes the stockpile configuration for the eight continental U.S. sites by agent, munition, and containment system prior to the start of agent destruction operations at the Tooele Chemical Agent Disposal Facility (TOCDF) (NRC, 1997).

CALL FOR DISPOSAL

Chemical Stockpile Disposal Program

Because of the age of the stockpiled chemical weapons, their lack of utility as effective weapons or deterrents, the continuing costs of maintenance, and the potential for accidental release, the United States and other countries have strong incentives to dispose of them. In 1985, Congress enacted Public Law 99-145 to initiate the process of eliminating the U.S. chemical weapons stockpile with an expedited program to dispose of

[1] The *stockpile* (the subject of the Army's Chemical Stockpile Disposal Program) consists of both bulk containers of nerve and blister agents and munitions, including rockets, mines, bombs, cartridges, projectiles, and spray tanks loaded with nerve or blister agents. Buried chemical warfare material, recovered chemical warfare material, binary weapons (in which two nonlethal components are mixed after firing to yield a lethal nerve agent), former production facilities, and miscellaneous chemical warfare material are not included in the stockpile. The disposition of these five classes of materials is the subject of the separate Non-Stockpile Chemical Material Program. Information on the Army's overall chemical material disposal programs is available at http://www-pmcd.apgea.army.mil/

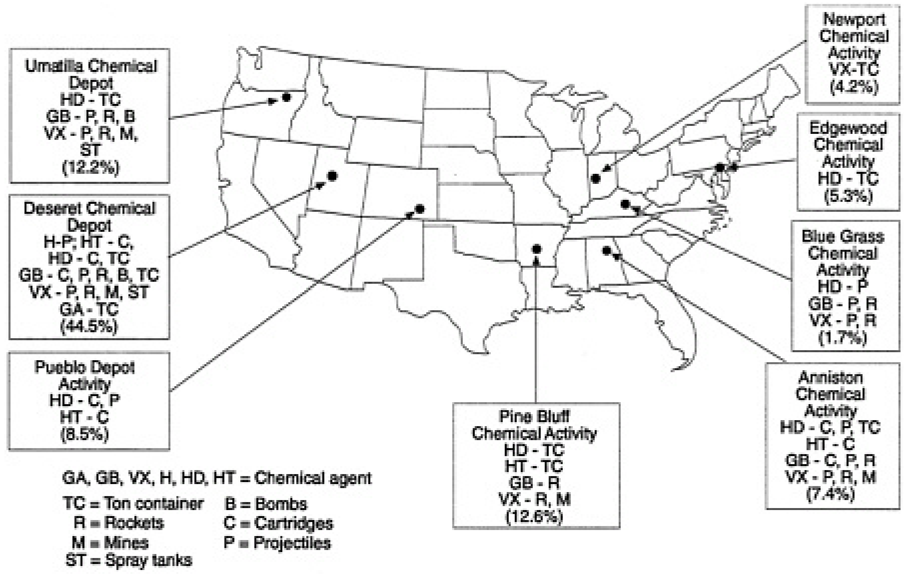

Figure 1-1 Location and size (percentage of original stockpile) of eight continental U.S. storage sites.
Source: OTA, 1992; NRC, 1997.

M55 rockets. These munitions raise special concerns because they are aging and because they contain agent, explosives, and propellants in an integrated configuration (as propellants age, stabilizer components degrade —increasing the potential for autoignition). In 1992, Congress enacted Public Law 104–484, which directed the Army to dispose of the entire unitary[2] chemical agent and munitions stockpile by December 31, 2004. Congress also directed that the Chemical Stockpile Disposal Program (CSDP) be implemented in a manner that ensured maximum protection of workers, the public, and the environment.

Chemical Weapons Convention

The CSDP has evolved in parallel with worldwide efforts to establish international control of chemical agent precursors and eliminate chemical agents and munitions. Over the course of several decades, a broad and complex agreement known as the Chemical Weapons Convention (CWC) was negotiated. Since 1993, the CWC has been signed by 165 countries and ratified by more than 100. The convention went into effect on April 29, 1997, six months after 65 countries had ratified it. Since then, the United States, which was actively involved in negotiating the CWC agreement, and Russia, the world's largest holder of chemical agents and munitions, have also ratified it.

The CWC prohibits the development, production, acquisition, stockpiling, retention, transfer, or use of chemical weapons. Article IV requires that signatories destroy chemical weapons and any special facilities for their manufacture within 10 years, (by April 29, 2007). Destruction of chemical weapons is defined as "a process by which chemicals are converted in an essentially

[2] The term *unitary* refers to a single chemical loaded in munitions or stored as a lethal material. More recently *binary* munitions have been produced, in which two relatively safe chemicals are loaded into separate compartments to be mixed to form a lethal agent after the munition is fired or released. The components of binary munitions are stockpiled separately, in separate states They are not included in the present Chemical Stockpile Disposal Program. However, under the Chemical Weapons Convention of 1993, they are included in the munitions that will be destroyed.

irreversible way to a form unsuitable for production of chemical weapons, and which, in an irreversible manner, renders munitions and other devices unusable as such" (Smithson, 1993). The method of destruction is to be determined by each country, but the manner of destruction must ensure public safety and protect the environment.

Selection and Development of the Baseline Incineration System

In the early 1980s, the Army investigated a number of strategies and technologies for the destruction or disposal of chemical weapons. Among these were chemical destruction ("neutralization"), ocean disposal (now banned by federal law), stockpile consolidation with subsequent destruction, and disassembly followed by component incineration. The Army then selected incineration as the preferred technology for stockpile disposal. The National Research Council (NRC) Committee on Demilitarizing Chemical Munitions and Agents was formed in August 1983 to review the status of the stockpile and to assess the available disposal technologies. In that committee's final report in 1984, incineration was endorsed as an adequate technology for the safe disposal of chemical warfare agents and munitions (NRC, 1984).

Pursuant to the enactment of Public Law 99–145, the Army began the development of components of the baseline incineration system at the Chemical Agent Munitions Disposal System (CAMDS) facility at Deseret Chemical Depot (DCD), formerly Tooele Army Depot, Utah. Construction and systemization of the first fully integrated baseline incineration system, the Johnston Atoll Chemical Agent Disposal System (JACADS), was completed in July 1990 on Johnston Island, located in the Pacific Ocean approximately 700 miles southwest of Hawaii. The JACADS facility has a two-fold mission:

- to destroy the chemical agents and munitions stored there
- to serve as a demonstration facility for the baseline incineration system

INCINERATION SYSTEM AT THE TOOELE CHEMICAL AGENT DISPOSAL FACILITY

The incineration system at the TOCDF represents a second-generation baseline system that incorporates improvements based on operating experience at the JACADS facility, advances in technology, and recommendations by the Committee on the Review and Evaluation of the Army Chemical Stockpile Disposal Program (Stockpile Committee), the successor to the Committee on Demilitarizing Chemical Munitions and Agents. The design was also based on the concept that the performance and safety of disposal are greatly enhanced if stockpile feed materials are separated into distinct streams of agent, energetic materials, metal parts, and dunnage (packing, activated carbon, and other waste material) prior to disposal treatment. A schematic drawing of the TOCDF incineration system is shown in Figure 1–2 (see Appendix A for a description of specific features of the TOCDF incineration system). Systemization (preoperational) testing at TOCDF began in August 1993, and agent operations began on August 22, 1996. Prior to the start of agent operations, a quantitative risk assessment (QRA) and a health risk assessment (HRA) were conducted (U.S. Army, 1996a; Utah DSHW, 1996). [3]

In the TOCDF baseline system, feed materials are separated inside a building that has areas capable of withstanding explosions. The atmospheric pressure in these and other areas where agent may potentially be present is controlled to be lower than the ambient atmospheric pressure to prevent leakage from the building to the outside atmosphere. Agents are removed from munitions and containers via remote control by two methods. Most containers are simply mechanically punched open and drained. Munitions, which also contain energetics (explosives/propellants), are mechanically disassembled and drained. These processes yield three material streams: agent, energetics, and metal parts. Energetics and metal parts may be

[3] The TOCDF QRA estimates the risk to the public and to workers from accidental releases of chemical agent associated with all activities during storage at DCD and throughout the disposal process at the TOCDF The HRA, which was conducted by the Utah Division of Solid and Hazardous Waste (Department of Environmental Quality), was a screening analysis to estimate possible off-site human health risks associated with exposure to airborne emissions from the TOCDF under normal and upset conditions. The HRA also estimates risks to wildlife and the environment

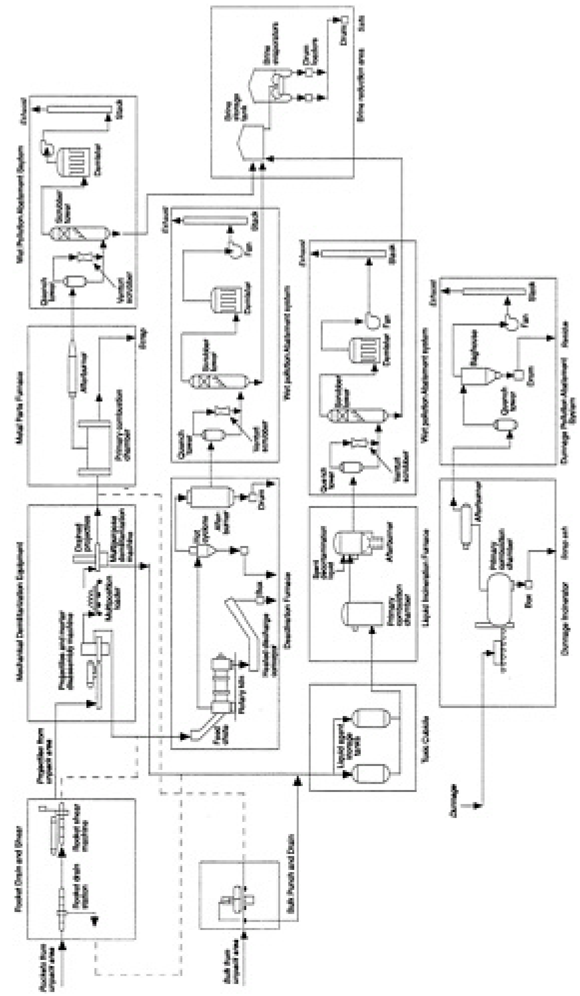

Figure 1-2 Schematic drawing of the TOCDF incineration system.
Source: U.S. Army, 1988; NRC, 1994b, 1994c.

contaminated by residual agent, but the vast majority of agent (95 percent or more) is usually recovered during the draining procedure. This material separation is a major safety feature of the TOCDF baseline system, which has parallel disposal systems for the treatment of these very different material streams.

At the TOCDF, agents are pumped to and destroyed in one of two specially designed liquid incinerators (LICs). Each LIC consists of a primary and secondary combustion chamber, and is followed by a pollution abatement system (PAS) consisting of a quick quench that saturates the gas stream, a venturi scrubber to control particulates, a tower scrubber to remove gaseous contaminants, and a demister to minimize water droplet carryover to the stack. Agent flow is stopped if the combustion chamber temperature drops below 2,550°F. Energetics are burned in a rotary kiln deactivation furnace system (DFS); exhaust gases are sent to an afterburner and then treated by a PAS before release to the atmosphere. Metal parts are decontaminated by heating in a metal parts furnace (MPF) to 1,000°F for a minimum of 15 minutes to vaporize and burn any residual agent; exhaust gases are sent to an afterburner and then to a PAS.

Agent compounds contain various inorganic elements that result in significant acid gas incineration products. Acidic gases in the discharge streams are scrubbed in the PAS of each furnace with alkali solutions to form salts. In the original plan, these wet salts, or brine, were to be processed in a brine reduction area (BRA) and the resultant dry salts stored for later disposal in hazardous-waste landfills. However, brine from the TOCDF is now shipped off site to a hazardous-waste disposal facility.

According to the original plan, contaminated and uncontaminated packing materials and miscellaneous waste, or dunnage, were to be burned in a dunnage furnace (DUN) and the exhaust gases discharged through a separate stack without acid gas scrubbing because only trace amounts of agent or other acid-producing species were expected to be present. Current practice at the TOCDF is to dispose of dunnage that is not contaminated with agent off site through normal waste-handling processes. Some agent-contaminated materials are decontaminated and disposed of as hazardous waste. Used activated carbon from the facility's air filtration system is a major waste component originally slated to be disposed of in the DUN. An alternate procedure for incinerating this material in the DFS is scheduled for testing in 2001.

Two auxiliary material streams are also processed: decontamination fluids are incinerated in the secondary combustion chamber of the LIC; and ventilation air is passed through banks of activated carbon filters to remove any trace contaminants.

Baseline monitoring systems are used to detect agent release and to monitor adherence to environmental requirements. The agent monitoring system consists of a combination of the automatic continuous air monitoring system (ACAMS) and the depot area air monitoring system (DAAMS). The ACAMS detects immediate threats with a three- to eight-minute response time for agent levels at 20 percent of the permissible eight-hour exposure concentration for workers. The DAAMS, which provide a much more sensitive and definitive measurement, has a slower response time because it requires transporting collection tubes to a central laboratory for analysis. An ACAMS alarm from monitoring the exhaust flow through the PAS results in an immediate shutoff of agent feed. Because the less selective ACAMS field monitors sometimes produce false alarms for certain nonagent emissions, DAAMS laboratory analyses are used to confirm or disprove ACAMS alarms and to document environmental compliance.

ROLE OF THE COMMITTEE ON REVIEW AND EVALUATION OF THE ARMY CHEMICAL STOCKPILE DISPOSAL PROGRAM

Concurrent with the beginning of construction of the baseline incineration facility at JACADS in 1987, the Army requested that the NRC review and evaluate the CSDP in order to provide advice and counsel. The NRC established the standing Stockpile Committee at that time to perform these tasks, beginning with a study of operational verification testing at JACADS, which was completed in March 1993. Several reports issued by the committee (e.g., *Recommendations for the Disposal of Chemical Agents and Munitions* [NRC, 1994a] and *Review of Systemization of the Tooele Chemical Agent Disposal Facility* [NRC, 1996a]) concluded that the baseline incineration system was an adequate and safe means of disposing of the chemical weapons stockpile (see Appendix B for a complete list of Stockpile Committee reports).

Composition of the Stockpile Committee

Since its inception in 1987, the Stockpile Committee has exercised an advisory and oversight role over the Army's CSDP. Over the years, the Stockpile Committee has adjusted the composition of its membership to maintain a balance of disciplines necessary to meet the task at hand. Current members have expertise in analytical chemistry; biochemical engineering; chemistry; chemical engineering; chemical industry management; combustion engineering; community health and urban studies; environmental health policy; environmental restoration; health risk assessment and environmental toxicology; mechanical engineering; monitoring and instrumentation; risk assessment, management, and communication; statistics and incinerator performance analysis; toxicology; and waste treatment and minimization.

OVERVIEW OF RELEVANT NRC RECOMMENDATIONS

Table 1-1 is a summary of recommendations from past NRC reports that are relevant to the present study. In the 1994 NRC report, *Recommendations for the Disposal of Chemical Agents and Munitions* (*Recommendations* report), the Stockpile Committee established its general criterion for evaluating CSDP activities. This criterion is included in the first recommendation (subsequently referred to as [RC-1]: "The Chemical Stockpile Disposal Program should proceed expeditiously and with technology that will minimize total risk to the public at each site" (NRC, 1994a).

Although the minimization of public risk continues to be the committee's major concern, the total risk is dependent on a number of factors:

- integrity of facility design, construction, operation, and maintenance
- a safety culture throughout the organization
- qualified, well trained, highly motivated managers and workers
- current, detailed safety analyses
- positive working interactions with regulatory agencies, emergency response services, community groups, and the general public

The 1996 NRC report, *Review of Systemization of the Tooele Chemical Agent Disposal Facility* (*Systemization* report), which was published several months before the start of agent operations at the TOCDF, contained 18 specific recommendations organized by the timing of the start of agent operations (NRC, 1996a). However, for the purposes of the present report, they are considered topically. A 1996 letter report, *Public Involvement and the Army Chemical Stockpile Disposal Program,* contained two recommendations (NRC, 1996b). In the 1997 NRC report, *Risk Assessment and Management at Deseret Chemical Depot and the Tooele Chemical Agent Disposal Facility* (*Risk Assessment and Management* report), 10 additional recommendations were made (NRC, 1997). In Table 1-1, the *Recommendations* report is designated [RC]; the *Systemization* report is designated [S]; the *Risk Assessment and Management* report [R]; and the *Public Involvement* report [PI]. A complete list of TOCDF-related recommendations is presented in Appendix C.

PURPOSE OF THIS REPORT

This report reviews the status of the CSDP with respect to earlier recommendations made by the Stockpile Committee. The primary objectives of this report are to assess the Army's progress and to acknowledge actions that satisfy prior recommendations, to identify recommendations that require further action, and to provide additional recommendations for improving overall performance at the TOCDF after more than two years of agent disposal operations. Although the focus of this report is on the TOCDF, some findings and recommendations apply to other sites and the CSDP as a whole. The statement of task concerning this report follows:

Statement of Task

The NRC study will accomplish the following:

- Gather and assess data and information from the Tooele Chemical Agent Disposal Facility (TOCDF) on systems performance and plant operations, e.g., incineration trial burns, brine reduction area testing and certification, slag removal system operations, monitoring systems operations, and other performance characteristics.
- Assess progress in the area of safety and risk management, e.g., establishment of a safety culture, establishment of safety performance goals, implementation of high quality, adequately staffed safety management systems, and implementation of other elements important to a sound risk management program.
- Evaluate and assess the Army's actions and programs designed to enhance public and community

TABLE 1-1 NRC Recommendations Addressed in This Report

Prior Recommendation	Area(s) Addressed by Recommendation	Chapter in Which Recommendation Is Discussed
RC-1	Program-wide risk reduction	2, 3, 4
S-1	Implementation of a safety program	3, 4
S-2	Incorporation of safety and environmental goals into award fees	4
S-3	Completion of QRA, resolution of safety-related issues	3
S-4	Improved public interactions and communications	5
S-5	Emergency preparedness training	5
S-6	Completion and practice of emergency preparedness plans	5
S-7	Completion of emergency-preparedness communications system for Tooele site	5
S-8	Completion of Army preoperational survey	2
S-9	Attainment of LIC 99.9999% DRE	2
S-10	Safety management	4
S-11	Completion of RCRA and TSCA trial burns	2
S-12	BRA certification; dunnage disposal	2
S-13	LIC slag removal	2
S-14	Completion of risk management plan (RMP)	3
S-15	Risk assessment integration	3
S-16	"Near misses" tracking and safety	3
S-17	Improvements in monitoring	2
R-1	Updating of QRA, HRA	3
R-2	Development and review of program-wide site-specific QRAs and HRAs	3
R-3	Update of QRA methodology manual	3
R-4	Inclusion of "safety culture" in *Guide*	4
R-5	Definitions of risk management roles and responsibilities in *Guide*	4
R-6	Inclusion of public involvement in RMP	5
R-7	Tracking of CMP performance	5
R-8	Understanding of risk assessment by workers, etc.	3
R-9	Implementation and updating of RMP	3, 4, 5
PI-1	Commitment of CSDP to public involvement	5
PI-2	Coordination of CSDP, CSEPP, public affairs, and RMP	3, 5

Legend: RC = *Recommendations for the Disposal of Chemical Agents and Munitions* (NRC, 1994a); S = *Review of Systemization of the Tooele Chemical Agent Disposal Facility* (NRC, 1996a); R = *Risk Assessment and Management at Deseret Chemical Depot and the Tooele Chemical Agent Disposal Facility* (NRC 1997); and PI = *Public Involvement and the Army Chemical Stockpile Disposal Program* (NRC, 1996b). See Appendix B for a complete list of reports by the NRC Stockpile Committee.

interactions on issues of mutual concern, e.g., risk reduction, change management, emergency management, etc.

- Extract valuable lessons learned and their programmatic implications.
- Provide recommendations that the committee believes are needed to enhance the overall Chemical Stockpile Disposal Program at the TOCDF and at other sites.

In performing this assessment, the entire Stockpile Committee visited the TOCDF in March 1997 and met with TOCDF staff in Salt Lake City in February 1998 (see Table 1–2). A working group of the committee also visited the site on December 9, 1997, and March 11, 1999. This report is based on those visits, prior visits, a review of reports and briefings by the Army and other groups, and the committee's extensive knowledge of the CSDP and the construction and systemization of the TOCDF.

This chapter has provided a brief description of the TOCDF facilities and the CSDP. Chapter 2 assesses systems performance and plant operations. Chapters 3 and 4 discuss risk assessment and risk management and safety issues, respectively. Chapter 5 reviews the relationships between the TOCDF (which is operated by Edgerton, Germerhausen and Grier [EG&G] Defense Materials Incorporated, an Army contractor, and the office of the U.S. Army Program Manager for Chemical Demilitarization [PMCD]) and relevant government and community groups. Committee findings and recommendations are presented in Chapter 6.

TABLE 1–2 Site Visits and Briefings

TOCDF Site Visits (1997–1999)	Committee Attendance
March 1997	full committee
July 1997	working group
December 1997	working group
February 1998	new members
TOCDF Briefings (1997–1999)	
March 6, 1997	full committee
June 19, 1997	full committee
September 18, 1997	full committee
February 26, 1998	full committee
June 25, 1998	full committee
September 24, 1998	full committee
January 7, 1999	full committee
March 18, 1999	full committee

2

Systems Performance and Plant Operations

In the areas of systems performance and plant operations, the Stockpile Committee recommended that the following conditions be satisfied:

- mandatory Army Preoperational Survey requirements prior to the start of agent operations [S-8]
- all Resource Conservation and Recovery Act (RCRA) and Toxic Substance Control Act (TSCA) trial-burn requirements for the LICs and DFS [S-9, S-11]
- testing and certification of the BRA and DUN or implementation of a satisfactory alternative [S-12]
- demonstration of the slag-removal system for the LICs [S-13]
- active pursuit of continual improvements in monitoring systems [S-17]
- continued evaluation of the proposed addition of a carbon-bed filter to the PAS [S-18] (the subject of a separate NRC report, *Carbon Filtration for Reducing Emissions from Chemical Agent Incineration* [NRC, 1999])

OVERVIEW

Activities since the Start of Agent Operations

The TOCDF began agent operations on August 22, 1996. As of May 19, 1999, 20,001 GB M55 rockets, 2,710 GB ton containers, 137,754 GB 105 mm projectiles, and 4,463 GB MC-1 bombs had been destroyed. The destruction schedule for M55 rockets had fallen behind the original timetable because of a delay in obtaining the TSCA permit; and more projectiles and fewer ton containers had been processed than was projected by the TOCDF QRA schedule. Approximately 2,751 tons of GB have been destroyed, more than 20 percent of the total DCD stockpile.

Every year the Army submits a report to Congress on the CSDP that includes a description of "other events" and a summary of significant events that resulted in plant shutdowns, of which there have been two each year. The most recent shutdown, which occurred on December 13, 1998, was caused by improper reassembly of an in-line filter after maintenance that resulted in 140 gallons of GB leaking into the toxic cubicle sump. Although all agent was contained by the safeguards built into the facility, this significant maintenance error suggests that there are problems in training and the implementation of a safety culture throughout the organization. This event also suggests insufficient communication between control room operations and maintenance personnel. None of the events resulted in exposure of personnel to chemical agent or its release to the environment.

RCRA trial burns have been satisfactorily completed with GB for LIC-1 and LIC-2, the MPF, and the DFS. The TSCA trial burn for the DFS had to be redone, however, which delayed the processing of M55 rockets. The second TSCA trial burn was successful.

The BRA did not pass its initial compliance test because of excessive particulate emissions, but the probable cause of the problem was identified. However, because economics favor the off-site disposal of brine, the Army has decided not to retest the BRA at this time. This has raised concerns on the committee about what would happen if the off-site shipping of brine becomes unavailable. TOCDF site managers have discussed alternatives to the off-site disposal of brine, and the BRA is presently in a long-term lay-up configuration, which means the equipment will be protected while it is inactive. Approximately four weeks would be necessary for the equipment to be made operational. The state of Utah has verbally agreed that, in the event of a change to requirements for brine management, it would allow the Army time to effect the transition. This could include authorizing the temporary storage of brines in isolation containers (as is done at JACADS) until the equipment in the BRA can be brought on line and tested to demonstrate compliance with regulatory requirements.

The DUN at the TOCDF has not been used because contaminated wastes that were scheduled for destruction in the DUN are being disposed of at qualified hazardous-waste management facilities. Although off-site disposal was always an option, the DUN was originally designed as part of the overall waste-minimization program required by the Environmental Protection Agency (EPA) and endorsed by the committee. The major contaminated waste stream scheduled for destruction in the DUN is the activated carbon from the facility's ventilation system. As an alternative, the Army is studying the installation of a micronizer and burner designed to dispose of activated carbon in the DFS. A prototype unit will be tested at JACADS during the closure phase of that facility (calendar year 2001).

Modifications to improve the LIC slag-removal system have been successful. As of December 1998, slag had been tapped approximately 45 times, almost all from LIC-1, which has an improved slag-removal system. During a recent maintenance shutdown, the slag-removal system for LIC-2 was also upgraded, but LIC-2 has not been operated long enough since then to demonstrate the performance of the upgraded system. To date, a total of approximately 22,000 lbs of slag has been drained from both incinerators; this has avoided approximately three maintenance shutdowns that would have been necessary to remove slag manually. A recurrent problem in the slag-removal system has been the failure of the heater, and the Army is evaluating ways to extend heater life.

Disposal Schedule

Because risk to the public is directly related to the existence of the stockpile, its rate of destruction is of key concern to the Stockpile Committee. The faster the stockpile can be safely destroyed, the lower the overall risk to the public becomes, and the Army has organized the disposal schedule to maximize risk reduction. The first campaigns, therefore, were focused on the disposal of M55 GB rockets, with co-processing of GB ton containers. At the start of agent processing, the expected value of the public acute fatality risk as calculated in the QRA was 1.4×10^{-3} per year.[1]

According to the schedule issued at the start of agent destruction operations, all GB M55 rockets were to have been processed within the first nine months of operation. In actuality, after about one-third of the rockets (11,592 units) had been processed, rocket processing was stopped because some of the exhaust gas samples collected during the first TSCA trial burn contained a specific polychlorinated biphenyl (PCB) cogener that later proved to be a random sampling or analysis artifact. Thus, results of the first PCB destruction and removal efficiency test were ambiguous, and the TSCA permit for processing M55 rockets at the full rate was delayed pending a successful retest. The recovery efficiencies of surrogate spikes during the TSCA trial burns were low, which was probably due to the severe weather conditions during testing in January 1997. (Severe weather can affect the sampling procedures.) When the trial burns were repeated in November 1998, the results met regulatory requirements, and the processing of M55 rockets was resumed. In the interim, ton containers were processed, and GB MC-1 bombs and 105 mm projectiles were moved up in the schedule to make the most effective use of the facility.

At the end of calendar year 1998 (after 28 months of agent operations), the TOCDF had processed 71,771 items (rockets, bombs, projectiles, and ton containers) containing approximately 2,495 tons of agent. The public acute fatality risk calculated in the QRA for the condition at the end of 1998 was 2.5×10^{-4} expected fatalities per year. According to the operations schedule in the QRA, by this time 47,162 items were to have been processed containing approximately 4,004 tons of agent. In percentage terms, 52 percent more items had been processed by the end of calendar year 1998, but 37 percent less agent had been destroyed than originally scheduled. The difference reflects that more projectiles and fewer ton containers have actually been processed than were projected in the QRA schedule.

Thus, the TOCDF is ahead of the original QRA schedule in the number of items processed but behind in the tonnage of agent destroyed. The changes in the order of agent disposal operations have reduced the

[1] To understand the expected value (average number) of fatalities, imagine a large number of identical plants, each operating for an identical disposal mission. Most would have no accidents; some would have accidents involving one fatality, and some might have accidents involving more than one fatality. The average number of fatalities for all of the plants is the expected value. See Appendix A of the *Risk Assessment and Management* report (NRC, 1997) for a more thorough discussion.

overall risk and enabled efficient utilization of the facility, which is processing three munitions (GB-filled rockets, ton containers, and projectiles) at the same time. Because of the delay, the stacking height of stored VX rockets was lowered to reduce the storage risk. The current schedule allows for a constant rate of agent processing during the overall GB campaign, but the delay in processing GB-filled M55 rockets has slowed the rate of risk reduction. At the completion of the GB processing campaign (third quarter of calendar year 2001), the TOCDF is now projected to have destroyed 929,865 items containing approximately 6,097 tons of agent. At a similar point in the original schedule, the TOCDF was projected to have destroyed a total of 942,561 items containing approximately 6,683 tons of agent, including some non-GB agent.

At the start of agent processing, the public acute-fatality risk calculated in the QRA for accidental agent release was 1.4×10^{-3} per year. This was based on five phases of disposal: (1) disposal of GB rockets and ton containers; (2) disposal of VX rockets and spray tanks; (3) processing of remaining GB items; (4) processing of remaining VX items; and (5) disposal of HD. Because of the delay in the processing of GB rockets, the Army decided to complete disposal of all other GB items first, followed by all VX items. Thus, the public acute-fatality risk at the end of 1998 was 2.5×10^{-4} per year (18 percent of the original rate at the start of operations). This risk is based on the disposal of the GB munitions and ton containers and the reconfiguration (by reducing the stacking height and banding rockets together) of the stored VX rockets. At the same time in the original QRA schedule, the calculated public acute-fatality risk was to have been 7.0×10^{-5} per year, or 5 percent of the original risk at the start of operations, based on the assumption that all GB rockets, VX rockets, spray tanks, MC1 bombs, weteye bombs, and a little more than half of the GB ton containers had been processed.

The TOCDF destruction program was behind schedule by approximately one month (33 days) as of the end of calendar year 1998. Given the recent regulatory approvals for the operation of both of the LICs and the DFS at the full rate and the successful completion of the TSCA trial burn for the DFS, the committee believes that the current schedule delay can be made up. The processing of GB rockets is expected to resume after the disposal of the M360 projectiles (which are processed in the MPF) has been completed in the third quarter of calendar year 2001. The remaining GB ton containers and munitions can be coprocessed during this same time, and GB rockets are being processed, as the system allows. Their disposal is expected to be completed in calendar year 1999. GB ton containers are processed whenever there is enough capacity in the LICs. This overall strategy is the shortest pathway through the TOCDF operations schedule that is consistent with the principle of processing the items with the highest storage risk as soon as practical.

At its meeting in September 1998, the committee was informed that the recent program-wide audit performed by the Arthur Anderson Company indicated that the present schedule and budget estimates were probably optimistic (Evans, 1998a; Arthur Anderson, 1998). Although safety is the committee's highest priority, the prompt destruction of the stockpile is the primary factor in risk reduction. A strong commitment program-wide and by site management to meeting schedules without compromising operational safety is essential to meeting the overall goal of safe and expeditious destruction of the stockpile.

TRIAL BURNS

Trial burns are conducted to demonstrate that incinerator systems perform as designed and meet applicable state and federal regulations and permit restrictions. The specific purpose of a trial burn is to demonstrate permissible emissions while processing at maximum allowable chemical agent feed rates under projected worst-case operating conditions for both the combustion chamber(s) and the air-pollution control equipment. The demonstrated worst-case operating conditions then become the operating limits in the operating permit. The facility operator is allowed to operate the incinerators at conditions equal to or better than the worst-case conditions. Hence, normal incinerator performance should always be as good or better than the performance demonstrated during the trial burn.

The TOCDF's LICs, DFS, and MPF were first tested using agent surrogates (i.e., chemicals that behave similarly to agents in incinerators but are not nearly as toxic at the same concentration). Once the surrogate trial burns demonstrated that the incinerators met the Army's performance standards, chemical agent trial burns were conducted to satisfy RCRA and TSCA requirements.

The sections that follow summarize the results of the surrogate and agent trial burns, discuss the implications of the agent trial-burn data for the HRA, and describe the problem with the TSCA trial-burn data that delayed the processing of M55 rockets. If compounds of concern were present in concentrations below the detection limits, the practical quantification limits (PQLs) were reported for most tests.[2] Consequently, the maximum amount of a compound of concern that might have been present is overstated by a factor of at least 3.3.

Surrogate Trial Burns

The TOCDF DFS, MPF, and one of two identical LICs were tested using agent surrogates. The DUN was not tested because DUN operations are no longer planned. The purpose of a surrogate trial burn is to demonstrate that an incinerator system (combustor plus air-pollution control system) can efficiently destroy and remove typically hard-to-burn compounds. The Army set a target destruction and removal efficiency (DRE) of 99.9999 percent, which is more stringent than the federal DRE requirement for all substances that do not contain polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/F). Surrogates were selected to meet the Utah Division of Solid and Hazardous Waste criteria. The surrogate trial burn for LIC-1 was successfully conducted between June 30 and July 7, 1995 (the results are summarized in NRC, 1996a). The results of the other three surrogate trial burns are summarized below.

Results of Surrogate Trial Burns

The TOCDF operates under RCRA permit UT5210090002 issued by the state of Utah. Under the requirements of this permit, the incinerator systems must demonstrate that they meet performance standards that ensure effective and safe destruction of chemical agents before beginning routine operations. The primary objective of the surrogate trial burns was to demonstrate that the incinerators meet the following performance criteria:

- DRE of at least 99.9999 percent for the surrogates, also known as principal organic hazardous constituents
- emissions of total particulate matter lower than the federal requirement of 180 milligrams per dry standard cubic meter (mg/dscm), which is equivalent to 0.08 grains per dry standard cubic foot (gr/dscf) at 7 percent oxygen (O_2); and the state requirement of 0.016 gr/dscf at 7 percent O_2 for particulate matter smaller than 10 microns[3] (PM_{10})
- hydrogen chloride (HCl) emissions, measured downstream of the pollution control equipment, less than four pounds per hour (lbs/hr) or less than 1 percent of the total organically-bound chlorine input to the furnace (i.e., chlorine in the surrogate, not salts that might contaminate the fuels)
- minimal emissions of products of incomplete combustion evidenced by 60-minute moving average carbon monoxide (CO) concentrations of less than 100 parts per million (ppm) on a dry, volumetric basis corrected to 7 percent O_2

Liquid Incinerator #2

LIC-2 surrogate trial burns were conducted on January 29 and 30, 1996. The surrogates selected to simulate the chemical agents were 1,2,4-trichlorobenzene and tetrachloroethylene (also known as perchloroethylene), which contain a lot of organically bound chlorine to challenge the PAS and have chemical bonds similar to those in the agents. The results should be reasonably representative of chemical agent operations.

Table 2-1 is a summary of the particulate matter, HCl, and CO emissions and DREs for the LIC-2 surrogate trial burns. Total particulate emissions were significantly lower than the PM_{10} requirement, showing that the fraction of emissions of sub-10 micron particulates was lower than the requirement. A greater than 99.9999 percent DRE was

[2] Footnotes in some test reports (see, for example, Tables 5–9 and 5–19 in EG&G, 1997b) state that practical quantification limits (PQLs) were reported when results were below the detection limit. When the concentration of a sample with 3 to 5 times the estimated detection limit was repeatedly measured, the replicates show some scatter, which typically follows a bell-shaped, Gaussian distribution. The standard deviation of this distribution (S_0) is used to define the detection limit as three times S_0 (EPA, 1997). For measurements at the detection limit, the analyst can be confident that the analyte is present but cannot make a firm statement about the amount. At or above the PQL, however, the analyst can be confident about the quantity. The PQL is defined as 10 times S_0 for air pollution control measurements, but in 1999 this unique definition was termed inappropriate (EPA, 1999). Based on these definitions, the PQL is 3.3 times the detection limit. Consequently, by reporting the PQL for results that are below detection limits, the maximum amount of pollutant is overstated by a factor of at least 3.3.

[3] A micron is a millionth of a meter, so 10 microns is 10^{-5} meters.

TABLE 2-1 Surrogate Trial Burns for LIC-2 in January 1996

		Test Run Results		
Parameter	Requirement	1	2	3
PM concentration[a] (gr/dscf)	< 0.08[b]	0.0040	0.0040	0.0017
HCI emission rate (lb/hr)	4[c]	< 0.003	< 0.003	< 0.003
CO Concentration[d] (ppm)	100	10.0	9.1	14.5
Trichlorobenzene DRE (%)	> 99.9999	> 99.999973	> 99.999973	> 99.999973
Perchloroethylene DRE (%)	> 99.9999	> 99.999983	> 99.999984	> 99.999991

[a] PM = particulate matter, corrected to 7 percent oxygen, dry basis.
[b] < 0.016 gr/dscf for particulate matter with a size: œ10 microns (PM_{10}).
[c] Or less than 1 percent of organically bound chlorine in exhausts gas prior to entering pollution control equipment, which averaged 8.7 lb/hr for all three test runs.
[d] Corrected to 7 percent oxygen, dry basis.
Source: Adapted from EG&G, 1996a.

demonstrated. Limitations for particulate matter, HCI, and CO emissions were met during the test.

Metal Parts Furnace

MPF surrogate trial burns were conducted on June 4, 5, and 6, 1996. The surrogates selected to simulate the chemical agents were a combination of monochlorobenzene and hexachloroethane. This combination was recommended by the Utah DSHW as one that would be more difficult to destroy than the chemical agents and would provide a maximum challenge to the PAS.

Six of the first seven runs were invalidated because of sampling and analytical problems, such as the inadvertent use of an incorrectly spiked resin or a sampling system leak. Another run, Run 6, was aborted because of operating difficulties with the MPF. Because the sampling problems are not associated with the ability of the incinerator to meet performance standards, and because the operating difficulty during Run 6 involved ancillary equipment that was not likely to affect emissions, the Utah DSHW, with the guidance of the EPA, agreed that additional performance runs could be conducted. The next few runs, Runs 8 through 10, were completed without incident.

Table 2-2 summarizes the particulate matter, HCI, and CO emissions and DREs for the MPF surrogate trial burns. The particle-size distribution was not measured so no information is available on the amount of PM_{10} actually emitted, but compliance with the PM_{10} standard (see performance criteria given earlier) was demonstrated because the total particulate emissions were less than the PM_{10} performance standard. The Army's 99.9999 percent DRE requirement was also demonstrated. Hence, the MPF surrogate trial burns demonstrated that the system could safely proceed to the second phase of the RCRA demonstration and testing requirements—the chemical agent trial burn (ATB).

Deactivation Furnace System

The DFS surrogate trial burns were conducted between September 30, 1995, and October 6, 1995. The tests included one run using only supplementary fuel and five performance runs with surrogates. The surrogate compounds selected by the Utah DSHW were monochlorobenzene and hexachloroethane. An error in sample recovery voided run 1. Run 2 was not completed because of a mechanical failure in a feed chute that interrupted incinerator operations. Incinerator performance was assessed using runs 3, 4, and 5.

Table 2-3 summarizes the particulate matter, HCI, and CO emissions and DREs for the DFS surrogate trial burns. Although particulate size was not measured, total

TABLE 2-2 Surrogate Trial Burns for the MPF in June 1996

		Test Run Results		
Parameter	Requirement	8	9	10
PM concentration[a] (gr/dscf)	PM < 0.08[b]	0.0018	0.0015	0.0038
HCI Emission Rate (lb/hr)	< 4[c]	< 0.016	< 0.009	< 0.009
CO concentration[d] (ppm)	< 100[e]	7.9	8.3	8.4
		7.2	6	7.3
Monochlorobenzene DRE (%)	> 99.9999	> 99.999966	> 99.999975	> 99.999976
Hexachloroethane DRE (%)	> 99.9999	> 99.999955	> 99.999955	> 99.999956

[a] PM = particulate matter, corrected to 7 percent oxygen, dry basis.
[b] < 0.016 gr/dscf for particulate matter with a size: œ 10 microns (PM_{10}).
[c] The 4 lb/hr emissions standard is greater than 1 percent of organically bound chlorine input to the furnace (1.05, 1.06, and 1.07 lb/hr for runs 8, 9, and 10, respectively).
[d] Corrected to 7 percent oxygen, dry basis.
[e] Standard is based on 60-minute moving average. The average of the one-minute moving averages recorded by two different continuous emission-monitoring system analyzers were reported to provide a more representative value over the feed time.
Source: Adapted from EG&G, 1996b.

TABLE 2-3 Surrogate Trial Burns for the DFS in September 1995

		Test Results		
Parameter	Requirement	3	4	5
PM concentration[a] (gr/dscf)	< 0.08[b]	0.0043	0.0048	0.0049
HCI emission rate (lb/hr)	< 4[c]	< 0.0183	< 0.0532	< 0.0040
CO concentration[d] (ppm)	100	10	10	10
Monochlorobenzene DRE (%)	> 99.9999	> 99.999990	> 99.999967	> 99.999999
Hexachloroethane DRE (%)	> 99.9999	> 99.999989	> 99.999988	> 99.999991

[a] PM equals particulate matter, corrected to 7 percent oxygen, dry basis.
[b] < 0.016 gr/dscf for particulate matter with a size œ 10 microns (PM_{10}).
[c] Or less than 1 percent of organically bound chlorine in exhaust gas prior to entering any pollution control equipment (0.40, 0.39, and 0.40 lbs/hr for runs 3, 4, and 5, respectively).
[d] Corrected to 7 percent oxygen, dry basis.
Source: Adapted from EG&G, 1995.

particulate emissions were less than the PM_{10} emissions standard. Therefore, the fraction of emissions smaller than 10 microns (10^{-6} m) meets the requirement. The Army's 99.9999 percent DRE requirement was also demonstrated. Hence, the DFS surrogate trial burns demonstrated that the system could proceed to the second phase of the RCRA demonstration and testing requirements—the ATBs.

Agent Trial Burns

The agent trial burns (ATBs) at the TOCDF site demonstrated that the incineration systems meet emissions requirements when burning chemical munitions. The ATBs are conducted (1) to demonstrate a DRE requirement for agent in accordance with the state of Utah permit, the Code of Federal Regulations (Title 40 Part 264), and RCRA regulations, and (2) to demonstrate system performance and the control of emissions. The results of the ATBs conducted to date for LIC-1, LIC-2, the DFS, and the MPF using agent GB are summarized below.[4] The following performance standards were characterized:

- DRE for the incinerator using agent GB as the principal organic hazardous constituent for fulfillment of RCRA requirements (i.e., 99.99 percent)
- compliance with the particulate-matter emission-rate limits in both the RCRA permit UT5210090002 and the Approval Order issued by the state of Utah
- compliance with the HCI emission-rate limits in the RCRA permit
- emission rates for phosphorus and the 20 metals estimated by the state of Utah for the screening HRA conducted by the Department of Environmental Quality DSHW (Utah DSHW, 1996)
- emissions of PCDD/F
- emissions of certain semivolatile organic compounds (SVOCs) and volatile organic compounds (VOCs)
- exhaust gas concentrations of O_2 and CO using the TOCDF continuous emission-monitoring systems (CEMS) to document one aspect of combustion conditions in the system and show compliance with the CO concentration limits in the RCRA permit

Liquid Incinerators

LIC-1 ATBs were conducted on February 26, 27, and 28, 1997, and LIC-2 ATBs, on August 20, 22, and 23, 1997 (EG&G, 1997a, 1997b). During these performance trials, agent GB was processed. The results presented in Table 2-4 show that emissions of particulate matter, HCI, agent GB, and CO were within the permit limits established by the state of Utah for liquid incinerator systems. Agent destruction was better than the minimum DRE requirement of 99.99 percent.

Emission rates of VOCs, SVOCs, PCDD/F, phosphorus, and metals were compared to the emission rates used in the HRA (Utah DSHW, 1996). The results of this comparison are summarized below and shown in Table 2-5:

- Emission rates for 20 of the metals were below the rates used in the screening HRA. The highest measurement for LIC-1 lead is a statistical outlier indicating a potential sampling problem (which, had it been confirmed prior to the publication of the test report, would have invalidated that particular run and indicated compliance). The phosphorus concentration measured for LIC-1 was above the HRA estimated rate. Mercury was not detected, but the detection limit was above the rate used in the HRA.
- The international toxic equivalent concentrations (ITEQ) for the PCDD/F averaged 0.00034 ng/dscm and 0.00053 ng/dscm (at 7 percent O_2) for LIC-1 and LIC-2, respectively. These are lower than the federal hazardous-waste incinerator regulatory limit of 0.2 ng/dscm (at 7 percent O_2) for new sources.
- Emission rates for two VOCs, ethylbenzene and m,p-xylene, were above the emission rates used in the HRA in at least one run on LIC-1. The other VOCs were either not detected or their emission rates were below the emission rates used in the HRA.
- The majority of the 141 target SVOCs were below measurement method detection limits. The measured emission rate for one SVOC, Bis (2-ethylhexyl) phthalate, was above the assumed HRA

[4] See Chapter 2 of the 1999 NRC report, *Carbon Filtration for Reducing Emissions from Chemical Agent Incineration,* for a thorough discussion of measuring trace emissions, sampling and analysis methodologies, and the characteristics of exhaust gas emissions at the TOCDF and JACADS.

TABLE 2-4 Agent Trial Burns of LIC-1 and LIC-2

Emissions Parameter	State of Utah Permit Limit	LIC-1 Results	LIC-2 Results
Maximum concentration of agent GB[a]	0.3 µg/m^3	< 0.0037 µ/m^3	< 0.0034 µg/m^3
Minimum DRE for GB	99.99%	> 99.999999969%	> 99.999999973%
Maximum concentration of particulate matter	0.016 gr/dscf @ 7% O_2[b] 0.08 gr/dscf @ 7% O_2[c]	0.0023 gr/dscf, @ 7% O_2	0.0016 gr/dscf, @ 7% O_2
Maximum emission rate of HCl	4 lbs/hr or 1% of total HCL prior to PAS	0.009 lbs/hr	< 0.016 lbs/hr
Maximum concentration of CO[d]	100 ppm @ 7% O_2	16 ppm @ 7% O_2	50 ppm @ 7% O_2
Maximum concentration of CEMS O_2	15%	9.2%	9.8%
Minimum concentration of CEMS O_2	3%	6.7%	6.7%
Maximum concentration of dioxin ITEQ[f]	0.2 ng/dscm @ 7% O_2[e]	0.00046 ng/dscm @ 7% O_2	0.00093 ng/dscm @ 7% O_2
Average concentration of dioxin ITEQ[f]	0.2 ng/dscm @ 7% O_2[e]	0.00034 ng/dscm @ 7% O_2	0.00053 ng/dscm @ 7% O_2

[a] Determined from analysis of DAAMS sorbent tubes (Station PAS 704 - LIC-1; 705 - LIC-2).
[b] Limit set by Air Approval Order for PM_{10} (i.e., particulate matter with a size of œ 10 microns).
[c] Limit set by RCRA Permit.
[d] Maximum one hour moving average.
[e] Proposed EPA limit; there is no state limit.
[f] ITEQ (international toxic equivalency) dioxin is 2,3,7,8 TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin), with toxicity equivalent to the complex mixture of 210 dioxin and furan isomers (with 4 through 8 chlorine atoms). This equivalency is based on the ITEQ scheme adopted by the United States and most other countries to simplify the reporting of dioxin emissions.
Source: Adapted from EG&G 1997a, 1997b.

emission rate. Measurement method detection limits were above the equivalent HRA emission rates for dimethylphthalate, however, so conclusions cannot be drawn about the relation of actual and projected emissions for this SVOC.

The list in Table 2-5 includes compounds for which a measured emission rate from LIC-1 or LIC-2 was higher than the value used in the HRA or for which the detection limit was too high to draw a meaningful conclusion.

Deactivation Furnace System

DFS ATBs with GB were conducted on January 7, 10, and 11, 1997. During these performance runs, M55 rockets were processed at an average rate of 35 rockets per hour. The rockets were punched and drained of GB prior to entering the DFS, although some residual agent remained after the draining operation. The test results are summarized below and in Tables 2-6 and 2-7:

- Emissions of particulate matter, HCl, GB, and CO were below the state of Utah permit limits established for the DFS.
- The measured 99.999981 percent DRE was better than the minimum 99.99 percent DRE requirement.
- Emission rates for 16 metals were below the HRA estimated values. Cadmium, lead, zinc, and phosphorus were higher than the HRA estimated emission rates. The detection limit for mercury was too

TABLE 2-5 Measured LIC-1 and LIC-2 Emissions or Reported Upper Limits That Exceed Values Estimated in the HRA

	Maximum Emission[a] (g/sec)	HRA Estimated Rate (g/sec)[b]	Source
Metals and Phosphorus			
Lead	4.0 E-04	6.01 E-05	EG&G, 1997a, Table 5-18
Mercury	< 1.1 E-05	2.44 E-06	EG&G, 1997a, Table 5-18
	< 5.7 E-06	2.44 E-06	EG&G, 1997b, Table 1-1
Phosphorus	1.9 E-03	1.18 E-03	EG&G, 1997a, Table 5-18
VOCs			
Vinyl chloride	< 3.6 E-06	4.07 E-07	EG&G, 1997a, Table 5-7
	< 6.7 E-06	4.07 E-07	EG&G, 1997b, Table 5-7
Chloroform	< 3.8 E-06	4.07 E-07	EG&G, 1997a, Table 5-7
	< 13 E-05	4.07 E-07	EG&G, 1997b, Table 5-7
Carbon tetrachloride	< 3.3 E-06	4.07 E-07	EG&G, 1997a, Table 5-7
Bromodichloromethane	< 5.2 E-06	4.07 E-07	EG&G, 1997a, Table 5-7
	< 1.7 E-05	4.07 E-07	EG&G, 1997b, Table 5-7
Dibromochloromethane	< 6.4 E-06	4.07 E-07	EG&G, 1997a, Table 5-7
	< 1.7 E-05	4.07 E-07	EG&G, 1997b, Table 5-7
Ethylbenzene	4.5 E-06	4.07 E-07	EG&G, 1997a, Table 5-7
	< 6.4 E-06	4.07 E-07	EG&G, 1997b, Table 5-7
m,p-xylene	6.1 E-06	3.98 E-06[c]	EG&G, 1997a, Table 5-7
	< 7.7 E-06	3.98 E-06	EG&G, 1997b, Table 5-7
Styrene	< 2.5 E-05	1.39 E-05	EG&G, 1997b, Table 5-7
	< 2.1 E-05	1.39 E-05	EG&G, 1997a, Table 5-7
Bromoform	< 1.3 E-05	1.19 E-05	EG&G, 1997b, Table 5-7
		SVOCs	
Dimethyl phthalate	< 1.2 E-04	8.18 E-05	EG&G, 1997a, Table 5-9
	< 1.5 E-04	8.18	E-05 EG&G, 1997b, Table 5-9
Bis (2-ethylhexyl) phthalate	< 3.2 E-04	4.79 E-05	EG&G, 1997a, Table 5-9
	2.2 E-04	4.79 E-05	EG&G, 1997b, Table 5-9

[a] For the emissions of VOCs and SVOCs reported as "<," the PQL is reported. The PQL is 3.3 times the detection limit.

[b] The highest concentrations measured during the initial JACADS trial burns were used by the State of Utah DSHW to estimate TOCDF emissions.

[c] HRA value is for total xylene.

Source: Adapted from EG&G 1997a, 1997b.

TABLE 2-6 Agent Trial Burns for the DFS in January 1997

Emissions Parameter	State of Utah Permit Limit	DFS ATB Results
Maximum concentration of agent GB[a]	0.3 mg/m^3	< 0.0117 μ/m^3
Minimum for DRE for GB	99.99%	> 99.999981%
Maximum concentration of particulate matter	0.016 gr/dscf @ 7% O_2[b] 0.08 gr/dscf @ 7% O_2[c]	0.0053 g/dscf, @ 7% O_2
Maximum emission rate for HCl	4 lbs/hr or 1% of total HCl prior to PAS	< 0.040 lbs/hr
Maximum concentration of CO[d]	100 ppm @ 7% O_2	8 ppm @ 7% O_2
Maximum concentration of CEMS O_2	15%	9.6%
Minimum concentration of CEMS O_2	3%	9.0%
Maximum concentration of dioxin ITEQ[f]	0.2 ng/dscm @ 7% O_2[e]	0.00061 ng/dscm @ 7% O_2
Average concentration of dioxin ITEQ[f]	0.2 ng/dscm @ 7% O_2[e]	0.00055 ng/dscm @ 7% O_2

[a] Determined from analysis of DAAMS sorbent tubes (Station PAS 702).
[b] Limit set by Air Approval Order for PM_{10}, (i.e. particulate matter with a size of = 10 microns).
[c] Limit set by RCRA Permit.
[d] Maximum one hour moving average.
[e] Proposed EPA limit; there is no state limit.
[f] ITEQ (international toxic equivalency) dioxin is 2,3,7,8 TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin), with toxicity equivalent to the complex mixture of 210 dioxin and furan isomers (with 4 through 8 chlorine atoms). This equivalency is based on the ITEQ scheme adopted by the United States and most other countries to simplify the reporting of dioxin emissions.
Source: Adapted from EG&G, 1998.

high to make a definitive statement. The measured concentration for lead plus cadmium was less than 20 percent of the 24 μqg/dsm^3 corrected to 7 percent O_2 limit for hazardous waste incinerators.

- The ITEQ concentrations for the PCDD/F emissions averaged 0.00055 ng/dscm (at 7 percent O_2), compared to the new source performance standard of 0.2 ng/dscm for hazardous waste incinerators.
- Detection limits for seven VOCs and three SVOCs were higher than the estimated values in the HRA in at least one sample set. The measured emission rates or detection limits for the other VOCs and SVOCs were below those used in the HRA or were not detected at all.

Table 2-7 lists compounds for which measured emission rates or detection limits from the DFS were higher than the value used in the HRA.

Metal Parts Furnace

ATBs of GB in the MPF were conducted on April 4, 15, and 17, 1997. During these performance runs, ton containers with residual GB were spiked with metals to represent the worst case of munitions feed containing heavy metals and agent-contaminated dunnage. In addition, 75 pounds of GB were added to each ton container. The agent feed rate for the MPF was nominally 110 lbs/hr, including both undrained heels (of gelled agent) and added agent. Packages of metal spiking compounds were placed on the feed cradle adjacent to each ton container. The results shown in Tables 2-8 and 2-9 are summarized below:

- Emissions of particulate matter, HCl, GB, and CO were within the state of Utah permit limits established for the MPF.

TABLE 2-7 Measured DFS Emissions or Reported Upper Limits That Exceed Values Estimated in the HRA

	Maximum Emission (g/sec)	HRA Estimated Rate (g/sec)[a]
Metals and Phosphorus		
Cadmium	1.8 E-04	1.83 E-05
Lead	7.3 E-03	4.32 E-04
Mercury	< 1.1 E-05	5.15 E-06
Zinc	1.3 E-03	8.23 E-04
Phosphorus	2.5 E-03	9.14 E-04
VOCs[b]		
Bromodichloromethane	< 1.5 E-05	1.15 E-06
Mono-chlorobenzene	< 9.9 E-06	3.77 E-06
Chloroform	< 1.1 E-05	7.84 E-06
Dibromochloromethane	< 2.3 E-05	1.15 E-06
Ethylbenzene	< 1.0 E-05	2.88 E-06
4-methyl-2-pentanone (MIBK)	< 5.0 E-05	1.15 E-06
Tetrachloroethene	< 2.2 E-05	1.15 E-06
SVOCs[b]		
di-n-butyl phthlate	< 2.6 E-05	2.24 E-05
Dimethyl phthalate	< 1.6 E-04	8.18 E-05
Bis (2-ethylhexyl) phthalate	< 8.6 E-04	4.79 E.05

[a] The highest concentrations measured during the initial JACADS trial burns were used by the state of Utah DSHW to estimate TOCDF emissions.
[b] For emissions of VOCs and SVOCs reported as "<," the PQL is reported. The PQL is 3.3 times the detection limit.
Source: Adapted from EG&G, 1998.

- The measured DRE was 99.9999 percent, which is better than the required minimum 99.99 percent DRE.
- Metals emission rates were below the rates used in the HRA. Phosphorus emission rates were higher than the HRA estimates.
- Emission rates for the PCDDs were below the rates used in the HRA. Emission rates for tetra-, penta-, and hexa-chlorodibenzofurans in two runs were higher than the HRA rates for these homologues. However, the ITEQ concentrations for the PCDD/F emissions averaged 0.025 ng/dscm (corrected to

TABLE 2-8 Agent Trial Burns for the MPF in April 1997

Emissions Parameter	State of Utah Permit Limit	Results
Maximum concentration of agent GB[a]	0.3 mg/m^3	< 0.0046 mg/m^3
Minimum for DRE	99.99%	> 99.99999972%
Maximum concentration of particulate matter	0.016 gr/dscf @ 7% O_2[b] 0.08 gr/dscf @ 7% O_2[c]	0.0097 g/dscf, @ 7% O_2
Maximum emission rate for HCl	4 lbs/hr or 1% of total HCl prior to PAS	< 0.015 lbs/hr
Maximum concentration of CO[d]	100 ppm @ 7% O_2	12 ppm @ 7% O_2
Maximum concentration of CEMS O_2	15%	13.9%
Minimum concentration of CEMS O_2	3%	12.6%
Maximum concentration of dioxin ITEQ[f]	0.2 ng/dscm @ 7% O_2[e]	0.042 ng/dscm @ 7% O_2
Average concentration of dioxin ITEQ[f]	0.2 ng/dscm @ 7% O_2[e]	0.025 ng/dscm @ 7% O_2

[a] Determined from analysis of DAAMS sorbent tubes.
[b] Limit set by Air Approval Order for $PM_{10,}$ i.e. particulate matter with a size of œ 10 microns.
[c] Limit set by RCRA Permit.
[d] Maximum one hour moving average.
[e] Proposed EPA limit; there is no state limit.
[f] ITEQ (international toxic equivalency) dioxin is 2,3,7,8 TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin), with toxicity equivalent to the complex mixture of 210 dioxin and furan isomers (with 4 through 8 chlorine atoms). This equivalency is based on the ITEQ scheme adopted by the United States and most other countries to simplify the reporting of dioxin emissions.
Source: Adapted from EG&G, 1997c.

7 percent oxygen), which is well below the new source performance standard for hazardous waste incinerators of 0.2 ng/dscm corrected to 7 percent oxygen.

- Two VOCs, m,p-xylene and o-xylene, were measured at levels slightly above the HRA estimated emission rate.
- The detection limits for four SVOCs and 12 VOCs were too high to verify that the maximum emission rates were lower than the assumed HRA emission rate.

Table 2-9 lists compounds for which measured emission rates or detection limits from the MPF were higher than the values used in the HRA.

Implications of the Trial Burn Data for the Health Risk Assessment

The purpose of a screening HRA is to estimate an upper bound of health risks to people outside the facility fence-line who could be exposed to facility emissions under worst-case conditions. The HRA is not intended to represent actual risk but to indicate whether risk thresholds have been exceeded and further investigation is warranted. Because the estimated emission rates generated by the Utah Department of Environmental Quality and used in the HRA (Utah DSHW, 1996) differ from several of the actual emission rates, the risks in the HRA would certainly be different if they were recalculated today. Many of the measured emission rates are lower

TABLE 2-9 Measured MPF Emissions or Reported Upper Limits Higher Than Values Estimated in the HRA

	Maximum Emission Rate[a] (g/sec)	HRA Estimated Rate (g/sec)[b]
Phosphorus		
Phosphorus	6.9 E-3	1.16 E-03
VOCs		
Bromodichloromethane	< 8.1 E-06	1.15 E-06
Chlorobenzene	< 5.3 E-06	3.77 E-06
Dibromochloromethane	< 1.2 E-05	1.15 E-06
1,1-dichloroethane	< 5.3 E-06	1.15 E-06
1,2-dichloropropane	< 5.3 E-06	1.15 E-06
Cis-1,3-dichloropropene	< 5.3 E-06	1.15 E-06
Trans-1,3-dichloropropene	< 5.3 E-06	1.15 E-06
Ethylbenzene	< 5.3 E-06	2.88 E-06
2-hexanone	< 2.7 E-05	1.15 E-06
4-methyl-2-pentanone	< 2.7 E-05	1.15 E-06
1,1,2,2-tetrachloroethane	< 5.3 E-06	1.15 E-06
Tetrachloroethene	< 5.3 E-06	1.15 E-06
m,p-xylene	4.8 E-06	1.15 E-06
O-xylene	4.8 E-06	3.98 E-06
SVOCs		
Diethylphthalate	< 4.7 E-05	3.21 E-06
Dimethylphthlate	< 4.7 E-05	4.45 E-06
Di-n-octylphthalate	< 4.7 E-05	3.21 E-06
3/4-methylphenol	< 4.7 E-05	3.60 E-06
Napthalene	< 4.7 E-05	3.21 E-06

[a] For emission values reported as "<," the PQL is reported. The PQL is 3.3 times the detection limit.

[b] The highest concentrations measured during the initial JACADS trial burns were used by the state of Utah DSHW to estimate TOCDF emissions.

Source: Adapted from EG&G, 1997c.

than those used in the HRA—particularly for major risk contributors, such as dioxins, furans, arsenic, and hexavalent chromium. A few are either higher than the estimated values or are measured with a technique whose detection limits are too high to determine that actual emission rates were below the estimated values. Therefore, to determine the net effect, the calculations will have to be revised using the original HRA model and actual emissions. To assess the potential effect of revised emission rates on the HRA, the committee members made preliminary computations based on the human health medium-specific screening levels established by the EPA (EPA, 1998). The committee found that the revised risk estimates would probably be lower than the original HRA values. Thus, the committee believes that the Army could facilitate use of the measured emission rates in HRAs in the following ways:

- The Army does not have jurisdictional authority for the TOCDF HRA, which was performed by the state of Utah. However, the committee believes the Army, which provided the initial trial burn data (from JACADS), should take the initiative in revising the HRA by issuing a brief update of HRA results based on measured emissions concentrations/upper limits. If and when these revisions are made, the committee urges that the revised figures be widely distributed to the public.
- Emissions estimates for future incineration facilities should take into consideration data from all existing facilities and not just JACADS, which was the only operating facility when the TOCDF emission rate estimates were prepared. New estimates should be based on appropriate statistical bounds scaled to the feed rates of the new facilities and should take into account differences in air pollution control technologies and measurement techniques. Upper confidence limits should be used for assessing latent risks; tolerance limits should be used for assessing acute risks.[5]
- Every effort should be made to ensure that the trial burn conditions and measurement techniques are consistent with the assumptions used for developing the emissions estimates and preliminary operating plans.

TABLE 2-10 Trial Burn Results for DFS PCB DREs

Run Number	PCB Train	PCDD/F Train
	January 1997	
1	> 99.999973	> 99.999950
3	> 99.999596	> 99.999949
4	> 99.999795	> 99.999940
Average	> 99.999783	> 99.999946
	November 1998	
1	> 99.999986	———
2	> 99.999986	———
3	> 99.999984	———
Average	> 99.999985	———

Source: Adapted from EG&G, 1997d; Holmes, 1999.

Public confidence in the risk estimates is eroded when actual emission rates are higher than those used in the initial assessment. Consequently, every effort should be made to use reasonable upper-bound emissions estimates at the outset of the HRA process, and the consequences of deviations should be explained in the HRA, not after the fact. In addition to design differences, estimates must account for differences in testing techniques and laboratory detection limits between the data used to prepare the projections and the testing procedures that will be used to demonstrate compliance and establish actual emissions rates.

Toxic Substances Control Act (TSCA) Trial Burns

A TSCA trial burn was required for the DFS because PCBs were used as lubricants inside the shipping and firing tubes of M55 rockets. During these trial burns, M55 rockets were processed at an average rate of 35 rockets per hour. The first TSCA trial burn was conducted in January 1997 and the second in November 1998. Results from both agent trial burns are presented in Table 2-10.

Analyses of some of the January 1997 trial burn samples found a tetra-chlorinated PCB congener (four

[5] Confidence limits set the bounds of expected long-term emissions performance; tolerance limits set the bounds of selected future emission rates.

chlorine atoms in the PCB molecule) in Runs 3 and 4. The tetra-chlorinated congener peak was not present in the samples for Run 1 or in one of the two scrubber liquor samples taken during Run 3. The tetra-chlorinated PCB congener appeared *randomly* throughout other process samples.

The PCB test series from the January 1997 trial burn resulted in calculated DREs that were better than 99.9995 but averaged slightly below the required 99.9999 regulatory limit for dioxin-containing wastes. During the trial burn, PCDD/F and PCB samples were taken simultaneously using the same sampling, recovery, and cleanup and analysis procedures. The PCDD/F sampling train was spiked with PCDD/F field and recovery surrogates, but not with PCB surrogates, and vice versa. Therefore, quality assurance indicators for the PCB test method cannot be calculated for PCB analyses performed on the archived portion of the PCDD/F samples. Archived PCDD/F samples were analyzed for PCBs and did not exhibit the tetra-chlorinated PCB congener peak. Because the tetra-chlorinated PCB congener only appeared randomly in the first PCB test series and was not found in the simultaneous PCDD/F sampling train, it is probably a sampling or analysis artifact that invalidates the PCB sampling train results. Consequently, the actual DRE for PCBs using the complete required methodology is unknown. PCB DRE results calculated from the PCDD/F samples (better than 99.99994 percent) are probably more representative of actual incinerator performance.

A second TSCA ATB with GB was conducted November 17 to 21, 1998. The uncertified November 1998 test results (the final report was not available when this report was prepared) showed no detectable dioxins, and only near-detection-limit values of dichlorobiphenyls (1.2 to 4.6 ng versus a 1 ng detection limit). Trichlorobiphenyls (2.1 to 2.7 ng versus a 1 ng detection limit) were also observed. The reported concentrations were lower than the concentrations found in the field-blank train (11 ng[6] and 2.7 ng[7] for dichlorobiphenyls and trichlorobiphenyls, respectively); however, regulatory practice prohibits deducting field-blank train results from sample measurements to correct for contamination (a common practice for analytical chemists). Consequently, the reported concentrations are likely too large. If these reported concentrations are simply extreme realizations of measurement uncertainty (i.e., data noise) or the result of undetected sample contamination, real PCB emissions may be zero and the calculated DREs significantly understated. The resulting PCB DREs (shown in Table 2-10) calculated from these test results range from 99.999984 to 99.999986 percent, all better than the 99.9999 percent DRE requirement for PCDD/F-contaminated wastes. Consequently, on December 23, 1998, the facility was authorized to process rockets at a rate equal to one-half the rate demonstrated during the November trial burn.

IMPROVING MONITORING SYSTEMS FOR AGENTS AND NONAGENTS

Background

In 1994, after reviewing monitoring systems for the detection and quantification of chemical agents and the by-products of agent and nonagent destruction at JACADS and proposed for the TOCDF, the Stockpile Committee issued the *Review of Monitoring Activities Within the Army Chemical Stockpile Disposal Program* (NRC, 1994b). This report included a wide range of recommendations for supplementing the ACAMS active alarms and passive DAAMS sampling systems routinely used at chemical demilitarization facilities for agent detection. It also recommended revising the operating procedures of on-site chemical laboratories that analyze DAAMS sample tubes for agent on a daily basis, as well as an aggressive program of the monitoring and analysis of stack emissions for a wide range of products of incomplete combustion at the TOCDF.

Progress made by the CSDP in addressing those recommendations was reviewed in the *Systemization* report (NRC, 1996a), which generally endorsed the Army's ongoing efforts to improve monitoring instruments and procedures at the TOCDF. The following additional recommendation was made in the *Systemization* report: "An active program for continual improvement of monitoring instrumentation, including techniques for more rapid recognition of significant levels of agent release, should be pursued" [S-17].

This section reviews the experience at the TOCDF with agent and nonagent (i.e., products of incomplete combustion) monitoring since the beginning of agent

[6] 11 ng is 11 times the detection limit. This is a real analytic response and indicates the existence of a procedural (contamination) problem.

[7] 2.7 ng is less than 3 times the detection limit. This value is lower than the quantification limit and could be data noise.

operations and the Army's progress in improving agent monitoring technology. EG&G and the Army have responded to the issue of monitoring products of incomplete combustion by installing a reasonable suite of CEMS on the common stack and feed ducts and have provided an active stack-sampling protocol for ongoing analysis of a wide range of SVOCs (EG&G, 1994).[8]

The major issues that required attention were both agent related: (1) the problem of sporadic, but too frequent, false positive ACAMS alarms; and (2) the selection, testing, and eventual deployment of advanced technology capable of more rapid (< 10 sec) detection of the release of significant levels of agent in the plant or through the common stack.

False Positive ACAMS Alarms

The problem of sporadic false positive alarms from plant and exhaust stack ACAMS monitors is apparent in operational data from the TOCDF (Holmes, 1998a). Between August 22, 1996, when agent operations began, and October 20, 1998, the seven ACAMS monitors associated with the PAS, including those sampling the common stack (PAS701A,B,C) and those sampling the ducts between individual furnaces and the common PAS (PAS702-PAS705), registered 98 false positive alarms. (In a false positive alarm, an ACAMS response indicates the possible presence of agent above threshold values although no agent is subsequently detected in the much more sensitive and discriminating analyses of material desorbed from the associated DAAMS tubes.) Of these, 39 were attributed to probable interference compounds, 35 were attributed to furnace upsets (which may include responses to odorant compounds in unburned natural gas), 18 were attributed to alarm malfunctions, and 6 were attributed to operator error (Holmes, 1998a). (False positive responses to sulfur-based natural gas odorant compounds may become more frequent when the ACAMS are switched from their current phosphorus-detection mode to the sulfur-detection mode used for mustard agent operation.)

Twenty-two of these PAS ACAMS false alarms automatically shut down agent feed to the LIC, interrupting operations for about an hour each time. Although the false alarm rate was lower than the rate during early JACADS operation, the committee believes that these disruptions are unnecessary and that the Army should continue to improve the instrument specificity and robustness of the monitoring systems.

The committee notes with approval the steps taken by the Army in response to this problem. First, they have defined specifications for an improved ACAMS instrument, which includes improved chromatography to increase specificity, better quantification algorithms to improve accuracy, and more modern electronics to improve signal processing. A competitive procurement for the development and demonstration of this improved ACAMS is planned. Second, the Army has instituted a parallel effort to upgrade the microprocessor and signal-processing software of the existing ACAMS and has initiated plans to test a prototype of the enhanced ACAMS at the TOCDF. Finally, the Army is investigating enhancements to the commercial gas chromatograph-mass spectrometric detector (GC-MSD) units deployed in the laboratories at CAMDS, JACADS, and TOCDF. These units are currently being used to identify interferant compounds that trigger false positive ACAMS alarms so that they can be eliminated from the plant and/or exhaust stream.

A GC-MSD unit with a parallel atomic emission detector designed to recognize phosphorus and sulfur-containing compounds that can trigger the ACAMS flame photometric detectors has been developed and is being tested at CAMDS. In addition, laboratory GC units, with and without MSDs, are being equipped and tested with recently developed pulsed-flame photometric detectors (PFPDs), which promise better, more reliable performance than the flame photometric detectors currently used (DAAMS tube analysis) (Amirav and Jing, 1996). These GC-PFPD and GC-MSD-PFPD units

[8] Agent emissions are the only highly toxic compounds monitored continuously. Although ACAMS alarms have a three to eight minute response time, emissions are continuously sampled by DAAMS tubes, which are analyzed daily or more often. Carbon monoxide concentration and system temperature are frequently used as continuously monitorable surrogate parameters for other hazardous compounds that might be emitted from the combustion zone under poor burning conditions or that might be formed between the flame of the incinerator and the downstream air pollution control equipment. These parameters have been incorporated into the TOCDF operating procedures and operating permit. Therefore, being unable to monitor trace pollutants directly and continuously is an intellectual concern for which a practical solution has already been implemented.

could also be used to identify interferant species that lead to ACAMS false positive alarms.

Real-Time Detection of Significant Agent Releases

The desirability of real-time or near real-time (< 10 sec) detection of significant agent releases from the viewpoint of both worker and resident safety has been discussed in two previous NRC reports (1994b, 1996a). The Army has responded to the Stockpile Committee's concerns in several ways. First, it has installed multiple ACAMS units on the common stack at the TOCDF. By phasing the sampling and chromatography cycles of these units, the intrinsic response time of the ACAMS has been cut from about eight to ten minutes to four to five minutes, providing significantly shorter response times for most releases. The Army has also made shorter intrinsic ACAMS response times a design specification for the improved ACAMS system.

Finally, the Army is supporting a project contracted to the University of Denver to investigate using Fourier transform infrared (FTIR) spectrometers as true real-time detectors. The initial FTIR project by the University of Denver investigated agent-detection limits of a commercial FTIR spectrometer with a conventional open-path, multipass absorption cell and spectral signal-processing techniques. The prototype unit was calibrated for GB and HD and tested at CAMDS. Under laboratory conditions, the system demonstrated an absolute detection limit for GB of ~0.005 mg/m^3 (Stedman and McLaren, 1996). Detection limits in the initial field trial at CAMDS, which were affected by the cleanliness of the multipass mirrors and their alignment, were significantly worse than the laboratory values. A second field trial designed to test the feasibility of detecting both agent and products of incomplete combustion in exhaust gases from the CAMDS incinerator stack was unsuccessful because of spectral interference from the high concentration of water vapor in the exhaust samples (Stedman and McLaren, 1996). Further field trials of the FTIR technology at CAMDS are planned.

The committee believes that the theoretical one to ten second FTIR spectral measurement times are encouraging enough that further development and testing of this technology for high-risk venues, such as the munitions unpacking area and the common stack, are warranted. The committee also encourages the Army to monitor published research that may result in new methods of fast-response agent detection.

Summary of the Monitoring Issues

The Stockpile Committee believes that the Army is pursuing a wise course in upgrading the current ACAMS monitors and simultaneously funding the development of a faster, more specific, more reliable ACAMS. In addition, the promise of combined GC MSD-atomic emission detector, GC-PFPD, and GC-MSD-PFPD for improving the laboratory identification and quantification of both agents and interferants is encouraging and should be vigorously pursued. Finally, FTIR spectroscopy, coupled with state-of-the-art multipass absorption cells and spectral signal-processing algorithms, is a promising technology for real-time monitoring of higher agent concentrations. The committee urges the Army to continue to support its development.

OVERALL ASSESSMENT

Although the Army has not fulfilled *all* of the Stockpile Committee's recommendations related to system performance and plant operations, it has completed the period of start-up operations, and its operating mode indicates that program destruction goals will be met (Holmes, 1998b). However, the delay in the processing of M55 rockets has significantly slowed the rate of risk reduction from stockpile storage. Some of the problems in early operation linked to safety management are addressed in Chapters 3 and 4. Although these problems, and the investigations that were necessary to follow up on them, have taken time and management resources that might otherwise have been applied to improving operations, the committee believes the management problems were of much higher priority.

LIC-1, LIC-2, MPF, and DFS RCRA trial burns have been passed satisfactorily, and the DFS TSCA permit is expected in 1999. Unresolved issues involving the management of dunnage, the slag-removal heater, and the need for a BRA are not critical to safe plant performance, although their prompt resolution remains a priority. The renewal application for the RCRA permit was submitted in late 1998. Thus, regulatory authorities had at least six months for review before the permit expired in June 1999.

The Army appears to be making progress in addressing the committee's previous recommendations for upgrading the ACAMS and DAAMS agent-monitoring systems and developing new technologies for real-time detection of agent release.

3

Risk Management

COMMITTEE OVERSIGHT

In keeping with the governing recommendation that the CSDP should proceed expeditiously and with technology that minimizes total risk to the public at each site [RC-1], the Stockpile Committee has continued to evaluate the risk assessment[1] and risk management[2] practices at the TOCDF and throughout the CSDP. The *Risk Assessment and Management* report provided a detailed overview of the status of risk evaluation and management as of September 1997 at the TOCDF (NRC, 1997). The present report concerns how the results of risk assessments; screening health, safety, and environmental evaluations; and other information have been used (from the Programmatic Lessons Learned [PLL] and other programs) to implement a sound risk management program. Recommendations are focused on the following areas: overall safety, risk assessment, and risk management. The recommendations in each of these areas are summarized below.[3]

Overall Safety

The development and implementation of the overall safety program at the TOCDF must be given a high priority [S-1]. Safety and environmental goals should be given at least equal weight with production goals in establishing contractor award fees [S-2]. Applicable portions of the QRAs (quantitative risk assessments) must be completed for all safety-related concerns before the start of agent destruction campaigns [S-3]. High-quality, well staffed safety management systems must be completely implemented prior to the start of agent

[1] As described in the *Systemization and Risk Assessment and Manag*ement reports, the risk assessment of the TOCDF was performed in two separate studies, called by the Army the quantitative risk assessment (QRA) and the health risk assessment (HRA) and used consistently throughout the CSDP and in its public statements. The committee has adopted the Army's usage to avoid confusion, although the terms are not standard in the wider risk assessment community. (The Army's HRA is, however, consistent with a screening-level HRA completed for other RCRA facilities.) In fact, both assessments look at impacts on human health, although from different perspectives.

The TOCDF QRA evaluated fatality risk to workers and the public from accidents involving agent due to all identifiable causes in the TOCDF and the associated DCD storage facility. Its purpose was to assist the Army in the management of the stockpile destruction process. The QRA analysis is intended to be realistic and current, with a realistic treatment of uncertainty. It was performed under the control of CSDP personnel by an Army contractor. Risk methodologies were developed for this particular application and extensively reviewed by an independent scientific peer review panel.

The TOCDF HRA is a screening assessment of the risk to the public associated with stack releases during routine operations and is performed in accordance with EPA guidance, the development of which is ongoing. The HRA evaluates normal operations under defined worst-case emissions and conservative upset conditions. It does not attempt to be realistic or to evaluate uncertainty. By agreement between the Army and the state of Utah, the TOCDF HRA was performed under state control, by the state's contractor. The assessment, which was not independently reviewed, was reportedly prepared according to guidance provided by the permitting agency and demonstrated that risk for particular individuals at particular locations would be below the regulatory thresholds.

[2] Risk management is a decision-making process focused on balancing alternative strategies and consequences associated with risk reduction and a process for implementing those decisions. It is based on: (1) a thorough assessment of performance and the full spectrum of risks to the public, workers, the environment, and property; (2) the ranking of risks so they can be addressed in order of their seriousness; (3) assessments of the impact on risk of proposed changes in procedures, management, or equipment; (4) evaluation of abnormal incidents for their effects on risk; and (5) a commitment to continual evaluation and improvement.

[3] Bracketed alpha-numeric designations refer to specific prior NRC recommendations. The full text of these recommendations appears in Appendix A. [RC] = *Recommendations for the Disposal of Chemical Agents and Munitions*. [S] = *Review of Systemization of the Tooele Chemical Agent Disposal Facility*. [R] = *Risk Assessment and Management at Deseret Chemical Depot and the Tooele Chemical Agent Disposal Facility*. [PI] = *Public Involvement and the Army Chemical Stockpile Disposal Program*.

operations [S-10]. The risk management plan (RMP) must be fully implemented during the first year of agent operations [S-14].

Risk Assessment

During the first year of agent operations, a comprehensive, integrated TOCDF risk assessment, including a full description of all significant, acute, and latent agent and nonagent risks (QRA and HRA) associated with disposal operations, as well as with the continued maintenance of the DCD stockpile, should be completed. A full explanation of the uncertainties associated with the various estimates should be included [S-15]. A system for tracking "near-misses" during operation should be developed and integrated into a plan for continual safety improvements at the TOCDF [S-16]. In addition, the Army should update both the QRA and the HRA at the TOCDF whenever system or operational changes occur that could significantly affect the risk estimates and should document the changes in *A Guide to Risk Management Policy and Activities* (the draft *Guide*) [R-1]. The Army should continue the site-specific QRA and HRA processes at all PMCD sites and heed the lessons learned from development of the TOCDF QRA [R-2]. If the QRA methodology is changed, the methodology manual should be updated [R-3].

Risk Management

The Army should expand its draft Guide to encourage the establishment of a "safety culture," including industrial safety, in all groups involved in the program and develop a management program (and include it in the *Guide*) that defines the integration of management roles, responsibilities, and communications across activities by risk management functions (e.g., operations, safety, environmental protection, emergency preparedness, and public outreach) [R-4]. The CMP (change management process)[4] developed in the draft *Guide* should be institutionalized and improved [R-7]. The Army should expand the implementation of the RMP to ensure that workers and emergency preparedness officials understand it and the QRA, as well as how their activities might affect risk [R-8]. The RMP should be implemented and updated as necessary to ensure that it reflects current practices and lessons learned [R-9].

OVERVIEW

Risk management at the DCD/TOCDF involves a number of activities intended to control the risks to the public and workers from potential releases of agent and products of incomplete combustion and to reduce the incidence of worker injuries during normal industrial operations (NRC, 1997). There are four steps to risk management:

- understanding the risk
- suggesting alternative ways to reduce risk
- evaluating risk-reduction alternatives
- selecting and implementing preferred alternatives

These steps must be tailored to address site-specific factors. A number of very diverse groups affected by DCD/TOCDF operations must be involved in the risk management process to ensure its effectiveness. Each group must understand the risk assessment process, the results of the assessments, and the significance of the results; each group must also participate in the process of resolving issues of interest. The Stockpile Committee has made several recommendations in previous NRC reports for improving risk management. Recommendations related to worker safety (industrial safety) are considered in Chapter 4. Recommendations related to public and community interactions are considered in Chapter 5. The recommendations related to chemical releases and general risk management policies are considered in this chapter.

In the *Systemization and Risk Assessment and Management* reports (NRC, 1996a, 1997), the committee reviewed the DCD/TOCDF risk assessments and risk management program. Findings in these reports indicated that the QRA was well done and that the HRA had satisfied most of the committee's previous recommendations (NRC, 1996a). These two reports also include extensive information about the risks at

[4] *The Risk Assessment and Management* report characterized the Army's CMP as "a process for managing changes that may affect the risk associated with PMCD activities" (NRC, 1997, p. 41). The CMP was conceived as a means of distinguishing risk assessment issues (the science) from risk management issues (policy and value judgments). The CMP attempts to establish an approach to integrating these issues in a process that involves the public.

DCD/TOCDF and the quality of the risk assessments. The committee concluded that certain aspects of risk assessment and risk management at DCD/TOCDF, and throughout the CSDP program, required refinement. Therefore, both reports also included additional risk-related recommendations.

RECOMMENDATIONS FROM THE SYSTEMIZATION REPORT

In the *Systemization* [S] report (NRC, 1996a), the committee endorsed the approach developed for the DCD/TOCDF QRA and initial risk management activities. To ensure continued application of these analytic methods and further development of the risk management processes, the committee recommended that the QRA be completed for all campaigns [S-3] and that the approach to risk assessment and risk management be formally established [S-14, 15, 16] (see Appendix C). As the committee noted in the *Risk Assessment and Management* report, the TOCDF Phase 2 QRA[5] was completed before the start of agent operations at the TOCDF. To date, all safety-related concerns identified in the Phase 2 QRA have been addressed before the start of each campaign.

Several of the issues identified in the *Systemization* report have been the subject of discussions between representatives of the Army and the Stockpile Committee, and the committee commends the Army for its proactive response. Nevertheless, risk management continues to be an informal, albeit thorough, process. The committee is concerned that an informal process directed by key individuals in the PMCD could break down if there are changes in personnel or that the process might not be fully transferred to the specific sites. Therefore, the committee urges the PMCD to order that a formal RMP be established for QRA-identified safety issues, including a tracking mechanism for identifying and compiling new issues as they arise and for monitoring their resolution.

In the *Risk Assessment and Management* report, the committee described the Army's draft *Guide and Chemical Agent Disposal Facility Risk Management Program Requirements* (U.S. Army, 1996b), which were developed during the first year of agent operations at the TOCDF. Unfortunately, significant gaps in the draft *Guide* still must be resolved [R-4, 5, 6, 7].

The two studies, the QRA and the HRA, that make up the complete DCD/TOCDF risk assessment are based on different methodologies for reasons documented in the *Risk Assessment and Management* report. Both the QRA and HRA were completed before the start of agent operations. The QRA provided a full analysis of the uncertainties, while the HRA calculated only an upper limit of risk. Therefore, it would be extremely difficult to integrate their data. Consequently, although the Army has not developed a single integrated risk report as recommended by the committee in the *Systemization* report [S-15], the committee believes that the Army has met the functional requirements of the recommendation.

In several cases, the HRA emissions estimates turned out to be lower than actual emissions in the subsequent trial burns. Therefore, the Army should provide a brief update of the HRA as necessary to reflect the trial-burn results. As discussed in Chapter 2, the overall results and conclusions of the HRA are not expected to change because of these higher measured emissions.

The PMCD collects key information on problems encountered through the PLL and publishes the information on a regular basis in a newsletter distributed to all sites. The PMCD has also held regular program-wide meetings at which Army and contractor managers from each site can share information. Managers at individual sites are responsible for disseminating the information to site employees.

The PLL programs have gone a long way toward providing a system for documenting and tracking unexpected upsets, errors, failures, and other concerns during operation of the facilities. The PLL programs have also provided a means of disseminating this information with the aim of promoting continual safety improvements at the TOCDF, as the committee had recommended [S-16], and at all other CSDP sites. However, at the site level, implementation is informally directed by certain individuals. The committee believes the Army should make PLL programs formal requirements for all CSDP organizations to ensure that this information is disseminated to employees at all sites.

[5] A Phase 1 QRA evaluates public risks for a proposed facility before it is constructed. A Phase 2 QRA is a detailed evaluation of the risks and consequences of accidental releases of agent to workers and the community based on the site-specific design and operations.

RECOMMENDATIONS FROM THE RISK ASSESSMENT AND MANAGEMENT REPORT

In the *Risk Assessment and Management* [R] report, the committee evaluated the QRA and HRA, as well as the independent Expert Panel review process for the QRA. The committee found that the QRA was performed to standards that met or exceeded the previous state of the art and appropriately modeled a wide variety of potential accidents involving the release of agent. The results and insights of the QRA were endorsed by the Expert Panel and the committee and were directly useful to PMCD and TOCDF personnel in managing the facility and developing practices to reduce risk to the surrounding population. The committee attributes the high quality of the assessment to the competence of the QRA team, the strength of the Expert Panel and other reviewers, and the responsiveness of the PMCD and the QRA team to comments and questions from reviewers.

The committee also evaluated the HRA in the *Risk Assessment and Management* report.

> The HRA performed by the Utah DSHW, which is based on many assumptions and follows EPA-mandated protocols, is appropriate at this stage of TOCDF operations because it approximates a worst case for all evaluated parameters . . . The HRA screens latent cancer risk to "maximally exposed" individuals, imposes an acceptability criterion (1×10^{-5} carcinogenic risk level over a 70-year lifetime), and infers that the exposure to multiple individuals at or below the screening level is acceptable.

The EPA screening approach defines a plausible "worst-case" scenario that is evaluated using a point-estimate HRA. This is not the realistic, integrated analysis (including uncertainty parameters) that the committee had recommended. However, the state of Utah's HRA, a "screening risk assessment," found the public risk from routine operations (normal operations with defined worst-case emissions and conservative upset conditions)[6] to be much lower than the risk from accidents determined by the QRA. Therefore, because the risk is dominated by the accidents modeled in the QRA, the committee agreed that Army funding of a more realistic analysis of the risk of routine operations was not necessary.

The data from the TOCDF trial burns showed that emissions of several compounds were actually higher than the estimated emissions in the HRA, indicating that some of the assumptions in the HRA were not as conservative as the state of Utah had intended (although the overall results and conclusions of the risk assessment are not expected to change). In subsequent reviews, the committee found that neither the most current risk assessment methods nor the air-dispersion and deposition models recommended by EPA at the time (e.g., guidance issued through December 1994) had been used in the HRA. The committee concluded that the Army should issue a brief update of HRA results using the measured trial-burn emission rates. To be comparable, the Army should follow the same guidance used in the original HRA.

For QRAs, continuing interactive review by an Expert Panel (whereby new methods were being developed as the TOCDF QRA progressed) may not be necessary. But before detailed analysis proceeds, the protocols, input data, calculations, and results should be reviewed.

In the *Risk Assessment and Management* report, the committee expressed its satisfaction with the risk assessment process at DCD/TOCDF. The committee included a number of recommendations related to risk management [R-1, 2, 3, 7, 8, 9, 10] to ensure that the lessons learned in the DCD/TOCDF risk assessment process would be applied at all CSDP sites and that the developing RMP would be strengthened. An analysis of the status of these recommendations follows.

> **Recommendation 1.** The Army should update both the QRA and HRA at the TOCDF whenever changes to system design or operations occur that could affect QRA or HRA calculations to ensure that estimates of risk are current and reflect changes in operating conditions and experience, assumptions, and program status (current Established Configuration). The process for updating the QRA and HRA should be included in the *Guide*. [R-1]

The Army has the overall responsibility for the safe operation of the TOCDF and must be in compliance with regulatory requirements in order to operate. The HRA is vital for understanding potential off-site health effects and for meeting regulatory requirements. Thus, the HRA has at least two uses: (1) off-site risk management, and (2) permit acquisition. The characteristics of a "good" or "correct" assessment vary, depending on whether the HRA is considered a compliance instrument or a risk management tool. As a tool used to manage risk on a continuing basis, the models must be applicable to

[6] *Conservative* in this sense means intentionally overestimating operating time under upset conditions and overestimating emissions during upsets.

the current conditions at the facility and, therefore, the HRA should have the following characteristics:

- It should be realistic and include a thorough exposition of uncertainty.
- It should be a living analysis maintained on site and continually updated and recalculated to guide risk management decisions.
- It should be done early enough for the results to affect design and operating decisions.

An HRA for regulatory compliance is designed to show one-time permitting compliance and, therefore, should have the following characteristics:

- It should conform to guidance provided by the permitting agency, which will necessitate it being conservatively biased. This is particularly true for screening-level HRAs.
- It should show that the maximum plausible risk for particular individuals at particular locations is less than regulatory thresholds, reflecting design or operational changes if necessary.
- It should be a one-time analysis, possibly supplemented with letter reports on particular issues (e.g., actual emissions data that are higher than estimates in the original HRA).

An HRA based on a conservative analysis acceptable for regulatory decision making, such as whether to grant a permit, lacks many essential details. If efforts to control risk are based on an HRA, they could mistakenly be focused on areas that have been artificially inflated in terms of frequency or consequences for the purposes of the conservative analysis. Problems that could arise from using an HRA performed for regulatory compliance in communicating with other interested parties are listed below:

- The HRA may be assumed to describe actual releases rather than upper-bound results. Thus, the Army could be accused of releasing more agent and products of incomplete combustion than are actually being released.
- Attempts to correct "conservative" assumptions could be interpreted as a cover-up.
- Risk management is likely to be focused on aspects of the HRA with the most pessimistic assumptions, rather than those with the most impact.
- The scenarios required for the HRA may not reflect the most serious facility risks.

Problems could also arise from using an HRA intended to be a risk management tool in communicating with other interested parties for the following reasons:

- It contains complex results that acknowledge uncertainties.
- It does not include simple worst-case scenarios based on point-estimate analyses, and results may be more difficult to interpret and explain.
- Because it is site-specific, it does not necessarily follow established generic screening guidance for compliance-oriented HRAs, which may compromise the credibility of the results.

The draft *Guide* requires that the QRA and HRA be updated to include significant changes to the facility (U.S. Army, 1997a). However, the process for updating analyses when plant changes are planned has not yet been incorporated into the *Guide*. All plant changes require some review of risk management. The procedure for determining the appropriate level of review, the review process, and whether or not the change may affect the QRA or HRA has not been described. For example, a change in paperwork that has no health or safety impacts may require minimal review. Major changes that could impact the QRA, or, in rare cases, the HRA, would require thorough review. Changes that may affect worker safety and health but do not involve any agent release would not be part of the QRA and might require an intermediate level of review.

The *Guide* should also outline the procedures for performing the health, safety, and environmental evaluations (e.g., hazard analyses, job activity analyses, training requirements) to assess whether a proposed change could affect worker safety, for reviewing options for mitigating increases in worker risk, and for deciding whether a change is justified. If PLL programs identify ways to reduce worker risk, mechanisms for incorporating these recommendations into the change management process should be described.

Another problem is that no requirements for updating the analyses based on new information (new emissions measurements or lessons learned) have been promulgated. It is particularly important that the QRA be updated because it can be significantly affected by plant changes. In addition, although Army plans call for updating QRAs at each site on an ongoing basis, the QRA at the TOCDF has yet to be updated (Holmes, 1998b).

> **Recommendation 2.** The Army should continue the site-specific QRA and HRA processes at all PMCD sites. The development of assessments for sites other than the DCD will be greatly simplified because much of the QRA methodology has already been established. The Army should continue to obtain interactive, independent expert reviews of all site-specific assessments. The Army should heed the lessons learned from development of the TOCDF QRA and should incorporate the changes recommended by the Expert Panel. [R-2]

The Army has continued site-specific QRA processes at other CSDP sites and has issued Phase 1 QRA reports for the Anniston, Pine Bluff, and Umatilla sites. It is important that the Phase 2 QRAs be initiated while construction at these sites is in the early stages so that the results can be used to implement necessary changes to the design or operations. The Army has stated that it intends to continue independent expert reviews for all site-specific risk assessments and is incorporating the lessons learned from the TOCDF QRA, including the recommendations by the Expert Panel that were adopted for the TOCDF QRA. The ongoing QRAs for the other sites have not yet progressed far enough to determine whether other recommendations by the Expert Panel will be adopted. The independent reviews of the QRAs for these sites have not yet begun. The committee believes these reviews should be in progress by the time the Phase 2 QRA process begins. Otherwise, the kind of productive, interactive process that resulted at the TOCDF will be impossible.

The committee has not been asked to review HRA studies for the other sites, all of which are now completed and show that the HRA risks are largely secondary to QRA risks at each site. In accordance with current EPA guidelines, however, uncertainty analyses (as part of HRAs) at future sites may not be necessary for screening-level HRAs if the risks are well below regulatory thresholds.

> **Recommendation 3.** The QRA methodology manual should be updated to reflect the significant improvements that have been made. [R-3]

The QRA methodology manual has not been revised. Extensive improvements to the methodology evolved during the DCD/TOCDF QRA. Although members of the QRA team are aware of the lessons learned, there is no guarantee that experienced individuals will not leave the team. In fact, several already have. The committee hopes the Army will capture their expertise while it still can.

> **Recommendation 7.** The Army should institutionalize the management of change process developed in the *Guide*. The Army should track performance of the change process and document public involvement and public responses to decisions. The Army should use this experience to improve the change process. [R-7]

Public input in the CMP was supposed to begin with a series of workshops to discuss and refine the process. After that, a revised draft of the *Guide* was expected to address the issues raised in the *Risk Assessment and Management* report. The revision to the *Guide* is not yet complete, and the entire process is far off schedule. (The public involvement aspects of this recommendation are discussed further in Chapter 5.)

> **Recommendation 8.** The Army should expand implementation of the risk management program to ensure that workers understand the results of the risk assessments and risk management decisions. The Army should also ensure that CSEPP and other emergency preparedness officials understand the QRA and how their activities might affect risk. CSEPP activities should be tracked by the Army as part of their risk management program. [R-8]

The RMP at DCD/TOCDF has been effective in dealing with technical issues related to risk. The draft *Guide* was issued by CSDP managers at the PMCD, and, more recently, *The Change Management Process to Accompany the Guide to Risk Management Policy and Activities* was issued (U.S. Army, 1997a; 1998b). Together, they have begun to define the CSDP's overall approach to risk management. In addition, CSDP managers have provided briefings on the HRA and QRA (which are both publicly available) to the communities near the TOCDF. However, in discussions with DCD/TOCDF workers and the public, it has become apparent that neither has a real understanding of the risks portrayed in these analyses. The CSDP will have to redouble its efforts to ensure that the information is understood. (The aspects of this recommendation that deal with the Chemical Stockpile Emergency Preparedness Program [CSEPP] are discussed in Chapter 5.)

> **Recommendation 9.** The Army should implement risk management plans and update them whenever necessary to ensure that they reflect current practices and lessons learned. [R-9]

At the time of the *Risk Assessment and Management* report, the Army had implemented a successful *ad hoc* risk management approach for the TOCDF, established preliminary RMPs, and issued the draft *Guide* and its companion volume. However, the recommended updates to the *Guide* have not yet been completed.

The committee strongly believes that the Army should rapidly document and formalize the RMPs that are presently being used effectively on site-specific and programmatic levels. Cross-communication, cooperation, and learning between sites has greatly enhanced the entire program and should be continued.

Recommendation 10. The Army should proceed with the application of its proposed methodology for evaluating the use of PAS carbon filters on a site-specific basis. For consistency with the HRA assumptions, the QRA should take into account the possible sudden release of agent that may have accumulated on the filter at a gas concentration equal to the lower detection limit. [R-10]

The PAS carbon bed filter technology and risk management is the subject of another NRC report that was not available at the time of this writing (NRC, 1999).

4

Safety Programs and Performance

The Stockpile Committee has been concerned with the CSDP's safety performance since its early evaluations of operational verification testing (OVT) at JACADS and has made many recommendations for improving safety, including the development of a well qualified and trained workforce and the establishment of a safety culture. This chapter revisits the recommendations discussed in Chapter 3 that pertain to worker safety and the implementation of sound industrial safety practices. These include: (1) putting a high priority on the development and implementation of the overall safety program [S-1]; (2) setting management goals for high levels of safety and environmental performance in all work areas and giving these goals at least equal weight with production goals [S-2]; and (3) developing strong safety management systems [S-10].

OVERSIGHT

When Congress authorized the destruction of the chemical agent and munitions stockpile in 1985 (PL 99-145), the law specified that destruction should be accomplished in a way that ensured the safety of the public, workers, and the environment. As part of its oversight responsibility, the Stockpile Committee has expressed continuing concerns over safety and has made many observations and recommendations in several reports for improving safety at specific sites and at the programmatic level. A summary of relevant observations and recommendations follows.

In an NRC letter report, *Evaluation of the Johnston Atoll Chemical Agent Disposal System Operational Verification Testing: Part I,* issued in July 1993, the committee made the following recommendation:

> The Army should use systemization of the Tooele Chemical disposal facility to implement improvements relating to safety, environmental performance, and plant efficiency. These improvements should be made at Tooele prior to initiating the destruction of agents and munitions (NRC, 1993).

In April 1994, the Stockpile Committee completed its evaluation of OVT at JACADS and issued Evaluation of the Johnston Atoll Chemical Agent Disposal System Operational Verification Testing: Part II, which contained the following findings and recommendations (NRC, 1994b):

> *Overall safety management*. Many OVT incidents [observed failure events] involved human error indicative of deficiencies in procedures, training, or management priorities.
> *Enforcement of safety requirements*. Safety violations observed during OVT, . . . are serious problems that require changes in training, job priorities, and management accountability.
> **Recommendation 1.** Give safety considerations priority over production goals.
> **Recommendation 5.** Develop systems to improve overall management of safety.

In March 1996, the committee issued *Review of Systemization of the Tooele Chemical Agent Disposal Facility,* the continuation of several earlier NRC reports, with the intention of (1) reviewing the completion of testing of certain secondary systems that had not been completely tested at JACADS, (2) reviewing the changes implemented by the Army in response to earlier recommendations pertaining to the TOCDF, and (3) providing an overview of the status of the facility at the end of the systemization period (NRC, 1996a). The following excerpts from this report are related to safety issues:

> *Personnel Issues (Recruitment, Training, Turnover)*. Training in process operations and agent operations appears to be thorough, but training in general safety practices requires improvement.
> *A General Observation*. There appears to be a general belief at the TOCDF that safety practices are primarily for agent

operations. As a result, the emphasis on safety has been focused on agent-related issues with less emphasis being given to industrial safety practices.

Recommendation 1. Development and implementation of the overall safety program at the TOCDF must be given high priority.

Recommendation 2. Safety and environmental performance goals should be given at least equal weight with production goals in establishing award fee criteria.

Recommendation 10. High quality, adequately staffed management systems must be completely implemented (including procedures for testing critical equipment; all necessary operating, maintenance, and emergency procedures; management of change procedures; training and cross-training programs; programmatic lessons learned activities; subject area reviews; and other safety oversight activities).

Safety at the TOCDF became a public issue when two former employees released detailed allegations that safety programs and performance were deficient. As a result of these allegations, seven independent assessments of the safety program at the TOCDF have been conducted:

- a courtesy chemical surety inspection by the U.S. Army Inspector General Agency, August 15–18, 1994 (U.S. Army, 1994a)[1]
- an investigation by the Army Safety Office into 119 safety-related deficiencies alleged by a former EG&G safety and security manager (U.S. Army, 1994b)
- a review of the 119 alleged safety-related deficiencies by the Army Chief of Engineers for design implications (U.S. Army, 1994c)
- a report by an independent evaluation team led by the Director of Army Safety (U.S. Army, 1997b)
- a joint review by the PMCD and EG&G Management Assessment Team (U.S. Army, 1997c)
- a report by AMH Consulting (commissioned by EG&G) (AMH Consulting, 1996)
- a report by IHI Environmental and Ralston Consulting Group (commissioned by the Utah Citizens Advisory Commission) (IHI, 1997)

ASSESSMENT OF PROGRESS AND CURRENT STATUS

In general, the Stockpile Committee believes that TOCDF operations are being conducted in a way that protects the public. All of the independent assessments conducted at the site reached the same basic conclusion. The following discussion points out opportunities for further improvement.

The committee began its ongoing dialogue with TOCDF management and the Army regarding safety performance at the site before the commencement of agent destruction. Numerous site visits by the Stockpile Committee, its subgroups, and individual committee members have focused on safety and the Army's progress in developing a safety culture. Several visits included meetings with employees and representatives of the Employee Safety Committee. The Stockpile Committee has systematically communicated its safety concerns to both the site management and the Army through recommendations in its reports.

In response to the committee's observations and recommendations, and out of desire to improve safety performance, management personnel at the TOCDF have developed a *TOCDF Safety Culture Plan* and have implemented several programs and initiatives to ensure that a "safety culture" is developed and sustained at the site (U.S. Army, 1997d). The safety culture plan includes comprehensive timelines and milestones, as well as interim goals and objectives. Key elements of the plan are described below.

Implementation of the Safety Training Observation Program

TOCDF management has purchased (from DuPont) and begun the implementation of the Safety Training Observation Program. This program focuses on training managers, supervisors, and employees to observe people and their work environments in terms of safety in order to identify and correct unsafe practices and conditions. The Safety Training Observation Program emphasizes the positive aspects of safety training and behavior and has been used successfully by many companies as a tool for driving behavioral change.

Occupational Safety and Health Administration Voluntary Protection Program

The Voluntary Protection Program developed by the Occupational Safety and Health Administration

[1] The term "courtesy chemical surety inspection" means that the U.S. Army Inspector General Agency conduct an informal inspection. Any deficiencies found at that time can be remedied without prejudice.

(OSHA) is a performance-oriented program that identifies the key elements of safety and health programs and provides measurement criteria for assessing them. The primary elements of this OSHA program are: management leadership, employee involvement, work site analysis, hazard prevention and control, and safety and health training. Each of these elements has a number of associated sub-elements. The Voluntary Protection Program is largely a self-assessment program, but it does provide for external audits. The TOCDF has completed its assessment of current status, and plans for corrective action have been generated. The TOCDF management has submitted an application for the facility to obtain Voluntary Protection Program status.

Safety Metrics

Recordable Injury Rate

The recordable injury rate (RIR), which can be used for comparisons with other industries, represents injuries and illnesses per 200,000 hours worked as defined by OSHA. The TOCDF management uses a 12-month moving ("rolling") average as its primary metric for tracking RIR (see Figures 4-1 and 4-2). The RIR is also tracked monthly and on a trimester basis, with the latter used to determine award fees. Since the commencement of agent operations, the rolling RIR at the TOCDF has been consistently higher than 3.0 and in some instances has exceeded 4.0. These values are within the range of the chemical industry as a whole but are not close to the best in the industry (< 1.0). Nor are they the best in the CSDP (the rate at JACADS was less than 2.0 during the same time period).

In keeping with its mandate to provide maximum protection, and with effective utilization of lessons learned and successful implementation of Safety Training Observation Program and Voluntary Protection Program, the management and staff at the TOCDF should strive to achieve a rolling RIR comparable to the best performing companies in the chemical industry.

Lost Workday Cases

TOCDF management tracks *hours since last lost workday case* as a measure of performance. This measure can also be tracked as *cases with days away*. The record through December 1998 was 478 days worked without a lost workday case. The 1998 lost workday case rate was zero.

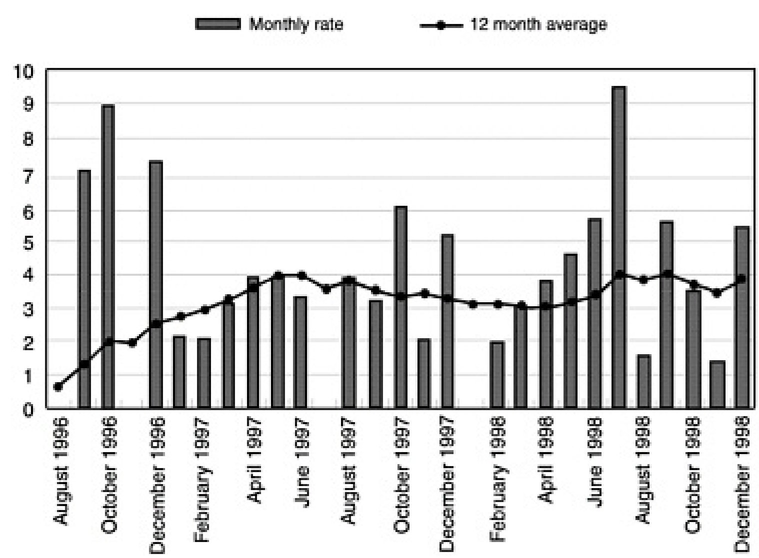

Figure 4-1 TOCDF recordable injury rate (RIR) 12-month rolling average since thestart of agent operations. Source Evans, 1998b.

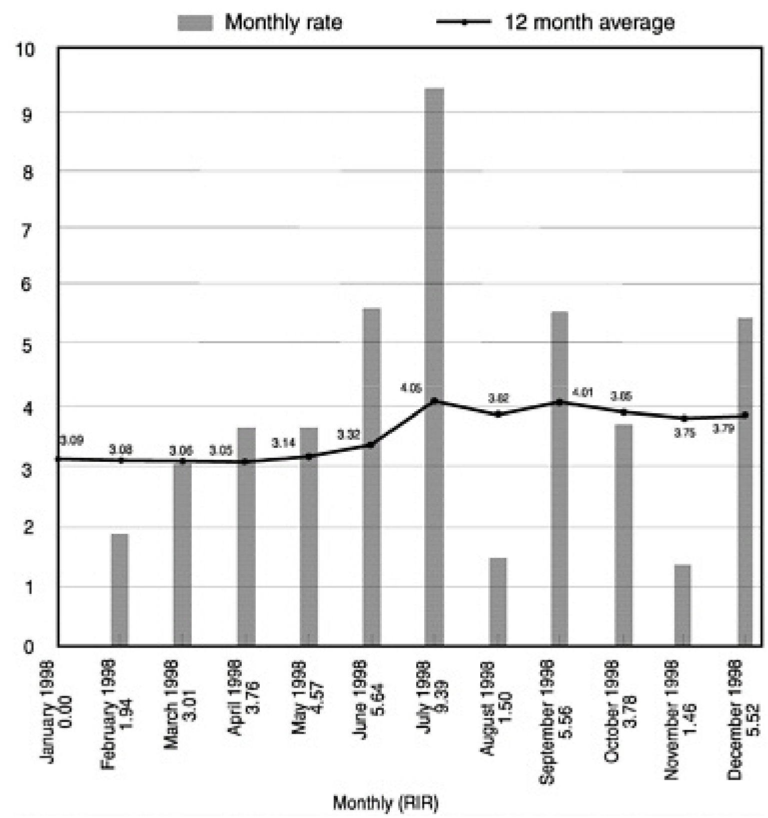

Figure 4-2 TOCDF 12-month recordable injury rate (RIR) rolling average and monthly RIRs from January 1998 to December 1998. Source. Evans, 1998b.

Total Number of Injuries

This measure is documented monthly by type—lost workday injury, recordable injury, and first-aid injury; the total for all three types is also tracked. Figure 4-3 shows the 12-month rolling average for all injuries. Although the trend for total injuries has been generally downward, this is largely because there have been fewer first-aid cases. The number of more serious recordable injuries has not decreased.

Safety Training Observation Program

Observations from the Safety Training Observation Program are tracked as the *overall safe percent* of total observations during each month. This metric, which was initiated at the TOCDF in late 1997, has averaged about 86 percent.

Other Metrics

The top five unsafe acts or conditions identified via the Safety Training Observation Program are tracked monthly. This metric is very useful for identifying areas that require more training, corrective action, or changes in procedures.

In general, the Stockpile Committee believes that the current metrics used at the TOCDF are all relevant and appropriate. As safety performance improves, some of them will become less meaningful; at that point they should be complemented with additional metrics relevant to the stage of development of the TOCDF safety culture.

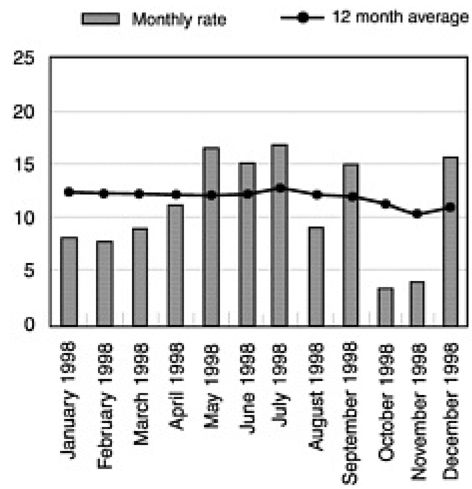

Figure 4-3 Total injury 12-month rolling average for the TOCDF.
Source. Evans, 1998b.

Employee Involvement

A key feature of a safety culture is the active involvement and commitment of all employees. The TOCDF management has established an Employee Safety Committee and has involved all employees in the Safety Training Observation Program and Voluntary Protection Program. Safety has also been included in job descriptions, and safety responsibilities, including training, are clearly defined. Management has also established reward and recognition programs for contributions to safety by employees. Safety messages and news are also included in employee communications, such as the "DEMIL-TRIB" newsletter. These regular formal and informal communications about safety can help to create an environment in which safety is highly valued.

Management Involvement and Commitment

After persistent urging from the Stockpile Committee and in the aftermath of allegations of poor safety practices by two former employees, management at the TOCDF has implemented a number of programs and procedures to improve safety. These activities are intended to establish a safety culture with equal emphasis on agent-related safety and general industrial safety and to balance production goals with safety goals.

One of the committee's continuing concerns has been that safety at the TOCDF has been primarily focused on agent-related issues and that traditional industrial safety practices and procedures have been neglected (NRC, 1996a). During visits to the TOCDF, the committee noted some improvements in this area, but progress has been slow. Many unsafe conditions and actions have been documented through the Safety Training Observation Program and observed by committee members during site visits. Failure to wear required protective equipment, poor housekeeping, and the existence of other unsafe conditions may be considered minor infractions, but the committee believes that they indicate the lack of an established safety mindset at the TOCDF and reflect negatively on management's commitment to establishing a true safety culture.

Although the absence of a pervasive safety culture with equal emphasis on agent-related and nonagent-related safety matters is unlikely to change public risk estimates, it could significantly increase worker risk. The establishment of a safety culture at the TOCDF will require continuous active involvement, knowledge, awareness, and a highly visible commitment by management to all aspects of the safety program—including management training and development. The committee notes that safety is included in all job descriptions and is clearly identified as an expectation for all managers and supervisors. Although progress in this area is difficult to assess, the committee believes that sustained improvement will only be possible with strong management involvement and commitment.

Criteria for Award Fees[2]

A growing body of evidence shows that chemical operations with a strong safety culture also have the highest productivity. The committee's recommendation that safety be given at least equal weight with production in establishing criteria for award fees has been satisfactorily addressed at the TOCDF and JACADS. However, considering that baseline incineration system facilities are currently under construction at three additional sites, the committee believes that modifying the criteria for award fees to include programmatic safety performance would enhance the overall CSDP and facilitate communications among disposal sites. Also, the committee believes that as new facilities are brought on line, their safety performance should reflect the lessons learned from other facilities. That is, at the start of operations, the performance metrics of the new facility should be equal to or better than those at operating facilities.

Programmatic Lessons Learned Program

In 1995, the Army implemented the PLL Program to facilitate the transfer of information from one site to another. Although TOCDF safety lessons learned are frequently included in PLL communications, a review of incidents in 1997 revealed that only about 27 percent of safety incidents (most of which were agent-related) were included in the PLL. In contrast, about 70 percent of operating and permit incidents were included. The committee reiterates its prior recommendation that agent and industrial safety be given *equal* emphasis.

SUMMARY

Overall, the committee is satisfied that its recommendations are being addressed and that progress has been made toward creating an environment conducive to the development of a safety culture at the TOCDF. Nevertheless, the committee also notes that safety performance at the TOCDF (as measured by RIRs, the frequency of unsafe actions identified by the Safety Training Observation Program, and such occurrences as the error in maintenance that resulted in a contained GB spill) has not improved significantly. A better balance between agent and industrial safety and strong management involvement and commitment will be necessary to meet the goals of the *Safety Culture Plan* (U.S. Army, 1997d).

[2] The term "award fees" refers to contractual payments provided to a contract facility operator for meeting predetermined performance criteria or milestones.

5

Public and Community Interactions

INTRODUCTION

The Stockpile Committee has made several recommendations related to both public involvement in the CSDP and emergency management and preparedness. In the *Systemization* report (NRC, 1996a), the recommendations dealt explicitly with activities at the TOCDF. In the *Risk Assessment and Management* report (NRC 1997), the recommendations were addressed to the overall disposal program as it relates to risk management and the involvement of the public in risk management decisions. The *Public Involvement* report (NRC, 1996b), a letter report issued subsequent to the *Systemization* report, focused on institutionalizing public involvement within the CSDP.

On the subject of public and community interactions for the duration of TOCDF operations, the Stockpile Committee recommended that the Army make a substantial effort to increase and improve communications with the host community and the Utah State Citizens Advisory Commission (CAC) on issues of mutual concern (e.g., the CSEPP, decommissioning of the facility, its future use, and risk reduction) [S-4]. The committee also recommended that the Army review and expand its draft RMP (risk management plan) to include public involvement in more areas than the CMP [R-6].

The Stockpile Committee recommended that at the start of agent operations the Army increase its efforts to work with the Utah Division of Comprehensive Emergency Management to ensure that: (1) first responders are properly trained and well equipped [S-5]; (2) local and state CSEPP plans are complete and have been practiced [S-6]; and (3) resources are provided in coordination with the Federal Emergency Management Agency (FEMA) to complete the emergency communications system for the Tooele County Department of Emergency Management [S-7]. The committee also recommended that the Army ensure that CSEPP and other emergency preparedness officials understand the QRA and its implications for emergency management and that the Army track CSEPP activities as part of its RMP [R-8].

The Stockpile Committee has repeatedly recommended that the Army and CSDP management at all levels make a strong commitment to public involvement throughout the entire program [PI-1]. Also, public affairs programs for all Army activities at stockpile locations and the CSEPP (now managed by FEMA), should be closely coordinated, which should be reflected in the RMP at each site [PI-2].

This chapter reviews the Army's responses to these recommendations, which are all concerned with emergency management or preparedness, public involvement, and the intersection of the CMP and public involvement. The following discussion is based on direct observations by committee members, briefings by the Army, and telephone interviews with key community personnel, local officials, county personnel, and CAC members. Either the full committee or a subgroup has visited the TOCDF and the Tooele community six times since the Systemization report was issued. In addition, members of the committee have been briefed by local officials on a regular basis on measures undertaken in Tooele County related to CSEPP. The following discussion focuses on: (1) public involvement, (2) surveys of public opinion, (3) emergency management and preparedness, and (4) the CMP.

PUBLIC INVOLVEMENT

The PMCD's past attempts at developing a national public outreach (i.e., public involvement) plan, as well as some site-specific plans, have not been successful. The Stockpile Committee has repeatedly emphasized the importance of "community involvement in decisions regarding the technology selection process, oversight of operations, and plans for decommissioning the facilities" [RC-6] (NRC, 1994a). Meaningful public involvement was also the subject of the *Public Involvement* letter report and a topic in the *Risk Assessment and Management* report.

The committee strongly believes that meaningful public involvement would enable the Army to respond to the concerns of local communities, thereby building trust and minimizing impediments to the timely disposal of the stockpile. The committee also addressed the importance of public involvement in a recommendation in the *Systemization* report:

> **Recommendation 4.** A substantial effort should be made by the Army to enhance interactive communications with the host community and the Utah Citizens Advisory Commission on issues of mutual concern (e.g., various elements of the Chemical Stockpile Emergency Preparedness Program, decontamination and decommissioning, future use of the facility, and risk reduction. [S-4])

The committee has monitored the development of the Army's public outreach programs through briefings by the Army, meetings with the Utah CAC, and public meetings. Since 1996, important changes have been made in the PMCD's management of the CSDP, specifically in the Public Outreach and Information Office (POIO) (U.S. Army, 1998a).

The PMCD's overarching strategy has shifted the POIO's mission from an "operational emphasis providing site-specific support to providing public involvement support on the program level" (U.S. Army, 1998d). Since 1998, the director of the POIO has been responsible for providing staff liaisons and some staffing for outreach activities at specific sites and other related programs. Two contractors were hired to help the Army: SAIC assisted in establishing public involvement (storefront) offices in major towns and communities near each site; Booz-Allen & Hamilton assisted the Army in developing both the *PMCD Overarching Public Involvement Strategy* (U.S. Army, 1998b) and the *Public Involvement Strategy for the CSDP* (U.S. Army 1998c). The POIO office now has the following responsibilities:

- public outreach at the baseline incineration sites at Tooele, Utah; Umatilla, Oregon; Anniston, Alabama; Pine Bluff, Arkansas; and Johnston Atoll (U.S. Army, 1998b)
- public outreach and public involvement in the selection and implementation of alternative disposal technologies for the bulk storage sites at Aberdeen, Maryland, and Newport, Indiana[1]
- public outreach in the non-stockpile program (i.e., the disposal of buried chemical warfare materials and binary chemical weapons, the cleanup of former production sites, etc.)
- outreach in the Army's cooperative threat-reduction program for assisting the Russian Federation with its disposal program (U.S. Army, 1998b).

The POIO will also provide legislative support, media relations, training, and crisis communication to the CSDP. Perhaps more importantly, the POIO now has a clearly stated mission (to provide "a public involvement program that supports meaningful public participation and dialogue") and a clearly stated vision ("to gain public acceptance of the need for the safe expeditious disposal of chemical material") (U.S. Army, 1998b). The *PMCD Overarching Public Involvement Strategy* is the first document that clearly indicates the direction of PMCD's public outreach.

Booz-Allen & Hamilton also helped the Army develop a public-involvement strategy document for the CSDP, the *Public Involvement Strategy for the CSDP* (U.S. Army, 1998c). This document outlines the "objectives, key messages, and operational framework" for the CSDP's public information and public involvement program. The document is designed to be continually updated and provides specific guidelines for public involvement programs at storage and disposal sites. The updated (September 1998) *Umatilla Chemical Agent Disposal Facility Public Involvement Implementation Plan* was reviewed by the committee for this report (U.S. Army, 1998d). Implementation plans for Anniston, Pine Bluff, Tooele, Aberdeen, and Newport, which are in various stages of development, will also be constantly updated as circumstances and resources change.

It is still too early to assess the impact of the reorganization and realignment of the POIO. Nevertheless, both the PMCD *Overarching Public Involvement Strategy* document and the *Umatilla Chemical Agent Disposal Facility Public Involvement Implementation Plan* represent significant improvements over previous efforts. Moreover, the new strategy seems to have encouraged the site outreach offices, which are closest to the local communities, to take the initiative in developing their

[1] The two remaining stockpile storage sites at Pueblo, Colorado, and Blue Grass, Kentucky, are no longer the responsibility of the PMCD but are currently under review in conjunction with the Assembled Chemical Weapons Assessment program of the Department of Defense to investigate alternative technologies.

own strategies within the context of the mission, vision, and programs of the POIO. All elements of the program organization are now united by a common mission and appear to have received strong leadership from the POIO (Campbell, 1998).

If the other site-implementation plans are of the same high quality as the plan prepared for the Umatilla site, then significant improvements have been made. For example, the Umatilla plan attempts to relate future activities to both past efforts at public involvement by the Army and present sentiments in the community, which were expressed in surveys (see below) (U.S. Army, 1998d). Perhaps even more important is the description of opportunities for public involvement, which reflects a substantial step in the right direction.

> For public involvement to be meaningful, it must come when stakeholders believe that what they have said or contributed has been heard, understood and incorporated into the decision-making process (U.S. Army, 1998d, p. 11).

Since the start of operations at the TOCDF, public outreach has been less than successful. First, involvement of the public and the CAC in several important developments could have improved communications and meaningful public involvement by the local community. For example, the committee learned that the Tooele public outreach office did not involve the public or the CAC in the development of its draft public-involvement implementation plan. A few CAC members were involved informally, but the Army made no formal attempt to obtain input from the CAC or the public. In the future, the Army should obtain public input before any plan (or substantive modification) is finalized.

Second, a public meeting sponsored by the Army on July 14, 1997, to discuss the proposed CMP (change management process) was not successful. Neither the personnel of the local outreach office nor the public had been involved in the development of the draft CMP prior to the meeting (Campbell, 1998). As a result, only a few members of the public and the CAC were present at the meeting, along with about 30 personnel associated with the Army and the TOCDF. This lack of public interest reflects both the past lack of communication between the community and the Army and the fact that the public has little interest in changes to the established technology. Based on this experience, the committee concluded that at sites where the technology is already established, the Army should expand the CMP to include other topics of interest to the public, such as plans for decommissioning the facilities.

Although reorganization of the POIO and the development of strategies for obtaining public involvement are important, neither is a substitute for an organizational culture that proactively seeks the involvement of not only the public, but also personnel of the local outreach office, who are best informed about local interests and issues.

In the 1996 *Systemization* report, the committee noted that the Army had missed an excellent opportunity by not making a concerted effort to involve the public in the development of the risk assessments for the TOCDF. The drafting of the CMP appears to be another lost opportunity, and as the committee notes in the recent report, *Carbon Filtration for Reducing Emissions from Chemical Agent Incineration,* the CMP has yet to be linked to issues that could arouse public interest (NRC, 1999).

In 1997, the Tooele outreach office had 575 visitors, participated in 35 speaking engagements attended by 2,800 people, and conducted 380 tours of the facility (U.S. Army, 1998e). The local outreach office at Tooele has since improved its tracking capability and expanded its staff and office space to three times its original size. The CAC meeting at the opening of this new office on April 16, 1998, was attended by more than 50 people involved in emergency management operations (Campbell, 1998; Sagers, 1998a). The office is now staffed by four Booz-Allen & Hamilton employees. In addition, it now maintains its own mailing lists. All of these changes are consistent with the new expanded mission for local offices and should provide local citizens with better information and more accessibility to the CSDP.

Nevertheless, despite these improved outreach capabilities at the local level and the reorganization of the POIO, this site has a long way to go to reach the level of public involvement in the decision-making process the committee recommended in the *Systemization* report [S-4] and again in the *Public Involvement* letter report [PI-1]. The sooner the public becomes meaningfully involved, the more widely accepted program decisions will be.

COMMUNITY SURVEY RESEARCH PLANS

In the past, the Stockpile Committee has been critical of the POIO's efforts to ascertain public views and attitudes, as well as to provide relevant information about the disposal program (NRC, 1996b). In June 1998, and again in December 1998, the POIO provided the committee with an overview of its preparations for conducting a stakeholder survey and incorporating the survey results into a database and tracking system (Williams, 1998; U.S. Army, 1998f). The survey plan indicates that local outreach offices will be involved in developing the surveys, and as of mid-April 1998, the Tooele County outreach office had already convened a meeting of various stakeholders to identify issues to be included in the survey (Campbell, 1998). One of the first decisions made by this local group was to invite some of the leaders or representatives of groups interested in the TOCDF, or incineration generally, to participate (Campbell, 1998). A consultant has informed the committee that similar stakeholder meetings have been held at the other sites and that additional efforts are under way to ensure the participation of a broad spectrum of stakeholders, including opponents of the baseline incineration system (Williams, 1998).

The committee is encouraged that the Delphi survey technique is being used to identify important issues that should be included in the survey. The extremely ambitious survey plan raises concerns, however, that the large number of responses necessary at each site to produce generalizable results may not be received. Therefore, the Army must seek the cooperation of all stakeholder groups at each site. The committee urges the Army and its contractor to build on this excellent beginning and take the necessary steps to obtain the cooperation from these groups.

EMERGENCY MANAGEMENT AND PREPAREDNESS

In the 1996 *Systemization* report, the Stockpile Committee made three recommendations concerning the coordination of emergency management, response, and preparedness with the start of agent operations. These recommendations are discussed below. In addition to these recommendations, part of another recommendation [S-4] called upon the Army to enhance its interactive communications with the host community on issues involving the CSEPP.

> Recommendation 6. The Army, and where appropriate the Federal Emergency Management Agency (FEMA), should ensure that local and state Chemical Stockpile Emergency Preparedness Program Plans for responding to potential chemical events are complete and well exercised as soon as possible. [S-6]

Since this recommendation was made, the CSEPP has been reorganized. The Army has retained control of on-site emergency preparedness, but all off-site responsibilities, including budgeting, have now been assigned to FEMA. Consequently, off-site emergency preparedness is no longer within the scope of the Stockpile Committee's oversight. Nevertheless, the committee has made several observations based on its oversight experience.

The General Accounting Office has prepared at least seven reports citing problems in the CSEPP (GAO 1993, 1994, 1995a, 1995b, 1995c, 1996, 1997). The committee is also concerned about the CSEPP and about the horizontal fragmentation of responsibility at the federal level. Previous briefings by directors (both Army and FEMA) of the CSEPP, as well as discussions with directors of state emergency management agencies, have all stressed the importance of a well coordinated response-management capability with the technical capacity to respond effectively to a chemical event. The recent reorganization will require excellent coordination and communication to overcome the barriers of separate organizational responsibilities. In fact, the committee is not convinced that the reorganization will improve the capacity for responding to an emergency.

The committee strongly recommended that the Tooele County Emergency Management Plan be completed and that the Army ensure that training exercises be carried out. Two issues underlie this recommendation. First, the committee's initial review in 1996 of the Tooele County Emergency Operations Plan and the functional appendices on chemical hazard/agent response revealed that several components of the plan and appendices were still in draft form. Second, the committee determined that, because of the disagreements over issues pertaining to the procurement of personal protective equipment, Utah County had not participated in the latest training exercise at that time. Moreover, for some time, both Salt Lake and Utah counties participated only minimally in these exercises. Both Army and FEMA guidelines state that all plans must be completed and that personnel must be trained to carry them out in order to ensure a comprehensive emergency-response capability to a chemical event (FEMA and Department of the Army, 1994).

In mid-1998, committee members were able to review the completed and updated Tooele County Emergency

Operations Plan (and the functional appendices pertaining to a chemical agent event). The Tooele County director of the Department of Emergency Management informed the committee that DCD, county, and state personnel had participated in a successful exercise of the Emergency Operations Plan (Sagers, 1998a). In September 1998, another exercise was held in which both Salt Lake and Utah counties participated. Observers from several FEMA regions, as well as FEMA headquarters personnel, also attended. In fact, more than 300 evaluators or observers were present (Sagers, 1998b). The increased interest in the September exercise was partly due to the Army's Integrated Process Teams' attempts to develop better exercises for CSEPP (Sagers, 1998b). At the time of this report, there were no negative findings on the exercise, and the basic response activities were positive (Sagers, 1998b). Thus, it appears that the committee's concerns in this area have been adequately addressed.

> **Recommendation 5.** The Army should increase its efforts to work with the Utah Division of Comprehensive Emergency Management to ensure that first-responders have been adequately trained to use personal protective equipment approved by the Occupational Safety and Health Administration. [S-5]

The committee recommended that the Army provide OSHA-approved personal protective equipment to local first-responders and train them in its use. In interviews with the director of the Tooele County Department of Emergency Management, the committee was assured that the equipment had been provided and that 250 local first-responders had been trained (Sagers, 1997, 1998a).

The committee had also been concerned about the delegation of responsibility for determining when an area was safe for reentry and whether adequate decontamination equipment was available for local emergency medical personnel. The committee has learned that three mobile decontamination units (to decontaminate patients prior to treatment) have been deployed in Tooele County, one of them stationed at the Tooele Valley Regional Medical Center. The adequacy of the decontamination capacity in Rush Valley is still being assessed by Tooele County (Sagers, 1998b). The reentry issue has been resolved through cooperation between local officials and DCD personnel. Emergency preparedness exercises have been planned and implemented for both decontamination and evacuation scenarios (Sagers, 1997, 1998a).

Two different emergency-management software packages are being used in Utah: FEMIS and EMIS. The Tooele County Department of Emergency Management now has the capacity to interface between the two so that it can work with the Army, which uses EMIS, and the state, which uses FEMIS. The committee commends the cooperative efforts of Army, state, and county emergency-management personnel. However, the committee notes that the use of different software packages is evidence of the lack of cooperative planning.

> **Recommendation 7.** The Army/FEMA should provide the necessary resources for completing the communications system planned by the Tooele County Department of Emergency Management. [S-7]

In 1994, the committee found that both the Army and FEMA recognized the importance of a highly reliable, highly redundant communications system that would serve the following functions (FEMA and the Department of the Army, 1994):

- issue notifications and warnings
- serve as incident command center
- function as emergency operations center
- establish and maintain links to state, county, and Army emergency operations centers
- maintain communications with local officials
- maintain links to all first responders, as well as various sheltering, medical, and decontamination sites

As of early 1996, however, Tooele County had still not completed its communication system.

Interviews in 1997 and 1998 with the Utah Department of Emergency Management showed that the communication system was almost completed. The Tooele County Department of Emergency Management's Communication Plan has been revised, and the system is now both highly reliable and highly redundant. Virtually the entire county is now covered by some type of communication band (microwave, 400 MHz, 800 MHz, or 900 MHz) (Sagers, 1998a). Although there are still some dead spots in Rush Valley, three critical links in the system have now been funded and are being phased into place. The communications system thus appears to be adequate to handle an incident. Most of Tooele County is covered by an 800-MHz band, except for police, fire, and emergency medical agencies (Sagers,

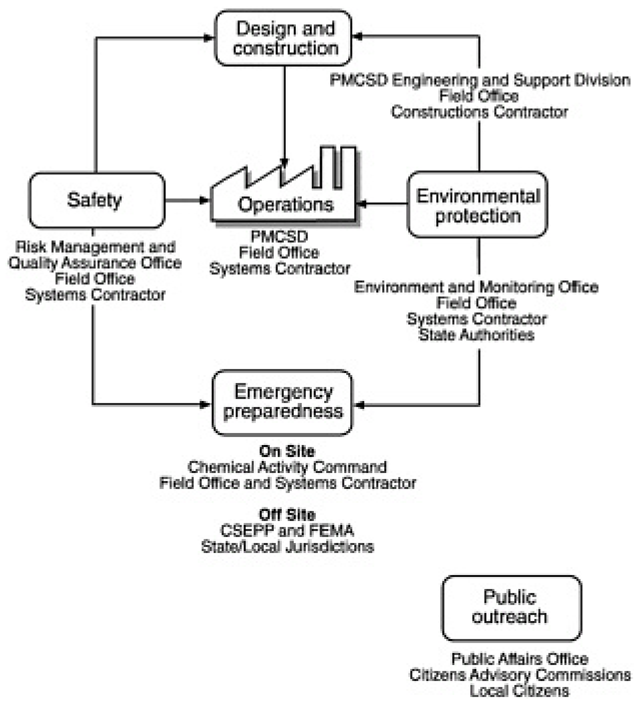

Figure 5-1 PMCD's organizational elements directly related to risk management (p. 63 in the *Guide*). Source: U.S. Army, 1997a.

1998c). However, the county can interface with all relevant response agencies.

The communications system can now notify and warn residents. Originally, Tooele County had planned to use tone-alert radios (indoor alert notification system 990-MHz radios), which had been funded but had not been distributed when the *Systemization* report was issued. The current notification system relies on National Weather Service radios (through an agreement concluded in 1994–1995). These radios have been widely distributed and can be activated in the event of an incident by either the National Weather Service or the operations center of the Department of Emergency Management (Sagers, 1998a). A small part of Rush Valley is without these radios because of difficulties with distribution or resident preferences. The Department of Emergency Management, in cooperation with other Tooele County departments and the local Army POIO outreach office, has devised and implemented a plan for distributing radios to new residents. (Warning sirens are included in the plan but were not evaluated for this report.) It is clear that substantial progress has been made in the critical area of communications and that the system is almost complete.

CHANGE MANAGEMENT PROCESS

The *Risk Assessment and Management* report included several recommendations ([R-5] through [R-8]) concerning the integration of the public-involvement and emergency-management functions (CSEPP) into the Army's draft Guide and RMP (risk management plan):

Recommendation 5. The Army should develop a management plan (and include it in the Guide) that defines the integration of management roles, responsibilities, and communications across activities by risk management functions (e.g., operations, safety, environmental protection, emergency preparedness, and public outreach). [R-5]
Recommendation 6. The Army should review and expand the current draft risk management plan to include public involvement in appropriate areas beyond the management of change process. [R-6]
Recommendation 7. The Army should institutionalize the management of change process developed in the *Guide*. The Army should track performance of the change process and document public involvement and public responses to decisions. The Army should use this experience to improve the change process. [R-7]
Recommendation 8. The Army should expand implementation of the risk management program to ensure that workers understand the results of risk assessments and risk management decisions. The Army should also ensure that CSEPP and other emergency preparedness officials understand the QRA and how their activities might affect risk. CSEPP activities should be tracked by the Army as part of its management program. [R-8]

These recommendations clearly reflect the committee's conviction of the importance of integrating both the public-outreach and the emergency-preparedness programs into the Army's draft *Guide,* as well as the CMP (which was planned as the last chapter of the *Guide*). The committee was convinced that the development of a CMP and its inclusion in the *Guide* would break new ground. The CMP would be "a process for managing changes that may affect the risk associated with PMCD activities" (NRC, 1997, p. 41), would distinguish matters of risk assessment (the science) from matters of risk management (policy and value judgments), and would establish an approach for integrating them that involved the public. In addition, the *Guide* would define and integrate management functions as they relate to risk management (Holmes, 1998c). The committee concluded that the development of an institutionalized CMP would be critical to comprehensive risk management. At the same time, the committee noted with concern that public involvement, as reflected in the draft *Guide's* organizational components, was not being integrated with risk management (see Figure 5-1). Nevertheless, the committee encouraged the completion of the draft *Guide,* especially Chapter 7, which focused on public involvement, so that the *Guide* could become policy.

Since the *Risk Assessment and Management* report was issued, the committee has monitored the Army's efforts to complete the draft *Guide,* especially the CMP and the public involvement components, and has documented its disappointment with the slow development of the CMP. (The lack of implementation of the CMP in the carbon filtration issue is discussed in the recent *Carbon Filtration for Reducing Emissions from Chemical Agent Incineration* [NRC, 1999]). The committee continues to be concerned that the results of both the QRA and HRA may still not be well understood by CSEPP and other emergency-management personnel, or by the public. The absence of a CMP that includes meaningful public and stakeholder involvement in the Army's risk management decisions is a notable lapse in the program. The Army has failed to use the CMP as a way of initiating two way communication and providing a mechanism for the public to participate in decision making.

6

Findings and Recommendations

In this report, the Stockpile Committee has reviewed the operations at DCD/TOCDF in terms of previous NRC recommendations. Table 6-1 summarizes these recommendations, indicates the chapter of this report where they are discussed, notes the committee's evaluation of the Army's response, and enumerates related new recommendations (presented below). If the committee found that a prior recommendation had been satisfied, the issue was considered closed. The new findings and recommendations in this chapter reflect the remaining and new issues that require further attention by the Army. Some of the new recommendations also have implications for future CSDP sites.

Finding 1. The committee considers the quantitative risk assessment (QRA) and the evolving risk management plan (RMP) as effective steps toward meeting the objective of minimizing public and worker risk.

Recommendation 1. The Stockpile Committee reiterates its earlier recommendation that the Chemical Stockpile Disposal Program should proceed expeditiously and should use technology that will minimize overall risk to the public and to the workers at each site.

Finding 2. The initial disposal campaigns at the Tooele Chemical Agent Disposal Facility (TOCDF) have destroyed a significant quantity of GB nerve agent, although the delay in the issuance of the Toxic Substances Control Act permit caused an interruption in the processing of GB M55 rockets. As a consequence, risk-reduction is well behind the original schedule. Although the Army seems confident that it can overcome this schedule slippage, a recent audit by the Arthur Andersen Company raises questions about the likelihood of meeting the disposal schedule. Extending the schedule will have adverse risk and cost implications.

Recommendation 2. The Army should process M55 GB rockets as soon as possible. The Army should also maintain a strong management commitment and close and effective working relationships with the relevant regulatory agencies to avoid future schedule slippages with their associated adverse risk and cost implications.

Finding 3. Several waste-handling aspects of TOCDF operations have not been resolved. These include performance in the brine reduction area (although the Army now plans to continue to treat brine off site), and plans to replace the dunnage furnace with an alternative method for the disposal of activated carbon. A micronizer and burner for activated-carbon disposal will be tested in the deactivation furnace system at the Johnston Atoll Chemical Agent Disposal System (JACADS) in 2001.

Recommendation 3. The Army should expedite the resolution of issues associated with the disposal of brine and dunnage in the interest of minimizing landfill disposal and minimizing overall waste as additional sites become operational.

Finding 4. The Army is pursuing a wise course in upgrading current automatic continuous air monitoring system (ACAMS) monitors while simultaneously funding the development of a faster, more reliable ACAMS. The Army has also significantly upgraded laboratory analysis tools for identifying species adsorbed on depot area air monitoring system (DAAMS) tubes that may trigger ACAMS false alarms. Infrared technology that may provide real-time detection of agent release is being investigated, and some progress has been made.

Recommendation 4. The Army should take the following steps to improve its monitoring systems:

- continue its vigorous efforts to improve the response times, agent specificity, and overall reliability of the ACAMS alarms
- continue to test and introduce improved laboratory instruments that can identify and quantify

TABLE 6-1 Summary of Prior and New NRC Recommendations

Prior Recommendation	Area(s) Addressed by Recommendation	Chapter in Which Recommendation Is Discussed	Response to Date	New Recommendation
RC-1	Program-wide risk reduction	2,3,4	Ongoing process	1
S-1	Implementation of a safety program	3,4	Ongoing process	1, 5, 6, 7, 9, 11
S-2	Incorporation of safety and environmental goals into award fees	4	Satisfied at the TOCDF and JACADS, but not program-wide	8
S-3	Completion of QRA and resolution of QRA safety-related issues	3	Good implementation at the TOCDF to date, but incomplete program-wide	5, 6, 7
S-4	Improved public interactions and communications	5	Ongoing process	10
S-5	Emergency-preparedness training	5	Satisfactory cooperative effort at the TOCDF, but ongoing concern about federal coordination at other sites	11
S-6	Completion and practice of emergency-preparedness plans	5	Satisfactory ongoing process	11
S-7	Completion of emergency-preparedness communications system for Tooele site	5	Significant progress and essentially complete	
S-8	Completion of Army preoperational survey	2	Completed	
S-9	Attainment of LIC 99.9999% DRE	2	Accomplished	
S-10	Safety management	4	Progress, but continuing concerns	5, 6, 7, 9
S-11	Completion of RCRA and TSCA trial burns	2	Completed	
S-12	BRA certification; dunnage disposal	2	Off-site disposal alternatives implemented; BRA certification on hold; DFS alternative to DUN to be investigated	3
S-13	LIC slag removal	2	Satisfactory performance of equipment	
S-14	Completion of risk management plan (RMP)	3	Progress but not complete	7

Prior Recommendation	Area(s) Addressed by Recommendation	Chapter in Which Recommendation Is Discussed	Response to Date	New Recommendation
S-15	Risk assessment integration	3	Satisfied in principle	
S-16	"Near misses" tracking and safety	3	Progress but not complete	6
S-17	Improvements in monitoring	2	Progress but continuing effort required	4
R-1	Updating of QRA, HRA	3	Documentation of updating process pending	6
R-2	Development and review of program-wide site-specific QRAs and HRAs	3	Ongoing process	6
R-3	Update of QRA methodology manual	3	Still pending	7
R-4	Inclusion of "safety culture" in *Guide*	4	Progress but not complete	9
R-5	Definitions of risk management roles and responsibilities in *Guide*	4	Progress but not complete	7, 8, 9
R-6	Inclusion of public involvement in RMP	5	Further refinement necessary	10
R-7	Tracking of CMP performance	5	Disappointing performance to date on carbon-filter issue	10
R-8	Understanding of risk assessment by workers, etc.	3	Progress but not complete	5
R-9	Implementation and updating of RMP	3,4,5	Progress but not complete	5, 6, 7
PI-1	Commitment of CSDP to public involvement	5	Recent indications of improved strategy but commitment yet to be demonstrated	10
PI-2	Coordination of CSDP, CSEPP, public affairs, and RMP	3, 5	RMP not complete	7, 10

Code Legend: RC = *Recommendations for the Disposal of Chemical Agents and Munitions* report; S = *Review of Systemization of the Tooele Chemical Agent Disposal Facility* report; R = *Risk Assessment and Management at Deseret Chemical Depot and the Tooele Chemical Agent Disposal Facility* report; and PI = *Public Involvement and the Army Chemical Stockpile Disposal Program* report. See Appendix B for a complete list of reports by the NRC Stockpile Committee.

interference species to minimize false positive ACAMS alarms

- continue to sponsor the development, testing, and potential deployment of new analytical instrumentation capable of providing real-time or near real-time (< 10 s) detection of significant levels of agent release and keep abreast of research in the area of rapid-response agent detection

Finding 5. No comprehensive, integrated program for managing risks or communicating them to workers and nearby residents has been established or implemented.

Recommendation 5. The Risk Management Program at stockpile storage and disposal facilities must be comprehensive and integrated to protect workers, the public, and the environment. The Army should incorporate current and planned risk management tools (quantitative risk assessments [QRAs]; health, safety, and environmental evaluations; health risk assessments [HRAs], etc.) into a comprehensive, integrated risk-reduction program to identify, prioritize, and reduce any (as yet undetermined) residual risks to workers and the public at Tooele and other disposal sites. The risk management program should be updated in response to experience and new information and should be a living, ongoing process that is integral to facility operations and adequately communicated. When used iteratively, it can help to identify and manage on-site and off-site risks. For example, lessons learned from Phase 2 QRAs can be incorporated into facility designs. Risk management decisions and HRA results should be used to determine if other mitigation measures are required.

Finding 6. The Army has briefed the committee on how various issues related to the QRA have been resolved, but no formal process has been established for identifying and tracking QRA issues that must be resolved before the beginning of each campaign. The committee was briefed on the Programmatic Lessons Learned (PLL) program and concluded that two aspects of the program require additional work: (1) formal specification of the lessons-learned program, including site responsibilities in responding to lessons learned, and (2) the dissemination of lessons learned among the personnel at each site. Moreover, procedures for updating the QRA, and when necessary the HRA, based on new information (as identified in the PLL) have not been established, and the process for updating them when plant configuration or operational changes are planned has not yet been incorporated into the *Guide*. The committee notes that the Army has fallen significantly behind schedule in implementing major elements of the RMP at the TOCDF.

Recommendation 6. As a formal process for each site, a list of outstanding issues related to the QRA for each campaign should be prepared and the resolution of each issue documented before the campaign begins. The Army should provide a formal specification for the lessons-learned programs, including individual responsibilities and definitions of how safety improvements at each site will be developed based on the lessons learned. The *Guide to Risk Management Policy and Activities* should be revised to include the process for updating the QRA and/or the HRA when significant new information is identified through the lessons-learned programs, or when significant plant, processing, or scheduling changes are planned. Based on its experience at the TOCDF, the Army should initiate Phase 2 QRAs for the chemical disposal facilities under development as soon as feasible, preferably while the risk information can still be used to improve the design and construction of the facility.

Finding 7. The Army has successfully implemented an informal risk management process for DCD/TOCDF, but has not finalized a formal plan or institutionalized programmatic lessons learned for the risk management process or for other informal cross-site risk communication programs. The QRA methodology manual has not been revised to reflect recent improvements.

Recommendation 7. The Army should formally and expeditiously implement risk management practices at site and programmatic levels into coordinated, well-documented plans and update them whenever necessary to ensure that they reflect current practices and lessons learned. The methodology manual for the quantitative risk assessment should be updated to reflect the significant improvements that have been made.

Finding 8. At the start-up of operations, industrial safety performance was poor at both of the currently operating facilities (JACADS and the TOCDF). The committee believes this reflects a disproportionate focus on chemical agent and a failure of management to build a total safety culture prior to plant start-up. Sharing of lessons learned among sites will be critical for improving CSDP-wide safety performance.

Recommendation 8. The Army should consider adding a Chemical Stockpile Disposal Program (CSDP)-wide factor for safety into the criteria for award fees at each site. This factor should be based on the safety performance at all CSDP sites. Operating sites should be required to demonstrate continued improvements in key safety metrics with "best of industry" standards, rather than "industry averages," as the target goal. The Army should insist that the safety performance of new facilities be comparable to the best safety performance of operating facilities.

Finding 9. After public allegations of safety deficiencies at the TOCDF by two employees, seven independent safety investigations at the site, and previous Stockpile Committee recommendations, TOCDF management implemented programs to improve safety performance and to lay the foundations of safety culture at the site. However, safety metrics do not yet indicate that performance has improved.

Recommendation 9. The Army should continue the vigorous implementation of all elements of the *Safety Culture Plan,* with visible commitment and involvement by management.

Finding 10. Recent efforts by the Army to improve public outreach are listed below:

- the reorganization of the Public Outreach and Information Office
- the development of the *PMCD* [Program Manager for Chemical Demilitarization] *Overarching Public Involvement Strategy*
- the publication of *Public Involvement Strategy for the CSDP*
- the publication of *Umatilla Chemical Agent Disposal Facility Public Involvement Implementation Plan*
- plans for a CSDP stakeholder survey
- the significant expansion of the capacity of the local Tooele public outreach office

The Army has not, however, increased the opportunities for meaningful public input and review of CSDP activities and plans. Furthermore, a component of meaningful public involvement, which is recognized in the *Umatilla Chemical Agent Disposal Facility Public Involvement Implementation Plan,* is still missing at the TOCDF. Public involvement has not come at a point in time "when stakeholders believe that what they have said or contributed has been heard, understood, and incorporated into the decision-making process." The change management process will be a major step forward, but public involvement should not be limited to the CMP.

Recommendation 10. The Army should continue to increase the involvement of local Citizens Advisory Commissions (CACs), stakeholder groups, and the public in the development of future CSDP planning, implementation, and public outreach activities (e.g., surveys). The public outreach activities should be integrated with other CSDP activities, and the committee again recommends that the public, CACs, and stakeholder groups play early and meaningful roles in the implementation of significant operational changes and in planning for the decontamination and decommissioning of disposal facilities. The integration of the Army's public outreach program and the CMP should be the first step in the development of a coordinated, efficient, effective, and meaningful public involvement program. Once the criteria are finalized for using the CMP and involving the public, the Army should actively expedite implementation of the process.

Finding 11. Most of the committee's recommendations concerning emergency management and preparedness at the TOCDF have been addressed. First responders have been well trained in the use of personal protective equipment. Emergency preparedness plans for Tooele County for incidents involving chemical agent have been completed, and training exercises are continuing. Efforts are being made to coordinate responses by the Army with state and local emergency management agencies. Although these efforts are being hampered by the use of different software packages, significant improvements in preparedness and planning have been made. Significant improvements have also been made toward completing the communications system in Tooele County, and radios for using the National Weather Service as a notification system are being distributed.

The committee is concerned that the current reorganization of the Chemical Stockpile Emergency Preparedness Program, under which FEMA now has responsibility for off-site plans and activities, may fragment authority and interfere with a well coordinated emergency management program.

Recommendation 11. The Army and the Federal Emergency Management Agency should work together to ensure that preparedness and planning, warning, response, and mitigation activities of the emergency management program for the TOCDF are well coordinated. Informal relationships and agreements among state, local, and federal personnel should be formalized to ensure a permanent emergency preparedness capacity. Interfaces for emergency management software should be provided as soon as possible.

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Appendices

Appendix A

Specific Design Features of the Tooele Chemical Agent Disposal Facility Baseline Incineration System

PROCESS DESCRIPTION

The Tooele Chemical Agent Disposal Facility (TOCDF) consists of five interconnected process systems:

1. The unloading and unpack system for receiving munitions from the Deseret Chemical Depot.
2. The demilitarization processing systems for handling rockets, containers, mines, and projectiles separately.
3. The furnace and incinerator systems, which include a deactivation furnace system, a metal parts furnace, two liquid incinerators, and a dunnage incinerator.
4. Various safety systems, including explosive containment, ventilation and filtering, fire protection, agent monitoring, and door monitoring.
5. Various support systems, including electric, fuel gas, instrumentation, compressed air, hydraulics, cooling, and the very important pollution abatement systems.

These systems are linked, monitored, and controlled through an advanced process management system operated from a central control room.

For practical purposes, the TOCDF is a scaled up and updated version of the Johnston Atoll Chemical Agent Disposal System (JACADS), which has been operating for nine years. Although JACADS was the first chemical agent disposal facility, its design was based on pre-existing commercial incinerators, as well as years of development and testing of special munitions-handling machinery. Very little new technology was incorporated into the TOCDF. The layout of the TOCDF is shown in Figure A-1.

Unloading and Unpack System

Munitions are brought by truck in sealed containers from the storage area in Deseret Chemical Depot into the container-handling building along dedicated and highly secure roads. The containers are lifted to the second floor of the building into the unpack area where they are opened, and the munitions are conveyed into the munition demilitarization building. No human contact with the munitions occurs after the munitions leave the unpack area.

Demilitarization Processing Systems

The purpose of demilitarization processing is to separate the components of munitions into separate streams that can be handled safely in the downstream furnace and incinerator systems. Each type of munition is unique and must be processed separately. Rockets, for example, contain agent, propellant, and burster energetics, which must be separated for processing. The rocket-handling system feeds rockets into an explosion-containment room through a rotating vestibule. In the explosion-containment room, the agent cavity is punched open, and the agent is drained into a separate holding tank. Eventually, the agent is fed into a liquid incinerator (LIC) and burned. The drained rocket proceeds to a shearing device where the fuse is sheared off, the burster is sheared off, and finally the propellant-containing motor is sheared off. The fuse, burster, and motor fall into a hopper that discharges them into the deactivation furnace system (DFS). The rocket-handling system is shown in Figure A-2.

Bulk munitions contain agent but no energetics. Therefore, they bypass the explosion-containment room and are conveyed into the upper munitions corridor of the munitions processing building to a bulk drain station. Bulk containers are hydraulically punched so that agent can be drained into a holding tank prior to incineration in a LIC. The drained container and the tray it was on are conveyed to the metal parts furnace (MPF) for cleanup. The bulk handling system is shown in Figure A-3.

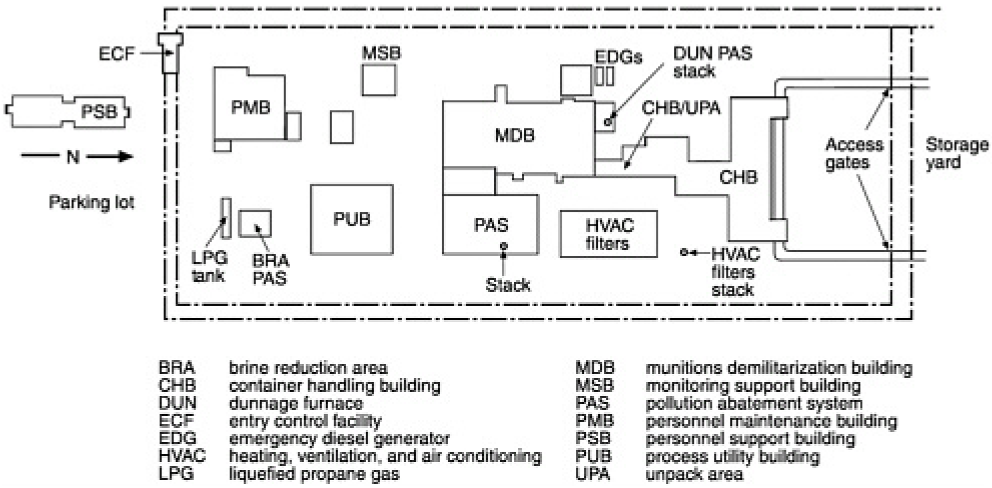

Figure A-1 Layout of the TOCDF. Source: Adapted from U.S. Army, 1996.

Projectiles are processed in a system similar to the rocket-handling system. Projectiles, either artillery shells or mortar shells, contain both agent and energetics. Projectiles enter the explosion-containment room by conveyer and are fed mechanically onto a projectile/mortar disassembly table. The table rotates so that nose closures (fuses or lifting plugs) can be mechanically removed. At another stop, burster material is removed. The shells are then placed in an egg-crate metal tray and conveyed into the munitions processing bay located in the upper munitions corridor. A robot unloads the shells onto another rotating table called the multi-purpose demilitarization machine, where they are milled to cut through burster tube welds, if necessary. Then the burster tubes are removed, and the agent is drained. Finally, the burster tube is crimped and reinserted, and the projectile is sent through the MPF. The projectile-handling system is shown in Figure A-4.

The mine-handling system is the last demilitarization processing system. Operators unpack mines from their drum containers in the unpack area. Each mine is then cycled through a glove box onto a conveyer in the explosion-containment vestibule. This conveyer takes them to a workstation where the arming plugs, fuses, and activators are removed and placed in a fuse box. The fuse box and the mine are then transported to the explosion-containment room, where a mine machine punches the mine and drains the agent. A burster punch machine removes the burster from the mine. The remnants of the mine and the fuse box are then sent to the DFS. Figure A-5 depicts the mine-handling system.

FURNACES AND INCINERATORS

The DFS is used to destroy explosives and propellants from rockets, projectiles, and mines. Basically, the DFS is a gas-fired rotary kiln (Figure A-6). Munitions pieces are fed down a chute from the explosion-containment room into the DFS. The chute has two blast gates that open sequentially. As the kiln rotates, the pieces are moved through the kiln by a spiral baffle that pushes them along. For rocket campaigns, the kiln runs at 1,100°F. For other campaigns, it runs at 1,500°F. The pieces burn rapidly rather than detonating. As added protection against detonation, the charge end of the kiln is constructed of two-inch thick steel. The burned munitions exit onto a discharge conveyer that carries them under two electric heater banks that keep the scrap at 1,000°F for 15 minutes. This ensures that the scrap is 5X clean, (i.e., 99.99999 percent free of agent). DFS exhaust gases go through a blast-attenuation duct, a cyclone separator (to remove ash), and an afterburner before entering the pollution abatement system (PAS).

The function of the MPF is to decontaminate munitions bodies after removal of agent and explosives. The

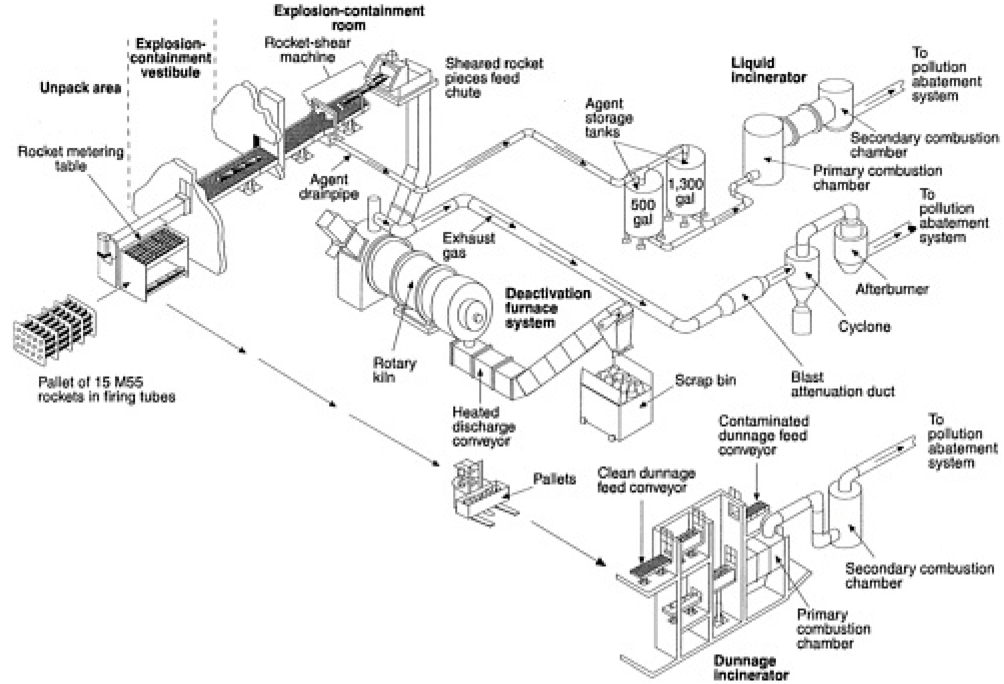

Figure A-2 Rocket-handling system. Source: Adapted from U.S. Army, 1996

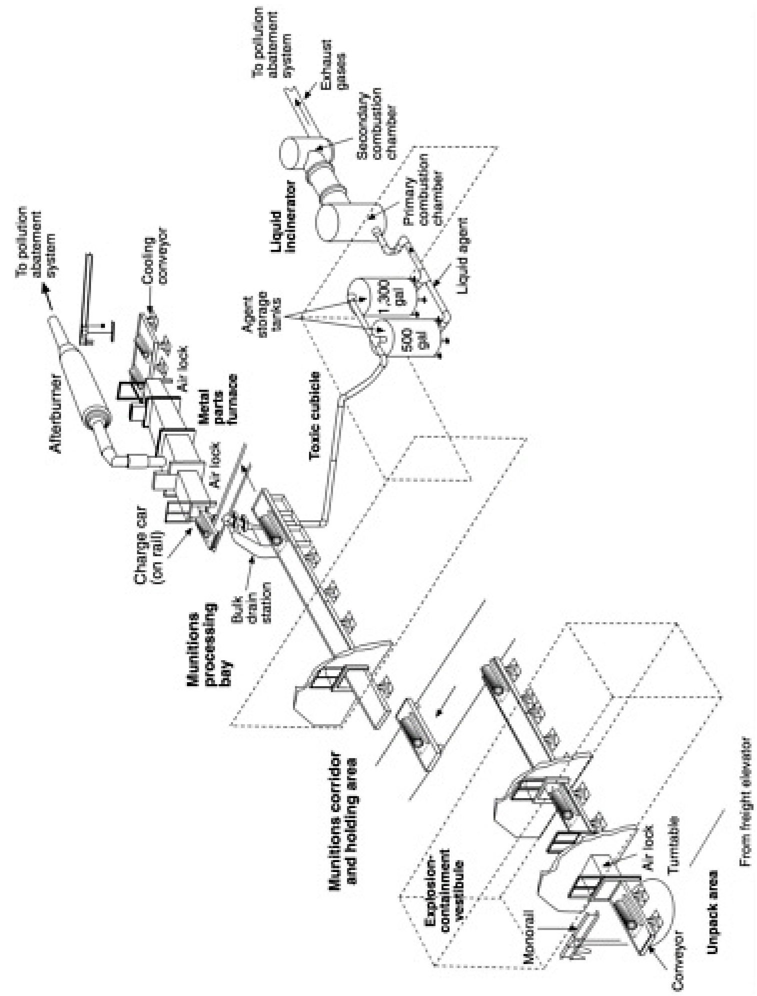

Figure A-3 Bulk handling system. Source: Adapted from U.S. Army, 1996.

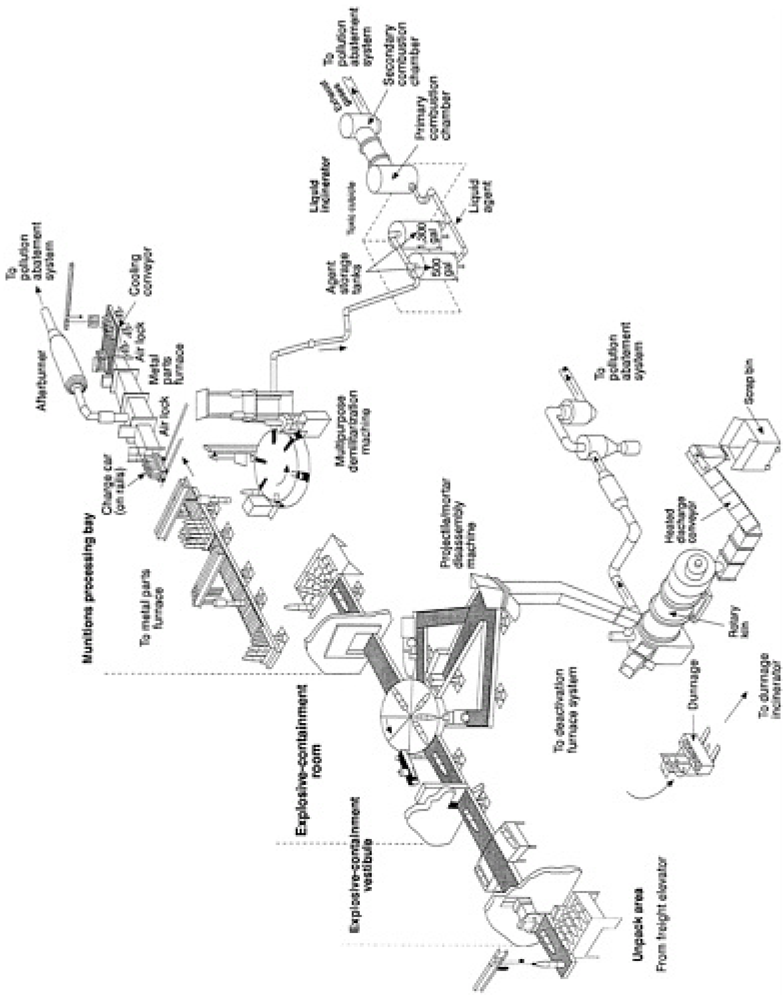

Figure A-4 Projectile-handling system. Source: Adapted from U.S. Army, 1996.

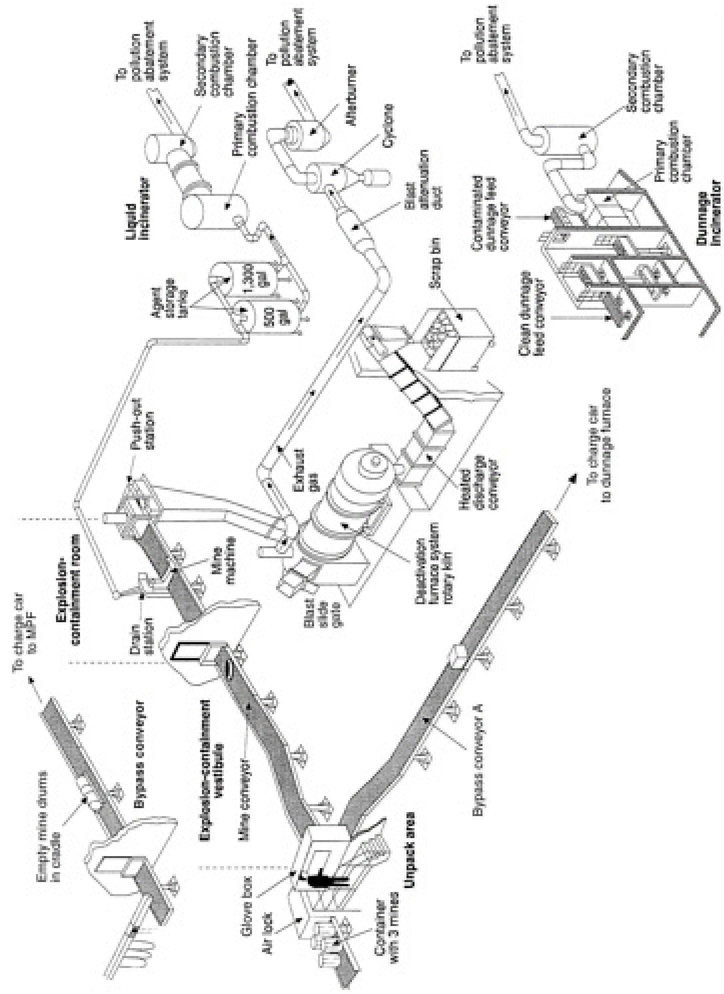

Figure A-5 Mine-handling system. Source: Adapted from U.S. Army, 1996.

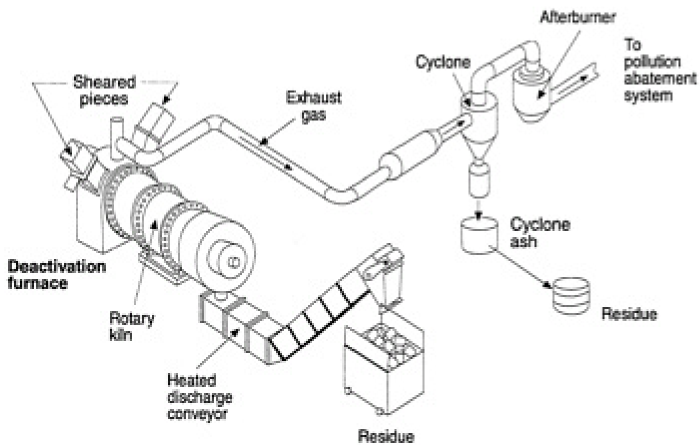

Figure A-6 Deactivation furnace system. Source: Adapted from U.S. Army, 1996.

MPF is diagrammed in Figure A-7. For ton containers, the MPF peaks at 1,450°F. For spray tanks, it operates at 1,525°F. For smaller items, it operates at 1,600°F. Contaminated items are conveyed semicontinuously through a charge air lock into the first of three heating, zones, each of which has an air-lock door. Pieces are held in the discharge air lock until they cool enough so that agent levels can be monitored. Pieces that are 5X clean are cooled and containerized for disposal. The exhaust gas from the MPF goes through an afterburner and then to the PAS.

Two LICs destroy liquid agent. Figure A-8 shows the LIC configuration. The primary chamber, a vertical refractory-lined cylinder with a natural gas burner, operates at 2,700°F. Agent is atomized as it is injected into the air stream going into the burner. As the agent burns,

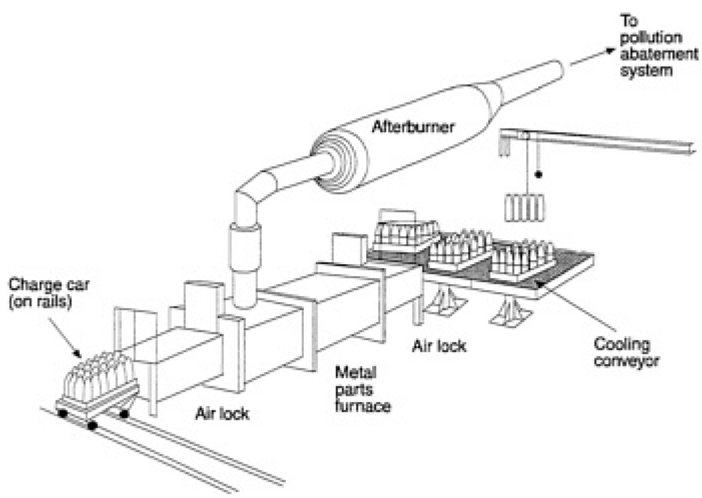

Figure A-7 Metal parts furnace Source: Adapted from U.S. Army. 1996.

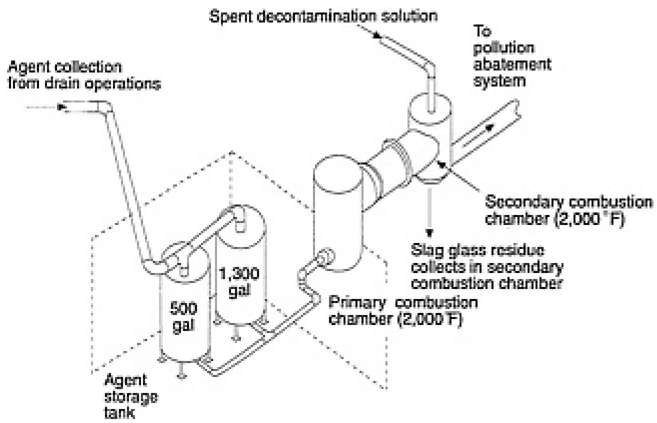

Figure A-8 Liquid incinerator. Source: Adapted from U.S. Army, 1996.

the natural gas supply is cut back to maintain the temperature at the desired level. The exhaust from the primary chamber goes into a similar, refractory-lined secondary chamber, in which the temperature is maintained at 2,050°F by burning natural gas. Spent decontamination solution is atomized and injected into the second combustion chamber. All of this forms a molten slag, which is drawn off through a bottom tap into barrels, where it solidifies. Once cool, these barrels are covered and stored prior to disposal.

A dunnage incinerator (DUN) is designed to destroy the plastic, wood, or paper packing cases, pallets, and other objects that may be contaminated by agent. In practice at the TOCDF, the DUN has not operated routinely because the listed materials could be safely disposed of in other ways. The DUN is designed to burn natural gas and dunnage combustibles at a temperature of 1,400°F. The configuration of the DUN is shown in Figure A-9. The primary combustion chamber is refractory-lined and has four side burners. Air is supplied both through

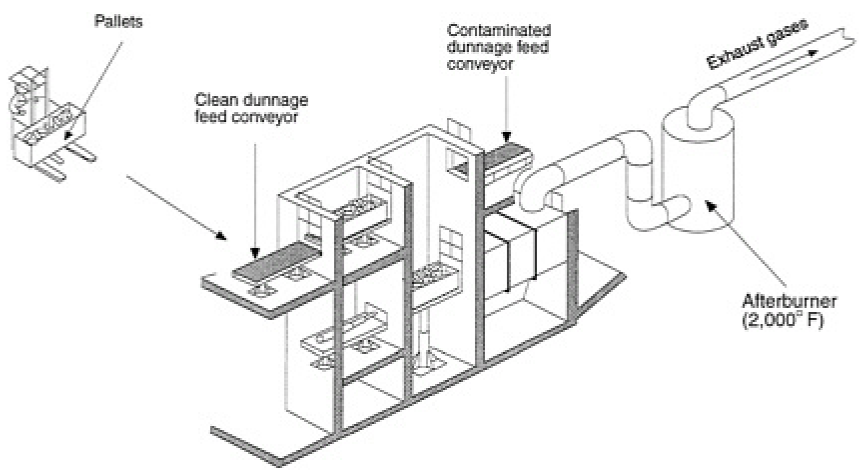

Figure A-9 Dunnage furnace. Source: Adapted from U.S. Army, 1996.

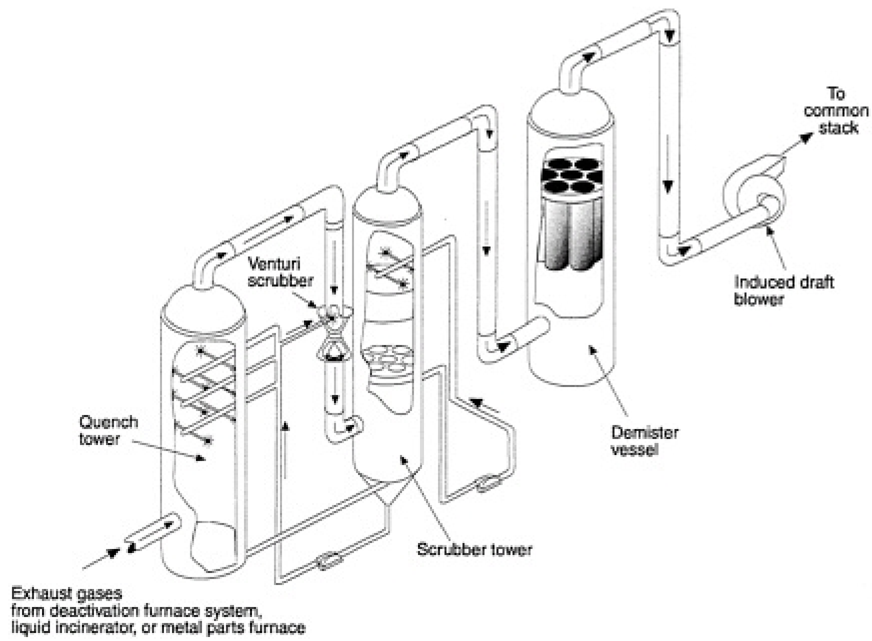

Figure A-10 Pollution abatement system. Source: Adapted from U.S. Army, 1996.

the burners and through side wall ports. Ashes are removed from the furnace periodically. Exhaust gases go to the afterburner, which operates at 2,000°F. Secondary exhaust passes into the PAS.

Safety Systems

Ensuring process safety is the prime concern of the design and operation of the TOCDF. Explosion-containment requirements were mentioned in several of the preceding sections. The overall design for explosion-containment rooms requires containment of a blast from 15 pounds of TNT. The DFS room is designed to contain a blast from 28.2 pounds of TNT. Interlocked blast gates and blast doors are used to ensure containment.

Agent dispersion in the air stream is another major safety concern. Avoiding contamination is accomplished by pressure cascading the air flow throughout the plant from areas with low contamination probability through areas with increasing contamination probability. The air from the most susceptible areas to agent contamination (the furnace rooms and the munition demilitarization building) is filtered through a series of high efficiency particulate air filters and carbon adsorption beds before being exhausted to a stack. In situ monitoring for agent occurs at many points within and around the perimeter of the plant. In addition, ambient air is continuously pumped through contaminant concentration tubes that are periodically collected and analyzed for agent by gas chromatography. There is also a system for monitoring and controlling doors so that the ventilation flowpaths are not upset even when personnel enter or leave the munition demilitarization building areas.

Fire protection is another critical safety concern. Automatic fire detectors are located throughout the plant. Sprinkler systems supplied from a large storage tank come on automatically in the event of a fire in the unloading and unpack areas. In other areas, dry chemical systems are deployed. Halon systems protect the control room and power supply room.

Support Systems

The electric, instrumentation, compressed air, hydraulics, fuel gas, and cooling systems are fairly standard industrial systems, but they are often paralleled to ensure reliability. Each furnace system has a downstream PAS to neutralize and remove the acidic components (hydrochloric, hydrofluoric, sulfuric acids, etc.) formed during the combustion of the agent so the exit gas can be safely released to the atmosphere. Figure A-10 illustrates a typical PAS configuration. The furnace outlet gases enter a quench tower in which a caustic solution is sprayed. The cooled gases exit into a venturi scrubber where they are again in contact with caustic brine. Finally, they go through a scrubber tower where they are in contact with additional brine, through an induced draft fan, and then to a common stack. The PAS for the DUN is simple. It has only a quench tower because the exit gases are far less acidic than those from the other furnaces.

The brine reduction area (BRA) process involves evaporating brine with steam generated on site, then drying it to salt with less than 10 percent water content. The gas from the evaporator is superheated and passed through a bag filter system before being exhausted to the atmosphere. Currently, brine from the PAS is collected, stored temporarily, and then disposed of off site as a hazardous waste. This brine disposal strategy is currently a cheaper alternative than operating the BRA.

Operations Control Room

The central control room provides surveillance and direction for all phases of TOCDF activities. It is kept at a higher positive pressure to prevent the possibility of any agent entering it, and the air intake is doubly filtered. Several consoles line the room, each with two advisor screen monitors, two closed-circuit TV monitors, and a keyboard through which commands are entered to control plant operations. Redundant computers, software, and plant instrumentation ensure that continuous real-time control is maintained.

Reference

U.S. Army. 1996. Tooele Chemical Agent Disposal Facility Quantitative Risk Assessment. SAIC-96/2600. Aberdeen Proving Ground, Md.: U.S. Army Program Manager for Chemical Demilitarization.

Appendix B

Reports of the Committee on Review and Evaluation of the Army Chemical Stockpile Disposal Program (Stockpile Committee)

Comments on Operational Verification Test and Evaluation Master Plan for the Johnston Atoll Chemical Agent Disposal System (JACADS) (1989)

Demilitarization of Chemical Weapons: On-Site Handling of Munitions (1989)

Demilitarization of Chemical Weapons: Cryofracture (1989)

Workshop on the Pollution Abatement System of the Chemical Agent Demilitarization System (Letter Report, May 1991)

Letter report on siting of a cryofracture chemical stockpile disposal facility (August 1991)

Comments on Proposed Cryofracture Program Testing (Letter Report, August 1991)

Review of the MITRE report: Evaluation of the GB Rocket Campaign: Johnston Atoll Chemical Agent Disposal System Operational Verification Testing, dated May 1991 (Letter Report, September 1991)

Review of the Choice and Status of Incineration for Destruction of the Chemical Stockpile (Letter Report, June 1992)

Letter Report to recommend specific actions to further enhance the CSDP [Chemical Stockpile Disposal Program] risk management process (January 1993)

Recommendations for the Disposal of Chemical Agents and Munitions (February 1994)

Review of Monitoring Activities Within the Army Chemical Stockpile Disposal Program (April 1994)

Evaluation of the Johnston Atoll Chemical Agent Disposal System Operational Verification Testing: Part I (July 1993) and *Part II* (April 1994)

Evaluation of the Army's Draft Assessment Criteria to Aid in the Selection of Alternative Technologies for Chemical Demilitarization (December 1995)

Review of Systemization of the Tooele Chemical Agent Disposal Facility (March 1996)

Public Involvement and the Army Chemical Stockpile Disposal Program (Letter Report, October 1996)

Risk Assessment and Management at Deseret Chemical Depot and the Tooele Chemical Agent Disposal Facility (September 1997)

Using Supercritical Water Oxidation to Treat Hydrolysate from VX Neutralization (May 1998)

Carbon Filtration for Reducing Emissions from Chemical Agent Incineration (July 1999)

Appendix C

TOCDF-Related Recommendations by the Stockpile Committee Addressed in This Report[1]

SYSTEMIZATION REPORT (NRC, 1996A)

Duration of TOCDF Operations

Recommendation 1. Safety program development and implementation at the TOCDF must be given high priority.

Recommendation 2. Safety and environmental performance goals should be given at least equal weight with production goals in establishing award fee criteria.

Recommendation 3. Applicable portions of the accident quantitative risk assessments must be completed and all safety-related concerns resolved before the start of specific agent-destruction campaigns.

Recommendation 4. A substantial effort should be made by the Army to enhance interactive communications with the host community and the Utah State Citizens Advisory Commission on issues of mutual concern (e.g., various elements of the Chemical Stockpile Emergency Preparedness Program [CSEPP], decontamination and decommissioning, future use of the facility, and risk reduction).

Coordinated with the Start of Agent Operations

Recommendation 5. The Army should increase efforts to work with the Utah Division of Comprehensive Emergency Management to ensure that first-responders have been adequately trained to use the personal protective equipment approved by the Occupational Safety and Health Administration. Tooele County must ensure their capability for responding to an emergency incident, especially because this condition relates to state requirements for the start of agent operations.

Recommendation 6. The Army, and where appropriate the Federal Emergency Management Agency (FEMA), should ensure that local and state Chemical Stockpile Emergency Preparedness Program (CSEPP) plans for responding to potential chemical events are complete and well exercised as soon as possible.

Recommendation 7. The Army/FEMA should provide the necessary resources for completing the communications system planned by the Tooele County Department of Emergency Management.

Prior to the Start of Agent Operations

Recommendation 8. All mandatory requirements of the Army's Pre-Operational Survey must be satisfied.

Recommendation 9. The liquid incinerator and deactivation furnace system must have demonstrated a destruction removal efficiency of 99.9999 percent (6-nines) during surrogate trial burns.

Recommendation 10. High-quality, adequately staffed safety management systems must be completely implemented (including procedures for testing

[1] Throughout the text of this report, references to recommendations from the 1996 NRC report, *Review of Systemization of the Tooele Chemical Agent Disposal Facility* (*Systemization* report), are designated by [S-#]; recommendations from the 1996 NRC report, *Public Involvement and the Army Chemical Stockpile Disposal Program* (*Public Involvement* letter report), are designated by [PI-#]; and recommendations from the 1997 NRC report, *Risk Assessment and Management at Deseret Chemical Depot and the Tooele Chemical Agent Disposal Facility* (*Risk Assessment and Management* report), are designated by [R-#].

critical equipment; all necessary operating, maintenance, and emergency procedures; management of change procedures; training and cross-training programs; programmatic lessons-learned activities; subject area reviews; and other safety oversight activities).

During the First Year of Agent Operations

Recommendation 11. The liquid incinerator must pass all required Resource Conservation and Recovery Act (RCRA) trial burns; and the deactivation furnace system must pass required Toxic Substances Control Act trial burns.

Recommendation 12. Testing and certification of the brine reduction area and the dunnage incinerator should be completed at the TOCDF, or a satisfactory disposal alternative must be implemented.

Recommendation 13. Performance of the slag removal system for the liquid incinerators should be demonstrated when sufficient slag has accumulated.

Recommendation 14. The Risk Management Plan must be fully implemented.

Recommendation 15. A comprehensive, integrated, and clear TOCDF risk assessment study, including a full description of all significant acute and latent agent and nonagent risks associated with disposal operations, as well as with the continued maintenance of the Tooele chemical stockpile, should be completed. A full explanation of the uncertainties associated with the various estimates should be included.

Recommendation 16. A system for documenting and tracking unexpected upsets, errors, failures, and other sources of problems that lead to "near misses" during operation of the facility should be developed as soon as possible. A program for integrating this information into a plan for continual safety improvements at the TOCDF should be implemented.

Recommendation 17. An active program for continual improvement of monitoring instrumentation, including techniques for more rapid recognition of significant levels of agent release, should be pursued.

Public Involvement Letter Report (NRC, 1996b)

Recommendation 1. The Army and the Chemical Stockpile Disposal Program management at all levels must make an increased commitment to public involvement throughout the entire program.

- The Program Manager for Chemical Demilitarization should establish and develop mechanisms and processes that allow direct input by affected citizens into the decision-making process for destruction of the stockpile.
- The Program Manager for Chemical Demilitarization should develop and implement a detailed public involvement plan that identifies program elements where the public and affected parties can make significant contributions to program decisions. The plan should be developed with input from the public, citizens advisory commissions, and other affected parties. The plan should define the goal of public involvement, a process for identifying opportunities for public input and review, mechanisms for interaction between the public and the parties responsible for implementing the disposal program, and individual and collective roles and accountability on the part of the Army, citizens advisory commissions, and others. Senior management of the Chemical Stockpile Disposal Program and management at each chemical stockpile site should be active and visible participants in the public involvement process.
- The Program Manager for Chemical Demilitarization should institute policies and procedures to ensure feedback to the communities detailing the Army's response to and use of input from the public and other parties in the decision-making process and program oversight.
- The Program Manager for Chemical Demilitarization is encouraged to provide independent technical assistance to the citizens advisory commissions as requested. This assistance should come from individuals or organizations that are without bias and have no conflicts of interest concerning the Chemical Stockpile Disposal Program.

Recommendation 2. The public affairs programs for the Chemical Stockpile Disposal Program, the Chemical Stockpile Emergency Preparedness Program, and other Army activities at stockpile locations should be closely coordinated to avoid adversely affecting public perceptions of the Chemical Stockpile Disposal Program and delaying implementation of stockpile destruction. In addition, the public affairs program for the Chemical Stockpile Disposal Program should be coordinated with the risk management plan at each stockpile site.

RISK ASSESSMENT AND MANAGEMENT REPORT (NRC, 1997)

Risk Assessments

Recommendation 1. The Army should update both the QRA and HRA at the TOCDF whenever changes to system design or operations occur that could affect QRA or HRA calculations to ensure that estimates of risk are current and reflect changes in operating conditions and experience, assumptions, and program status (current Established Configuration). The process for updating the QRA and HRA should be included in the *Guide*.

Recommendation 2. The Army should continue the site-specific QRA and HRA processes at all PMCD sites. The development of assessments for sites other than the DCD will be greatly simplified because much of the methodology has already been established. The Army should continue to obtain interactive, independent expert reviews of all site-specific QRAs. The Army should heed the lessons learned from development of the TOCDF QRA and should incorporate the changes recommended by the Expert Panel.

Recommendation 3. The QRA methodology manual should be updated to reflect the significant improvements that have been made.

Risk Management

Policy

Recommendation 4. The Army should expand its draft report on risk management policy, *A Guide to Risk Management Policy and Activities,* to encourage the establishment of a "safety culture" within the PMCD and its field offices and among contractors and other government agencies. The *Guide* should elucidate the Army's policy on industrial safety, including the responsibilities of individuals and managers in the field and the definitions of acceptable performance.

Recommendation 5. The Army should develop a management plan (and include it in the *Guide*) that defines the integration of management roles, responsibilities, and communications across activities by risk management functions (e.g., operations, safety, environmental protection, emergency preparedness, and public outreach).

Recommendation 6. The Army should review and expand the current draft risk management plan to include public involvement in appropriate areas beyond the management of change process.

Recommendation 7. The Army should institutionalize the management of change process developed in the *Guide*. The Army should track performance of the change and document public involvement and public responses to decisions. The Army should use this experience to improve the change process.

Recommendation 8. The Army should expand implementation of the risk management program to ensure that workers understand the results of the risk assessments and risk management decisions. The Army should also ensure that CSEPP and other emergency preparedness officials understand the QRA and how their activities might affect risk. CSEPP activities should be tracked by the Army as part of their risk management program.

Recommendation 9. The Army should implement their risk management plans and update them whenever necessary to ensure that they reflect current practices and lessons learned.

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Appendix D

Biographical Sketches of Committee Members

David S. Kosson (*chair*) has a B.S. in chemical engineering, an M.S. in chemical and biochemical engineering, and a Ph.D. in chemical and biochemical engineering from Rutgers, The State University of New Jersey. He joined the faculty at Rutgers in 1986 and was made an associate professor with tenure in 1990 and a full professor in 1996. Dr. Kosson teaches graduate and undergraduate courses in chemical and environmental engineering and conducts research for the Department of Chemical and Biochemical Engineering on the development of microbial, chemical, and physical treatments for hazardous waste. He is responsible for project planning and coordination, from basic research through full-scale design and implementation. He has published extensively in the fields of chemical engineering, waste management and treatment, and contaminant fate and transport in soils and groundwater. Dr. Kosson has served on several Environmental Protection Agency advisory panels involved in waste research and is the director of the Physical Treatment Division of the Hazardous Substances Management Research Center in New Jersey. He is a member of the American Institute of Chemical Engineers and recently served as a member of the National Research Council Committee on Alternative Chemical Demilitarization Technologies.

Charles E. Kolb (*vice chair*) is president and chief executive officer of Aerodyne Research, Inc. Since 1971, his principal research interests at Aerodyne have included atmospheric and environmental chemistry, combustion chemistry, materials chemistry, and the chemical physics of rocket and aircraft exhaust plumes. He has served on several National Aeronautics and Space Administration panels dealing with atmospheric chemistry and global change, as well as on five National Research Council committees and boards dealing with environmental issues. From 1996 to 1999, he was atmospheric sciences editor for *Geophysical Research Letters*. In 1997, he received the Award for Creative Advances in Environmental Science and Technology from the American Chemical Society.

David H. Archer, a member of the National Academy of Engineering, has a Ph.D. in chemical engineering and mathematics from the University of Delaware. He is a retired consulting engineer with the Westinghouse Electric Company and is currently adjunct professor at Carnegie Mellon University. Dr. Archer has worked in both industry (at Westinghouse as an engineer, supervising engineer, department manager, and consulting engineer) and academia (at the University of Delaware and Carnegie Mellon University for almost 10 years). He has considerable experience in research and management related to chemical engineering, as well as experience with combustion and plant management.

Piero M. Armenante has a Ph.D. in chemical engineering from the University of Virginia and is currently professor of chemical engineering at the New Jersey Institute of Technology. Dr. Armenante's research interests include multiphase mixing in agitated systems, the biological treatment of hazardous waste, industrial sterilization processes, and biomedical engineering. He has an extensive list of peer-reviewed and other publications and has administered numerous grants, studies, and projects.

Dennis C. Bley is president of Buttonwood Consulting, Inc., and a principal of The Wreath Wood Group, a joint venture company that supports multidisciplinary research in human reliability. He has more than 25 years of experience in nuclear and electrical engineering, reliability and availability analysis, plant and human modeling for risk assessment, diagnostic system development, and technical management. Dr. Bley has a Ph.D. in nuclear engineering from the Massachusetts Institute of Technology and is a registered professional engineer in the state of California. He has served on a number of technical review panels for U.S. Nuclear Regulatory Commission and U.S. Department of Energy programs and is a frequent lecturer in short courses for universities, industries, and government agencies. He is active in many professional organizations and is on the Board of Directors of the International Association for Probabilistic Safety Assessment and Management. Dr. Bley has published extensively on subjects related to risk assessment. His current research interests include applying risk analysis to diverse technological systems, modeling uncertainties in risk analysis and risk management, technical risk communication, and human reliability analysis.

Jerry L.R. Chandler has a Ph.D. in biochemistry from Oklahoma State University and has done extensive postgraduate study in mathematics. He is currently a research professor at the Krasnow Institute for Advanced Study at George Mason University. During his long career, Dr. Chandler served with the U.S. Public Health Service, the National Institute for Occupational Safety and Health (NIOSH), the Food and Drug Administration, and the National Cancer Institute Epidemiology Program. More recently, he was a neuropharmocologist in the Epilepsy Branch of the National Institute of Neurology and Stroke for the National Institutes of Health. Dr. Chandler is a founding member and president of the Washington Evolutionary Systems Society and has published extensively on using mathematical category theory to understand the origins of disease. He previously served as a NIOSH observer with the National Academy of Science/National Research Council Panel on Risk Assessment.

Frank P. Crimi is a part-time consultant and retired vice president of Lockheed Martin Advanced Environmental Systems Company. He has a B.S. in mechanical engineering from Ohio University and has done graduate studies in mechanical engineering at Union College in Schenectady, New York. In addition to his appointment to the National Research Council Committee on Decontamination and Decommissioning of Uranium Enrichment Facilities, Mr. Crimi has firsthand knowledge and experience with radioactive and hazardous-waste treatment and disposal technologies.

Elisabeth M. Drake, a member of the National Academy of Engineering, is the associate director of the Massachusetts Institute of Technology Energy Laboratory. A chemical engineer with experience in risk management and technology associated with the transport, processing, storage, and disposal of hazardous materials, as well as chemical engineering process design and control systems, Dr. Drake has a special interest in the interactions between technology and the environment. She has often been a consultant to government and industry and has been active in the American Institute of Chemical Engineers, especially the Center for Chemical Process Safety. She belongs to a number of environmental organizations, including the Audubon Society, the Sierra Club, and Greenpeace.

J. Robert Gibson is the assistant director of the Haskell Laboratory, E.I. du Pont de Nemours and Company, and an adjunct associate professor of marine studies at the University of Delaware. Since receiving his Ph.D. in physiology from Mississippi State University, Dr. Gibson has specialized in toxicology. He has been certified by the American Board of Toxicology and has written numerous publications.

Michael R. Greenberg is a professor in the Department of Urban Studies and Community Health at Rutgers, The State University of New Jersey, and is an adjunct professor of environmental and community medicine at the Robert Wood Johnson Medical School. His principal research and teaching interests include urbanization, industrialization, and environmental health policy. Dr. Greenberg holds a B.A. in mathematics and history, an M.A. in urban geography, and a Ph.D. in environmental and medical geography.

Kathryn E. Kelly received her Ph.D. in public health from Columbia University, with a concentration in environmental toxicology and the health effects of hazardous waste incineration. She also studied toxicology at the New York University Institute of Environmental Medicine. Dr. Kelly is the founder and president of three companies: Delta Toxicology, Inc., Crystal Bay, Nevada; Environmental Toxicology International, Seattle, Washington; and Alden Analytical Laboratories of Seattle, Washington. She has broad experience in toxicology, waste combustion, environmental policy, and risk communication.

Peter B. Lederman is director of the Center for Environmental Engineering and Sciences, executive director of the Office of Intellectual Property, and research professor of chemical engineering and environmental policy at the New Jersey Institute of Technology. He received his Ph.D. in chemical engineering from the University of Michigan. Dr. Lederman has 45 years of experience in all facets of environmental management, control, and policy development; hazardous substance treatment and management; process engineering; and more than 18 years of experience as an educator. He is a registered professional engineer and a diplomate of the American Academy of Environmental Engineers. Dr. Lederman has worked on environmental policy at the federal and state levels and has served on several National Research Council committees, most recently the Committee on Decontamination and Decommissioning of Gaseous Diffusion Plants.

Richard S. Magee (chair from 7/94 to 7/98) is a professor in the Department of Mechanical Engineering and the Department of Chemical Engineering, Chemistry, and Environmental Science and associate provost for research and development at the New Jersey Institute of Technology (NJIT). He also directs the Environmental Protection Agency's Northeast Hazardous Substance Research Center. He is a fellow of the American Society of Mechanical Engineers (ASME) and a diplomate of the American Academy of Environmental Engineers. Dr. Magee's research expertise is in combustion, with a focus on the incineration of municipal and industrial wastes. He has served as vice chairman of the ASME Research Committee on Industrial and Municipal Wastes and as a member of the United Nations Special Commission (under Security Council Resolution 687) Advisory Panel on Destruction of Iraq's Chemical Weapons Capabilities. He was recently a member of the North Atlantic Treaty Organization (NATO) Science Committee's Priority Area Panel on disarmament technologies and is presently a member of the NATO Science Committee's Security-Related Civil Science and Technology Panel. He recently chaired the National Research Council Panel on Review and Evaluation of Alternative Chemical Disposal Technologies.

James F. Mathis, a member of the National Academy of Engineering, graduated from the University of Wisconsin with a Ph.D. in chemical engineering. Dr. Mathis was vice president of science and technology for Exxon Corporation, where he was responsible for worldwide research and development programs, and chair of the New Jersey Commission on Science and Technology until his retirement in 1997. Dr. Mathis' expertise is in research and development and chemical engineering.

Walter G. May has a B.S. in chemical engineering and an M.S. in chemistry from the University of Saskatchewan and a D.Sc. in chemical engineering from the Massachusetts Institute of Technology. He joined the faculty of the University of Saskatchewan as a professor of chemical engineering in 1943. In 1948, he began a distinguished career with Exxon Research and Engineering Company, where he was a senior science advisor from 1976 to 1983. From 1983 until his retirement in 1991, he was professor of chemical engineering at the University of Illinois, where he taught process design, thermodynamics, chemical reactor design, separation processes, and industrial chemistry and stoichiometry. Dr. May has published extensively, served on the editorial boards of *Chemical Engineering Reviews* and *Chemical Engineering Progress,* and has obtained numerous patents in his field. He is a member of the National Academy of Engineering, a fellow of the American Institute of Chemical Engineers, and has received special awards from the American Institute of Chemical Engineers and the American Society of Mechanical Engineers. He is also a registered professional engineer in the state of Illinois. Dr. May was a member of the National Research Council Committee on Alternative Chemical Demilitarization Technologies and the Committee on Decontamination and Decommissioning of Uranium Diffusion Plants.

Charles I. McGinnis has an M.E. from Texas A&M University. He retired from the U.S. Army as a major general and former director of civil works for the U.S. Army Corps of Engineers and recently served in senior positions at the Construction Industry Institute in Austin, Texas. He was also director of engineering and construction for the Panama Canal Company and was subsequently vice president of the company and lieutenant governor of the Canal Zone. As director of civil works for the Corps of Engineers, he was responsible for a $3 billion per year budget for the planning, design, construction, operation, and maintenance of public works nationwide.

Alvin H. Mushkatel, professor in the School of Planning and Landscape Architecture, Arizona State University, is an expert in emergency management risk perceptions. His research interests include emergency management, natural and technological hazards policy, and environmental policy. He has been a member of the National Research Council Committee on Earthquake Engineering, the Committee on Decontamination and Decommissioning of Uranium Enrichment Facilities, and the Panel on Review and Evaluation of Alternative Chemical Disposal Technologies. His most recent research has been focused on intergovernmental policy conflicts involving high-level nuclear waste disposal and the role of citizens in decision-making processes. He has published extensively on issues related to siting.

H. Gregor Rigo attended Ohio University and earned his Ph.D. in mechanical and environmental engineering from the University of Illinois. He is currently president of Rigo & Rigo Associates, Inc., in Berea, Ohio. He has extensive experience in plant start-up, process and environmental engineering, and applied statistics focused on the use and control of emissions from nontraditional fuels; technical, environmental, and economic evaluations; and multipathway health risk assessments.

Kozo Saito has a Ph.D. in mechanical engineering from Seikei University in Tokyo and is currently professor of mechanical engineering in the Department of Mechanical Engineering at the University of Kentucky. Dr. Saito's expertise and experience are in experimental combustion studies, thermal sensing and control, and lean manufacturing and control. He is a member of the Combustion Institute, the American Society for Engineering Education, and the American Society of Mechanical Engineers.

W. Leigh Short earned his Ph.D. in chemical engineering from the University of Michigan. He recently retired as a principal and vice president of Woodward-Clyde, where he was responsible for management and business development associated with the company's hazardous waste services in Wayne, New Jersey. Dr. Short has expertise in air pollution, chemical process engineering, hazardous waste services, feasibility studies, site remediation, and project management. He has taught courses in control technologies, both to graduate students and as a part of the Environmental Protection Agency's (EPA' s) national training programs. He has also served as chairman of the EPA's NO_x Control Technology Review Panel.

Arnold F. Stancell, a member of the National Academy of Engineering, graduated from the Massachusetts Institute of Technology with an Sc.D. in chemical engineering. Dr. Stancell is currently a professor of chemical engineering at Georgia Institute of Technology and recently was visiting professor of chemical engineering at the Massachusetts Institute of Technology. For many years he worked for Mobil Oil, where he started in research and eventually became vice president of Mobil Chemical and then vice president in the crude oil and natural gas business, both domestic and international. He was responsible for a $5 billion per year business with 5,000 employees. Dr. Stancell's expertise is in the management of large businesses, including chemical operations.

Steven R. Tannenbaum, a member of the Institute of Medicine, has a Ph.D. in food science and technology from the Massachusetts Institute of Technology. He is currently the codirector and Underwood-Prescott Professor, Division of Bioengineering and Environmental Health, and professor of chemistry, Department of Chemistry at the Massachusetts Institute of Technology. Dr. Tannenbaum's research interests include the chemistry and pathophysiology of nitric oxide, the quantitative measurement of human exposure to carcinogens, and tissue-based microsensors for toxin detection and drug metabolism. He has been a member of the National Research Council (NRC) Board on Environmental Studies and Toxicology and several NRC committees.

Chadwick A. Tolman received his Ph.D. in physical chemistry from the University of California at Berkeley and is currently a program officer in organic and macro-molecular chemistry in the Division of Chemistry at the National Science Foundation. He has extensive experience and expertise in chemistry and chemical process development. Dr. Tolman spent 31 years in Central Research at the DuPont Experimental Station. His work has spanned a broad range of subjects, including hydro-carbon oxidation, organometallic chemistry, and the destruction of toxic organic compounds in wastewater.

William Tumas graduated from Ithaca College with a B.A. in chemistry and earned his Ph.D. in organic chemistry from Stanford University, with a National Science Foundation and Hertz Foundation Fellowship. After conducting postdoctoral research in organometallic chemistry at the California Institute of Technology as a National Institutes of Health and Chaim Weizman Postdoctoral Fellow, he worked for six years at DuPont Central Research and Development. Since 1993, Dr. Tumas has been at Los Alamos National Laboratory, where he is currently group leader of the Chemical and Environmental Research and Development Group in the Chemical Sciences and Technology Division. He has previously served on two National Research Council committees, including the Panel on Review and Evaluation of Alternative Chemical Demilitarization Technologies (1995–1996). His research interests include catalysis, supercritical fluids, environmental chemistry, and waste treatment technology assessment.